

**AN EXPLORATORY STUDY TO DETERMINE  
THE RELATIONSHIP BETWEEN LEVELS OF  
HABITUAL ACTIVITY AND NUTRITIONAL  
STATUS, FUNCTIONAL STATUS, DIETARY  
INTAKE AND FATIGUE IN OLDER ADULTS.**

JACKLYN JONES

A thesis submitted in partial fulfilment of the  
requirements for the degree of Doctor of  
Philosophy

QUEEN MARGARET UNIVERSITY

2015

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## RELEVANT PUBLICATIONS

### Original Communications

JONES, J, BAER, G, and DAVIDSON HIM. 2014. Higher levels of fatigue are associated with poorer functional status in healthy community dwelling older adults The Nutrition Society, London. (9 - 10<sup>th</sup> December 2014).

JONES, J, BAER, G, and DAVIDSON HIM. 2012) Healthy Scottish Elderly Fail To Meet Current Activity Guidelines World Congress on Healthy Ageing "Evolution: Holistic Ageing in an Age of Change" Kuala Lumpur (19<sup>th</sup> - 22<sup>nd</sup> March 2012) poster no 65

JONES, J, BAER, G, and DAVIDSON HIM. 2012 Fatigue Scores Are Associated With Indices Of Physical Function In Older Adults World Congress on Healthy Ageing "Evolution: Holistic Ageing in an Age of Change" Kuala Lumpur (19<sup>th</sup> - 22<sup>nd</sup> March 2012) poster no 66

JONES, J, BAER, G, and DAVIDSON HIM. (2010) Grip strength is associated with nutritional status and energy intake in healthy community living older adults. The Nutrition Society, Edinburgh. (July 2010), Proceedings of the Nutrition Society. 69: OCE6, E454.

## DECLARATION

I declare that the work contained within this thesis is original. I have solely been responsible for the organisation and day to day running of the study contained herein, as well as all of the aspects of data collection and the analysis of the results, unless otherwise referenced.

A handwritten signature in cursive script that reads "Jacklyn Jones". The signature is written in black ink on a white background. The first name "Jacklyn" is written in a large, flowing cursive, and the last name "Jones" is written in a slightly smaller, more compact cursive. There is a small dot at the end of the signature, indicating a full stop.

Jacklyn Jones

## ABSTRACT

**Introduction:** Scotland has an ageing population which has significant implications for health and social care services. Encouraging older people to engage in healthy lifestyle behaviours has the potential to maintain a person's functional ability, increase healthy life years and thus has the potential to enable older people to live at home independently for longer. Recommendations for levels of activity have been produced for older adults but whether these are being achieved is currently unknown. Levels of activity are influenced by many factors including nutritional and functional status, dietary intake and fatigue but as yet the relationship between these parameters and habitual activity has not been established. Therefore the aims of this study were 1) to determine the relationship between levels of habitual activity and nutritional status, functional ability, dietary intake, and levels of fatigue in older adults and 2) to inform physical activity targets for the aging population.

**Methods:** Older adults were recruited from a range of social and leisure facilities across central Scotland. Habitual activity was measured continuously for seven consecutive days using an *activPAL*<sup>TM</sup> accelerometer. Nutritional status (BMI, waist circumference (WC), tricep skinfold and mid arm muscle circumference) was measured using ISAK methodology. Functional status (handgrip dynamometry, sit to stand (STS), six minute walk (6MW) and gait speed (m/s)) was measured along with dietary intake using a seven day unweighed diet diary. In addition levels of fatigue were measured using the Multi-dimensional Fatigue Inventory. Pearson's correlation coefficient analysis was utilised to establish relationships between levels of habitual activity and markers of nutritional status, functional status and dietary intake. Spearman's rho correlation analysis was utilised to establish the relationship between levels of habitual activity and levels of fatigue. Partial correlation analysis was used to establish the influence of age and gender on these relationships.

**Results:** Forty four (21m, 23f) healthy older adults were recruited and completed the study. Participants were found to spend a mean $\pm$ sd 551  $\pm$  88 min in sedentary behaviour daily which equates to 61 $\pm$ 10% awake time being sedentary. They took 8721  $\pm$  3585 steps daily and spent 108 $\pm$ 38 min stepping, 253 $\pm$ 78 min standing and 1080 $\pm$ 103 min sitting or lying each day. Percent time in sedentary behaviour was positively associated with BMI ( $r=.302$ ,  $p=.049$ ), WC (cm) ( $r=.302$ ,  $p=.049$ ), percent energy intake from fat ( $r=.535$ ,  $p<.001$ ) and saturated fat ( $r=.381$ ,  $p=.011$ ) and was negatively associated with 6MW (m) ( $r=-.445$ ,  $p=.002$ ) and % energy from non-milk extrinsic sugar ( $r=-.314$ ,  $p=.038$ ). Total weekly time in moderate intensity activity accumulated in blocks of at least 10 minutes was positively associated with 6MW ( $r=0.321$ ,  $p=.041$ ), daily protein intake (g) ( $r=.350$ ,  $p=.025$ ) and mean daily vitamin D intake ( $\mu$ g) ( $r=.404$ ,  $p=.009$ ) and was negatively associated with STS ( $r=-.321$ ,  $p=.041$ ). Age but not gender influenced the relationships.

**Conclusion:** This is the first study to report objectively measured levels of sedentary behaviour where habitual activity was measured continuously over seven days and sedentary behaviour was considered during waking hours only in a Scottish older adult population. Recommendations for physical activity were not consistently met and there is therefore some indication that current recommendations for sedentary behaviour and physical activity should be reviewed. However activity cannot be considered in isolation as many factors influence this including nutritional status, functional status, dietary intake and levels of fatigue.

### Key words

older adults, habitual activity, nutritional status, functional status, fatigue

## ABBREVIATIONS

6MW	Six minute walk
25OHD	25-hydroxy vitamin D
ADL	Activity of daily living
AOS	Antioxidant status
ATS	American Thoracic Society
BAPEN	British Association of Parenteral and Enteral Nutrition
BCM	Body cell mass
BIA	Bioelectrical impedance
BMI	Body mass index
CES-D	Centre for Epidemiologic Studies-Depression scale
CI	Confidence interval
cm	Centimetre
COMA	Committee on Medical Aspects of Food and Nutrition Policy
COPD	Chronic obstructive pulmonary disease
CRP	C-reactive protein
CT	Computerised tomography
CVD	Cardiovascular disease
DEXA	Dual energy X-ray absorptiometry
DHHS	United States Department of Health and Human Services
dL	Decilitre
DM	Diabetes Mellitus
DoH	Department of Health
DRV	Dietary Reference Value
EAA	Essential amino acid
ECW	Extracellular water
EWGSOP	European Working Group on Sarcopenia in Older People
FEV	Forced expiratory volume
FFM	Fat free mass
FM	Fat mass
FRAP	Ferric reducing antioxidant capacity of plasma
g	Gram
HBV	High biological value
HCl	Hydrochloric Acid
HDL	High density lipoprotein
HGD	Handgrip Dynamometry
HT	Hypertension
ICW	Intracellular water
ICC	Intraclass correlation
IL6	Interleukin-6
ISAK	International Society for the Advancement of Kinanthropometry
l	Litre
LDL	Low density lipoprotein
m	metre



MAMC	Mid-arm muscle circumference
MET	Metabolic equivalent
MFI	Multi-dimensional fatigue inventory
mM	Millimolar
mmHg	Millimetres of mercury
mmol	Millimole
MSe	Mean squared error
MUAC	Mid upper arm circumference
NHANES	National Health and Nutrition Examination Survey
NCD	Non-communicable disease
NDNS	National diet and nutrition survey
nm	nanometre
OR	Odds ratio
PAL	Physical activity level
PBS	Phosphate buffer saline
PWV	Pulse wave velocity
QMU	Queen Margaret University
REE	Resting energy expenditure
SACN	Scientific Advisory Committee on Nutrition
SD	Standard deviation
SH	Sulfhydryl group
SOP	Standard Operating Procedure
RDA	Recommended daily amount
SE	Standard error
SHS	Scottish health survey
STS	Sit to stand
STS5	Sit to stand 5
STS10	Sit to stand 10
STS60	Sit to stand 60
T2DM	Type 2 diabetes mellitus
TBK	Total body potassium
TC	Total cholesterol
TPTZ-Fe <sup>2+</sup>	Ferrous-2, 4, 6-tri-2-pyridyl-s-triazine
TPTZ-Fe <sup>3+</sup>	Ferric-2, 4, 6-tri-2pyridyl-s-triazine
TEE	Total energy expenditure
TG	Tri-glycerides
TNF $\alpha$	Tumour necrosis factor alpha
TSF	Tricep skinfold thickness
WC	Waist circumference
WHO	World Health Organisation
$\mu$ L	Microlitre

## **ACKNOWLEDGEMENTS**

There are many people I would like to thank for their support through the completion of this thesis but in particular I would like to express my sincere thanks and gratitude to the following people:

Firstly I would like to thank my supervisory team, Professor Isobel Davidson (Director of Studies) and Dr Gill Baer (Second Supervisor) for their continued support, guidance and encouragement throughout the completion of the thesis. I am extremely grateful for the time and wise counsel you provided throughout. I would also like to thank Dr Iain Gow who stepped in to help out for a short time.

I am indebted to Robert Rush for his informative and much appreciated statistical guidance throughout the entire research study.

Thanks also to Fiona Lemmon and Tanith Allison for their laboratory assistance at QMU and to the clinical chemistry laboratory staff at the Royal Infirmary of Edinburgh for their assistance with the hsCRP measurements.

Of course none of this would have been possible without the willingness of the participants who volunteered to take part in the study. Their enthusiasm and zest for life should be an inspiration to us all and I am grateful to them for giving up time to participate in the study.

The continued support, encouragement and sense of perspective of my friends and family throughout the completion of the thesis have been invaluable. I am not sure I would have made to the end it without you. A special note of thanks goes to my husband Stephen, a patient and tolerant man who has been a constant support throughout the entire study but especially during the writing of this thesis.

Finally to my Dad who didn't get to see this thesis finished, I dedicate this to you.

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# **CHAPTER 1: LITERATURE REVIEW**

## **1.1 INTRODUCTION**

The changing demographics within the UK has seen people living longer but, with decreasing levels of physical activity and increasing levels of overweight and obesity, this does not always result in those people who are living to an older age doing so in good health. Like the UK as a whole, Scotland too has an ageing population with the proportion of people aged 65 and over increasing from 5% to 17% in the past 100 years (National Records of Scotland, 2014). It is therefore now predicted that those of pensionable age will increase by 26% between 2010 and 2035 (General Register Office, 2013a) and this increase has significant implications for health and social care expenditure. Indeed it is has been suggested that spending on health and long term care will account for about half of the increase in age-related social expenditures between 2000 and 2050 (Gray, 2005). This however has been disputed with the suggestion that increases in life expectancy merely delay the time of the spending rather than increase the costs per se (Appleby, 2013). Whether this is the case or not consideration should be given, not only to ageing, but also to the dependency of the population and the dependency ratio, i.e. the ratio of people aged both under 16 and over pensionable age relative to those of working age. This is predicted to rise from 60 per 100 people in 2010 to 64 per 100 people in 2035 (General Register Office Scotland, 2013b). This has further implications for social spending as a smaller proportion of the population will be earning a wage, contributing to taxable spending resulting and thus in fiscal restructure.

Within the population it is predicted that the age group to increase most dramatically are the most elderly with the number of people aged 75 and over increasing by 82%

between 2010 and 2035 (General Register Office for Scotland, 2013a) resulting in estimated number of centenarians in Scotland increasing from 820 in 2010 to 7,600 in 2035 (General Register Office for Scotland, 2013b). Whilst overall life expectancy is increasing, healthy life expectancy is not increasing as quickly. Recent data has identified that on average woman in the UK will live to 80.9 years but only 62 of these years will be in a healthy state and men will live on average to 76.9 years but only 59.4 of these will be healthy (The Scottish Public Health Observatory, 2013). This means that as people age there is the likelihood that there will be a deterioration in function and independence meaning more people will require additional care or support either within their own homes or in care settings impacting on health and social care spending within Scotland.

It has been predicted that the number of older people requiring some form of care will increase by up to one quarter by 2016 and by nearly two thirds by 2032 (The Scottish Government, 2012). Currently Scotland spends £4.5 billion each year on providing health and care services for those aged 65 years and over. If care continues to be provided in the same way the impact of the ageing population will result in additional spending of £1.1 billion by 2016 and a further £3.5 billion by 2031 (The Scottish Government, 2012). Some of this inevitable increase in the use of health and social care systems will be as a result of a number of age related disorders e.g. cardiovascular disease (CVD), diabetes (DM) and arthritis. These diseases are often termed non-communicable diseases (NCDs) and all have a small set of common risk factors i.e. poor quality diet, physical inactivity and tobacco use (WHO, 2011). These NCDs are the leading cause of death in the world today and the impact of these is steadily growing. In 2008 63% of all global deaths were as a result of NCDs and it is projected that this will increase by a further 15% globally between 2010 and 2020 (WHO, 2011). Clearly the economic burden and the social



impact of NCD are significant and by the nature of the diseases the impact is likely to be greatest amongst older people. There is potential to reduce the impact of these significantly by reducing modifiable risk factors and this would in turn prevent 80% of premature heart disease, 80% of premature stroke, 80% of type 2 diabetes (T2DM) and 40% of cancer (WHO, 2011). An attempt to reduce premature death and disability from NCD and in turn to minimise increases in health and social care expenditure is therefore warranted. In view of this it is important to encourage the ageing population to optimise their health through improving diet quality and levels of physical activity which in turn has the potential to improve or prevent a deterioration in functional ability and thus potentially a person's ability to live independently.

Improving or maintaining health has the potential to maintain an older person's functional ability and thus influence their ability to participate in activities of daily living (ADL) i.e. bathing, dressing, eating and transferring from bed to chair. It is this ability to fulfil these ADL which has the potential to enable older people to live independently in their own home for longer which is the preferred option for the majority of older people (The Scottish Government, 2012). This may then result in a reduced reliance on Scottish care systems, with the potential to maintain a person's quality of life. Maintaining or improving health status in older people should therefore focus on changing lifestyle factors and in particular consuming a healthy diet and changing activity patterns to meet current recommendations for physical activity. This requires older people to increase levels of physical activity and reduce levels of sedentary behaviour (i.e. activities where a person is awake and seated or reclining and participating in activities which require low levels of energy expenditure (i.e. < 1.5 METs) (Owen et al., 2010a). These healthy behaviours may not only help alleviate some of the burden associated with NCDs but may also help prevent or

alleviate some of the inevitable changes in body composition and functional status seen with ageing.

## **1.2 PHYSIOLOGICAL CHANGES IN NUTRITIONAL STATUS AND BODY COMPOSITION WITH AGEING**

The normal ageing process results in progressive and irreversible biological changes that are associated with changes in body composition. In particular a reduction in fat free mass (FFM) and an increase in fat mass (FM) is seen with a consequent reduction in functional ability. These changes occur in the absence of disease and are seen across both genders. The body comprises of a number of different compartments and it is important to understand these to appreciate the changes in body composition as a result of ageing. Primarily the body can be divided into two basic compartments i.e. FM and FFM. FFM is primarily responsible for metabolic activity, functional ability and strength and as such has the greatest influence on a person's ability to perform ADL. FFM can be subdivided into smaller compartments i.e. body cell mass (BCM), intracellular water (ICW), extracellular water (ECW) and bone mineral (Roubenoff, 1999). Any loss of FFM and in particular BCM will result in a loss of strength and function and this has the potential to result in greater levels of disability and mortality in older adults. The ageing process influences the size of these body compartments and slowing or reversing any change in these may result in better health for older people.

It is been established for some considerable time that as people age there is a steady decline in FFM. As 60% of the body's potassium is found in skeletal muscle, and the remainder is found in other organs and tissues (Snyder at al., 1975) total body potassium (TBK) can be used as a measure of FFM and as an index of skeletal muscle mass. An early cross-sectional study of age related changes in

body composition measured TBK in 1,589 people (1,057 males and 532 females) across a range of age groups (Allen et al., 1960). As there were large numbers included in the study it was clearly shown that FFM peaked in the third and fourth decade of life and then declined with advancing age. Further studies have supported these findings with Novak (1972) assessing the body composition of more than 500 men and women between the ages of 18 and 85 years using TBK. A sharp decrease in TBK was seen in the oldest group of men and women which in this study was those people aged 65 and over. The results showed that FM increased and FFM steadily decreased with increasing age. Due to the differences in body composition between genders, the results were different for men and women with men showing an increase in percentage body fat from 17.8% to 36.2% and a reduction in FFM from 82.2% to 63.8% in the youngest group compared to the oldest group. Whereas in females FM increased from 33.0% to 44.8%, while FFM decreased from 67.0% to 55.2%.

Measuring TBK is however expensive and with advancing technology further studies have been performed to establish if alternative more accessible methodologies can be used to measure FFM. Dual-energy X-ray absorptiometry (DEXA) is one such methodology and this has been shown to be a valid measure of both bone mineral density and soft tissue composition (Lohman et al., 2000). Kyle et al. (2001) utilised DEXA to determine levels of FM and FFM in groups of people aged 18 – 94 years and compared results from DEXA to results using TBK. Both techniques were consistent in finding that in a group of 253 men and 180 women FFM peaked in men between the ages of 35 - 59 years (mean±sd FFM 63.3±5.6 kg) and was significantly lower ( $p<.05$ ) in men aged > 75 years (mean±sd FFM 55.1±6.0 kg). In the female participants FFM was highest in the 18 - 34 year old age group (mean±sd FFM 45.0±3.6 kg) and this then gradually reduced with advancing age

with woman aged > 75 years having a mean $\pm$ sd FFM of 40.2 $\pm$ 4.2 kg ( $p < .05$ ). Although DEXA is a valid and reliable measure of body composition it lacks portability and is expensive to administer and so more accessible methodologies have been compared with DEXA. In a comprehensive study which measured body composition using DEXA and anthropometry in 187 healthy older men (aged 65 years and over) Baumgartner et al. (1995) also found that FFM declined with advancing age. This study demonstrated that FFM continues to decline throughout the ageing process as in those people aged 80 years there was around 4.8 kg less FFM compared to their younger counterparts aged 60 to 70 years.

The findings from these studies are supported by Cohn et al. (1980) who confirmed that not only was there a reduction in FFM with ageing but that the main component of FFM loss was a decrease in muscle mass with only very little change in non-muscle mass seen. These physiological changes seen with ageing are not solely down to a reduction in FFM and an increase in FM, there is also a change in the fat patterning within the body. Early studies have shown that as the amount of body fat increases with age it is preferentially stored in the abdomen rather than in peripheral adipose tissues (Borkan & Norris, 1977). Baumgartner et al. (1995) confirmed this finding through the analysis of regional body composition measurements where it was established that at least 60% of the reduction in FFM was from lean soft tissue in the arms and the legs. There were however some gender differences found with women showing a reduction of both FM and FFM with age. A loss of FFM including a reduction in both lean soft tissue in the trunk and the limbs was seen along with loss of total bone mineral whereas in elderly men FM remained stable.

These changes in body composition can be seen in the absence of changes in body mass (Hughes et al., 2002) although there is strong evidence to show that body

weight generally changes throughout adulthood (Guo et al., 1999) with some sectors of the adult population gaining weight and some sectors losing weight (Jackson et al., 2012; Livshits et al., 2012). Over the past few decades there has been a general trend for weight gain with ageing and this has resulted in Scotland having one of the highest rates of overweight and obesity in the world (The Scottish Government, 2011). Overweight and obesity is a major public health problem and in particular within a Scottish population where obesity rates continue to rise and could exceed 40% of the Scottish population by 2030 (The Scottish Government, 2010). Weight gain is seen when energy intake exceeds energy output and as older people expend less energy as a result of lower metabolic rates (due to a reduction in FFM) and changes in lifestyle including increased levels of sedentary behaviour (Phillips, 2003; Johannsen et al., 2008) many will gain weight. With the consequent reduction of FFM seen in ageing reducing functional ability and the increase in FM as a result of weight gain this has the potential to compromise activity levels further. Overweight and obesity are generally measured using body mass index (BMI) which is a measure of body size and provides an indication of an individual's crude nutritional status. BMI is a measure of the weight of a person scaled according to their height and the World Health Organisation (WHO) has developed an international classification for BMI (WHO, 2006) which is shown in table 1.1.

This classification identifies a normal healthy BMI to be one which falls between 18.5 - 24.99 kg/m<sup>2</sup>. This level has been determined due to the plethora of existing evidence that has shown that BMI levels greater than this are linked to increased risk of cardiovascular disease (CVD), T2DM, cerebrovascular disease and many types of cancer (WHO, 2010a).

**Table 1.1 The international classification of adult underweight, overweight and obesity according to BMI**

Classification	BMI (kg/m <sup>2</sup> )	
	Principal cut-off points	Additional cut-off points
Underweight	<18.50	<18.50
Severe thinness	<16.00	<16.00
Moderate thinness	16.00 - 16.99	16.00 - 16.99
Mild thinness	17.00 - 18.49	17.00 - 18.49
Normal range	18.50 - 24.99	18.50 - 22.99 23.00 - 24.99
Overweight	≥ 25.00	≥ 25.00
Pre-obese	25.00 - 29.99	25.00 - 27.49 27.50 - 29.99
Obese	≥ 30.00	≥ 30.00
Obese class I	30.00 - 34.99	30.00 - 32.49
Obese class II	35.00 - 39.99	35.00 - 37.49 37.50 - 39.99
Obese class III	≥ 40.00	≥ 40.00

The levels of overweight and obesity in older people in Scotland, as measured by BMI and using the WHO classification, are shown in table 1.2.

**Table 1.2 The prevalence of obesity in older people in Scotland**

Age	Men		Women	
	Overweight	Obese	Overweight	Obese
65 - 69 years	44%	35%	39%	36%
70 - 74 years	46%	34%	38%	32%
75 - 79 years	47%	30%	38%	34%
80 - 84 years	53%	19%	38%	26%
85+ years	51%	14%	42%	22%

(The Scottish Government, 2011)

The traditional classification system for BMI however may not be appropriate for older people due to the changes seen in body composition with ageing. There is therefore the potential for BMI to be misleading in an older population. As FFM is lost in ageing and as it is heavier than FM, this loss results in a lower body weight and thus a lower BMI even if there was no change in body size. It is also well established that as people age, changes occur in skeletal integrity and most noticeably that of the vertebral or spinal column causing loss of height (Fernihough & McGovern, 2014). This resultant loss of height occurs in both men and women, and adults can lose as much as 1 - 2.5 cm per decade of adulthood. These changes in height then influence the interpretation of BMI where a person would

appear to have a higher BMI without an overall change in body mass. In view of these considerations the normal cut-offs for BMI are unlikely to be appropriate in an older adult population. It has been postulated that alternative cut-offs be used to interpret BMI in an older population to mitigate for these changes in stature and body composition. Wynn & Wynn (1995) have suggested that rather than the traditional cut-off of 20 – 24.99 kg/m<sup>2</sup> a more appropriate cut-off should be a lower limit of >27 kg/m<sup>2</sup> to identify overweight in an older population. Whilst Ham (1992) has suggested that the optimal range of BMI for healthy elderly people should be higher than this and suggests that the normal range should be increased from 20 - 24.99 kg/m<sup>2</sup> to 24 - 29 kg/m<sup>2</sup>.

Consideration of BMI should include not only changes in body composition but also the resultant risk of a higher or indeed lower BMI in an older population compared to younger adults. A systematic review which considered BMI in terms of mortality risk in a healthy older population (i.e. those aged 65 years and older) found a similar mortality risk in the older adults who had a BMI of 25–29.9 kg/m<sup>2</sup> (traditionally considered overweight) compared to those with BMI 18.5–24.9 kg/m<sup>2</sup> (traditionally considered normal weight) suggesting no increased risk in a higher BMI category in older people (Janssen & Mark, 2007). Alongside this, a number of cohort studies have considered lower BMI measurements and have shown there to be increased risk of mortality in older people with a BMI of <22 kg/m<sup>2</sup> (Kulminski et al., 2008; Berraho et al., 2010). A lower BMI in older adults may then suggest increased risks of mortality and should therefore not be encouraged. In fact in a recent meta-analysis of BMI in older people it was established that being overweight was not found to be associated with an increased risk of mortality but there was an increased risk for those at the lower end of the recommended range (Winter et al., 2014).

Many studies have therefore considered the appropriateness of using BMI as a measure of nutritional status and whilst it has limitations there is agreement that it is a useful albeit crude marker of nutritional status and it may be more appropriate to use alternative cut-off points for older people rather than disregarding it as a measurement. Beck & Ovesen (1998) in their review of the use of BMI in older adults suggest that cut-offs of 20 kg/m<sup>2</sup> will probably only identify those people who are already in nutritional difficulty. More recent studies have confirmed this and suggest that BMI appears to have a J-shaped or U-shaped relationship with mortality in older adults with the lowest mortality levels occurring with a BMI around 23 – 28 kg/m<sup>2</sup> (Janssen & Mark, 2007; Flicker et al., 2010; Engeland et al., 2003; Adams et al., 2006; Calle et al., 1999; Corrada et al., 2006). When using BMI as a marker of overall nutritional status in older people it is therefore important to be cognisant of the limitations of BMI and to interpret it in relation to more appropriate age related cut-off points. If this is not done there is the potential to consider people to be normally nourished when they may indeed have nutritional depletion or to be overnourished when they are not.

### **1.3 UNDERNUTRITION IN THE OLDER ADULT POPULATION**

Whilst overweight and obesity are a significant problem in older people, the older adult population is extremely heterogeneous and there are also significant proportions of the population who experience weight loss rather than weight gain and who go on to develop undernutrition. It has been extensively shown in reports from the British Association of Parenteral and Enteral Nutrition (BAPEN) that the older population are at greater risk of undernutrition than the remainder of the population (Russell & Elia, 2014). Weight loss and undernutrition within the UK was first reported as a significant problem by McWhirter & Pennington (1994) who found that 40% of all people admitted to a UK hospital were undernourished. Since then



the picture has not changed significantly with the most recent data from the BAPEN nutrition screening week showing that rates of malnutrition and nutritional risk remain high in the UK with 25% of patients being admitted to hospital and 41% of people within a care home setting being identified as being at nutritional risk (Russell & Elia, 2014). Whilst this screening was done within a care home setting the figures suggest that much of this deterioration in nutritional status begins within the community setting. This survey found that malnutrition was common in all age groups although it was significantly more common in women (28% v 22%) and in subjects aged 65 years and over compared to those people under the age of 65 (28 vs 21%). Undernutrition is therefore a significant problem within the UK older adult population.

The financial impact of undernutrition is significant as seen by a study in Ireland where the cost of managing undernutrition has been estimated to be over €1.4 billion equating to 10 % of the overall health-care budget (Rice & Normand, 2012). Less than 3% of this spend was on the provision of nutrition support with the majority of the costs being attributed to the cost of bed usage within the care setting along with managing disorders associated with undernutrition. A similar study within England reviewing the prevalence of undernutrition in English hospitals over a 17 year period found similar estimates of undernutrition as seen in the BAPEN nutrition screening week (i.e. 30 – 40%). Most worryingly this data was from 1994, 2003, 2004, 2007 and 2010 and there has been little change in prevalence of undernutrition despite increased knowledge of the condition and improvements in nutritional care (Ray et al., 2013). These figures do however have to be interpreted with caution as the method for assessing prevalence was different across the studies included within the review. Nonetheless the suggested levels consistently

provide a consensus opinion of high prevalence rates which is extremely concerning.

A further consideration is that these rates of undernutrition were from a hospital setting and are unlikely to truly reflect a community setting in that the population assessed is by nature a less healthy population. Despite this, the data are worrying as with changes in the provision of health and social care moving to more community based settings the potential for nutritional problems to develop within a community setting is significant. There are no similar studies undertaken within the community setting, indeed there is a dearth of data to indicate levels of undernutrition within the community and whilst the prevalence would be expected to be lower due to far greater numbers of healthy individuals the data from BAPEN suggests that undernutrition starts within the community setting and is a relatively common problem in the elderly. Observational studies of healthy older adult populations have shown a normal age related weight loss of only 0.1 - 0.2 kg a year (Wallace & Schwartz, 2002; McMinn et al., 2011) which does not explain the high prevalence of undernutrition seen within the older adult population and so causes of undernutrition have been researched for some considerable time. The reasons for weight loss and undernutrition in the elderly are wide ranging and encompass underlying disease, physiological changes, socio-economic and environmental factors (European Nutrition for Health Alliance 2006; Schenker 2003; Denny 2008). Additional factors have been summarised by Volkert (2013) and include a decline in the drive to eat and drink (anorexia of ageing), changes in taste and smell, chewing and swallowing difficulties, physical and cognitive changes, depression, social influences such as loneliness and poverty all of which have the potential to exist both within a community and a hospital setting. Preventing undernutrition can result

in significant cost savings within health care budgets as it has the potential to enable people to live more independently without the need for care.

As there are many potential nutritional problems in an older adult population and due to the limitations of BMI, fully assessing nutritional status requires a number of methodological approaches each of which has a distinct role. Consideration has to be given not just to overall body size, but also to body composition and in particular levels of FFM and FM along with the distribution of these. There are many methods of assessing body composition but in view of the nature of the population under consideration it is important to utilise methodologies which are considered to have a high degree of accuracy whilst being relatively quick and easy to use and also take into consideration the comfort of the individual being measured. Such measures include the measurement of waist circumference (particularly in relation to overweight, obesity and CVD risk), limb circumference and skinfolds. In particular upper arm measurements prove useful because when upper arm circumference and upper arm skinfolds are used in combination they have the ability to differentiate between FM and FFM (Heyward & Wagner, 2004). Waist circumference and upper arm anthropometry are some of the most inexpensive and least invasive methods of assessing body composition and provide a clear picture of a person's overall nutritional status.

#### **1.4 WAIST CIRCUMFERENCE**

Waist circumference (WC) can be used to provide additional information about nutritional status, body composition and fat distribution. As discussed previously there is a loss of FFM and an increase or redistribution of FM with ageing and WC can provide details of body fat distribution. There is significant evidence to show that abdominal fat distribution as measured by WC correlates highly with both total

and intra-abdominal fat and can therefore provide additional important information about a person's nutritional status which cannot be determined by measuring BMI alone (Van der Kooy et al., 1993; Lemieux et al., 1996; Barreira et al., 2012). It has the added benefit that it is as good, or perhaps even better as a marker of increased adiposity (Klein et al., 2007). WC is a marker of visceral adiposity and it is this intra-abdominal fat layer which is key to identifying risk of NCDs as it is considered to be more metabolically active and as such plays a role in metabolic and age related disorders (Janssen et al., 2002a; Barreira et al., 2012). Indeed intra-abdominal fat is considered more pathogenic than subcutaneous adipose tissue (Fox et al., 2007; Despres et al., 2008) and has greater health risks associated with it. In view of this there is strong evidence to support the notion that WC may be equally as important or even more so than the use of BMI in the older adult population as it has the ability to determine health risk associated with obesity in older ages which may be lacking from BMI measurements (WHO, 2010a; Wannamethee et al., 2007; Price et al., 2006).

The role of WC in determining health risk was demonstrated in a large population based study within the USA of 48,500 men and 56,343 women aged over 50 years (Jacobs et al., 2010). WC measurements were recorded at baseline and participants were then followed up over a 10 year period. The results showed that those individuals with a high WC (in this case 110 cm for men and 95 cm for women) were twice as likely to die from all-cause mortality over the follow up period compared to those who had a low WC. Importantly these mortality rates were shown to be independent of BMI and the risk was still seen in those people aged 70 years and over. Although this study was undertaken in a USA population it does provide important information about the use of WC as a marker of health risk. This is particularly so in the context of the Health Survey for England which found that in

a group of community dwelling older adults aged 70–89 years (7,129m and 9,244f) who had their WC measured between 1993–2010 there was a shift upwards in WC measurements over the years with a median increase of 4.5 cm in men and 5.1 cm in women (Howel, 2012). Similar results have been seen in Scotland where between 1998 and 2008 there has been 5–10 cm increase in WC levels in both men and women aged between 50 and 70 years (Han et al., 2011). This indicates that a high proportion of the older Scottish population have a high WC. Results from the most recent Scottish Health Survey for older people have shown that older adults (aged 65 years and older) were more likely to have a higher WC than younger people (aged 16 - 64 years) with 52% of older men and 56% of older women having a raised WC (The Scottish Government, 2011). As WC is associated with an increased risk of NCDs this trend of increasing WC levels has major health and economic implications for Scotland and the UK as a whole.

As the Scottish population become older and more overweight and/or obese, as seen by increasing BMI and WC measurements, so the prevalence of Type 2 Diabetes (T2DM) increases (Han et al., 2011). The risks associated with T2DM are inextricably linked to the risks associated with central obesity. In those people who have central obesity (as measured by WC) and T2DM there is increased arterial stiffness seen. This increased arterial stiffness predisposes the risk of hypertension (HT) which is implicated as a risk factor for CVD. This was shown in a group of 860 Scots who had T2DM where it was shown that WC was independently associated with pulse wave velocity (PWV), a measure of arterial stiffness, and this association was independent of both age and gender (Teoh et al., 2013). The impact of a raised WC on arterial stiffness therefore has the potential to impact on blood pressure levels with higher WC associated with increased levels of HT. In fact in this study a high WC was a better predictor of HT than BMI alone and the relationship between

these was consistent even in the older old age group (Teoh et al., 2013). This study provides further support for the use of WC as a marker of health risk with or without BMI.

A further large cross sectional study of a Chinese population found similar results with WC having a modestly higher odds ratio (OR) for HT (10.71 (95% CI 8.64,13.29)) than BMI (10.37 (95% CI 8.58,12.53)) in older men and this remained evident with increasing age (Deng et al., 2013). BMI was also found to be important for men in this study as this had a higher OR for prehypertension (7.44 (95% CI 4.14,13.37)) than WC (1.91 (95% CI 1.21,3.00)). Whilst these results were seen in increasing age there were gender differences found with the female population having a higher adjusted OR for BMI (4.74 (95% CI 3.90,5.76)) than WC (4.08 (95% CI 3.60,4.61)) suggesting that both BMI and WC should be considered together. As this study was in a Chinese population the results may not necessarily be found to be consistent across the UK population. The population of the USA is likely to have a greater similarity with the UK population and in a large USA study it has been shown that WC was independently associated with HT (OR 1.51, 95% CI 1.27,1.81) and this was after controlling for BMI. Additional analysis was performed to stratify for BMI in addition to WC (i.e. those classified as abdominally obese with a normal BMI; as abdominally obese and overweight; and abdominally obese and obese) and results showed that there was a progressive increased risk of developing HT with increasing WC compared with individuals who had a normal BMI and no abdominal obesity (Ostecheaga et al., 2012). As WC is associated with HT and as HT is one of the key risk factors for developing CVD, measuring WC is useful. Other risk factors for CVD should also be considered and as such the relationship between WC and blood lipid profile may also be important, as dyslipidemia is one of the other key risk factors for developing CVD.

In terms of CVD risk high levels of total cholesterol (TC), low density lipoproteins (LDL), and triglycerides (TG) along with low levels high density lipoprotein (HDL) are associated with increased CVD risk. It has been established for some time that a high WC is associated with lower levels of HDL and higher levels of TG (Despres et al. 1989.; Mykkanen et al., 1992). Whilst these studies are relatively old more recent studies have confirmed the relationship between WC and lipid profile. In a cross sectional study of 4,809 Turkish adults it was found that TC, LDL, TG, and TC/HDL ratio all increased with age, with the highest prevalence in the 60 – 69 year old age group. Alongside that it was also found that WC increased in parallel with blood lipids with TC, LDL, TG and a high TC/HDL ratio increasing steadily in line with increasing WC, whilst HDL reduced as WC increased (Erem et al., 2008). As obesity, CVD and T2DM are all also associated with increased levels of inflammatory markers it is not surprising to find that a high WC has also been shown to be associated with increased circulatory markers of inflammation and like other relationships these increased levels are seen irrespective of BMI (Festa et al., 2001; Panagiotakos et al., 2005).

It is therefore clear that raised WC levels are associated with increased health risk irrespective of BMI measurements (Barreira et al., 2012; Turcato et al., 2000; Harris et al., 2000). This independent relationship may be partly explained by the age dependent height loss seen in older people which affects BMI measurements but which may not influence WC measurements (Visscher et al., 2001; Zamboni et al., 2005). As WC is an important indicator of CVD risk cut-off values for abdominal obesity and overweight have been developed and are >102 cm (obesity) and >94 cm (overweight) in men and > 88 cm (obesity) and > 80 cm (overweight) in women (Lean et al., 1995). The obesity cut-offs are indicative of substantial increased risk

and the overweight cut-offs are indicative of increased risk of CVD. These cut-off values have been adopted by WHO for application in all adults under 70 years of age (WHO, 1998). Some consideration does however have to be given to older adults where changes in both stature and body composition occur and there have been concerns expressed about the misclassification of the health risks related to obesity in older people when using standard WC cut-off values (Visscher et al., 2001; Molarius et al., 2000). It has therefore been suggested that additional cut-offs should be developed for those people aged 70 years and over and these have been proposed based on findings from a prospective population-based cohort study of 2,232 Dutch people. The suggested cut-offs from these findings are 100 – 106 cm in men and 99 cm in women (Heim et al., 2010).

The practicalities of using these cut-offs have however been disputed (Howel, 2012). In a retrospective study of 7,129 men and 9,244 women, aged 70 - 89 years, WC measurements were categorised using both the standard cut-off values and the cut-off suggested by Heim et al. (2010). Findings showed that overall abdominal obesity prevalence estimates would be much lower using the new cut-points. There were gender differences seen with the suggested new cut-offs increasing the prevalence of abdominal obesity in older men whilst in women using the standard cut-offs would result in a higher prevalence of abdominal obesity. These results provide information about expected changes in prevalence using alternative cut-off values however there is nothing to determine whether these changes in prevalence alter the CVD risk for an older person. Whilst it may be that age and gender specific cut-offs are required for WC more work is required to ensure that risk is correctly established at both an individual and at a population level.



Despite the lack of clarity in cut-offs for WC, it is clear that these measurements provide information about the health of the population and the risk of CVD for each individual. It provides additional information to that seen with BMI although the focus of the measurement is the accumulation of intra-abdominal adiposity and as such it gives no indication of levels of FFM. As previously discussed, FFM decreases with age and it is therefore important to measure this alongside overall body mass (BMI) and intra-abdominal FM (WC). It is possible to estimate levels of FFM using limb circumference and skinfold thickness measures. These alongside BMI and WC give a clearer overall picture of a person's body size and body composition.

## **1.5 UPPER ARM ANTHROPOMETRY**

The use of upper arm anthropometry has become increasingly popular as a marker of nutritional assessment and as a method of determining body composition. Upper arm anthropometry can be used to measure both FM and FFM and there are three individual components which enable this; mid upper arm circumference (MUAC), tricep skinfold thickness (TSF) and mid arm muscle circumference (MAMC). FM and FFM together can be measured by MUAC, FM alone can then be measured by TSF and in combination these can then predict levels of FFM by calculating MAMC using a standard equation:

$$\text{MAMC (cm)} = \text{MUAC (cm)} - (0.314 \times \text{triceps skinfold thickness (cm)}) \text{ (Frisancho, 1990)}$$

### **1.5.1 Mid upper arm circumference**

MUAC reflects FFM plus FM although there is no indication as to the differentiation between each component. As it is a measure of FM and FFM it will be influenced by energy balance and it will increase or decrease in size depending on changes in body weight and overall nutritional status. As it measures overall body composition

it correlates well with BMI and as such can be used to predict BMI in those people where it is not possible to obtain a weight and/or height measurement (Powell-Tuck & Hennessey, 2003). As it has such a strong relationship with BMI it also has a predictive role in establishing mortality risk in older adults. In a group of 160 men aged over 65 years it was found that MUAC was a better predictor of mortality risk than BMI (Tsai et al., 2012). As this study population were institutionalised Taiwanese veterans and as a result had existing co-morbidities the results cannot be fully applied to a healthy UK population. A larger study in a European population of community dwelling individuals has however found similar results which can more easily be applied to a UK population (Wijenhoven et al., 2010). This population based study which included 1,667 older adults who were followed up over a 15 year period showed that the hazard ratio of mortality of MUAC per 1 standard deviation lower than the mean was 1.79 (95% CI 1.48,2.16) in men and 2.26 (95% CI 1.71,3.00) in women which were higher than the hazard ratios for BMI. This equates to a low MUAC being associated with an increased 15 year mortality risk in both men and women and this association was stronger than the association of low BMI and 15 year mortality risk. Measuring MUAC is therefore important in an older population and the measurement is quick and easy to perform.

The circumference of the mid-point of the upper arm (i.e. the midpoint between the acromion and the olecranon processes) is measured to the nearest 0.1 cm using a steel tape measure. The obtained measurement can be evaluated for each individual using normative population centiles. Normative values for older adults have been published for the UK population (Burr & Phillips, 1984) although these may no longer be appropriate as there have been significant changes in body weight and body composition in the UK since that time. More recent data has been published for a smaller older adult Irish population (276m, 598f) (Corish & Kennedy,

2003). It is worth noting that these normative values are from a relatively small sample of the Irish population and alternative normative values are available using data from NHANES (McDowell et al., 2008). The NHANES data are from a much larger sample size and as such may give greater accuracy in terms of population based norms however it is based on an American population who at present are generally heavier than a UK population (although this trend is changing) (National Obesity Observatory, 2009) and so whilst they better reflect the USA population they may not necessarily be more applicable to a UK population. In view of this the data from Corish & Kennedy (2003) are being used. There are few differences in values between the datasets with the Irish data generally being lower than the USA data.

Although there are normative data for MUAC and there is evidence to support its use as a marker of nutritional status along with its ability to predict nutritional risk it is rarely used in isolation as it does not differentiate between body compartments. In view of this it is commonly used alongside TSF which is a measure of FM and is reflective of total body fat stores (Heyward & Wagner, 2004).

### **1.5.2 Tricep Skinfold Thickness**

Skinfolds are indirect measures of the thickness of subcutaneous adipose tissue and measuring skinfolds at selected sites has been shown to provide similar results to those found using MRI and CT both of which are direct rather than indirect measures of FM (Hayes et al., 1988; Orphanidou et al., 1994). Clearly MRI and CT lack practical application for population based studies as they are expensive and lack portability. This is also true of DEXA which is commonly used to assess body composition. There is however a strong association between FM measured by DEXA and FM measured by upper arm anthropometry ( $r=.91$ ,  $p<.001$ ) (Patel et al., 2013) indicating that TSF can be used as an indirect measure of FM. The use of

TSF as surrogate measure of FM can therefore be justified and as the upper arm is considered accessible and easy to measure whilst still having the capacity to determine body composition it is commonly used as a single site skinfold measurement. There are however concerns about inter and intra observer variability in results obtained in untrained individuals but these issues can be overcome by the use of a single trained observer, appropriate calibrated equipment and standardised protocols (Jebb & Elia, 1993; Norton & Olds, 1999). Importantly the error of measurement can be quantified by calculating the technical error of measurement (TEM). The TEM is the square root of the measurement error of variance (Ulijaszek & Kerr, 1999). Essentially the TEM is established by the same observer taking repeat measurements from a number of subjects and calculating a one-way ANOVA to determine the mean error square. The TEM can then be calculated by using the equation i.e.  $TEM = \sqrt{MSe}$  (where MSe is the mean error square). Measuring TSF is simple and inexpensive to perform with little or no discomfort to the person being measured. This makes it ideal as a field measure and results obtained can be compared to normative data for the population (Corish & Kennedy, 2003).

Measuring fat mass has value in that it provides information about gains or losses in body composition and large gains in adiposity may well impact on a person's ability to perform ADL. However a more important component of body composition is FFM as this is the tissue which has most influence on a person's ability to participate in ADL as it is this compartment which influences functional ability. MUAC and TSF together allow MAMC to be determined and it is this measurement which determines FFM.

### **1.5.3 Mid arm muscle circumference**

Although MAMC is reflective of FFM within the arm it is also considered to reflect total FFM stores. It has therefore been used in a plethora of body composition studies and these have shown MAMC to be a reliable and useful indicator of nutritional status and muscle mass (Miller et al., 2002; Wannamethee et al., 2007). MAMC is calculated directly from MUAC and TSF and normative values are also available for older adults for the UK population (Corish & Kennedy, 2003).

A relationship between MAMC measurements and functional ability in older people has been shown by Landi et al., (2010). In this study 357 older adults were stratified into tertiles for MAMC and functional status was measured by gait speed, grip strength and the Short Physical Performance Battery score (Guralnik et al., 1994). Results showed that as mean $\pm$ se MAMC increased, gait speed (m/s) also increased (0.38 $\pm$ 0.02 vs 0.53 $\pm$ 0.02 vs 0.53 $\pm$ 0.02,  $p < .001$ ). This was also the case for the Short Physical Performance Battery scores (5.14 $\pm$ 0.37 vs 7.38 $\pm$ 0.33 vs 7.38 $\pm$ 0.32,  $p < .001$ ) and grip strength (kg) (24.76 $\pm$ 1.46 vs 31.88 $\pm$ 1.15 vs 34.11 $\pm$ 1.34,  $p < .001$ ). These improvements in function seen with increased MAMC measurements also translated into improvements in performance in mean $\pm$ se ADL scores as measured by MDS-HC instrument (Morris et al., 1996) (2.27 $\pm$ 0.25 vs 1.06 $\pm$ 0.19 vs 0.94 $\pm$ 0.18,  $p < .001$ ). It seems that upper arm anthropometry therefore plays an important role in not only establishing nutritional status and measuring FFM but it also plays a role in the diagnosis and prediction of functional status in older adults.

## **1.6 SARCOPENIA**

Sarcopenia was first suggested as the term to describe loss of muscle mass seen in ageing (Rosenberg, 1997) and original definitions referred only to loss of skeletal muscle mass and strength seen with advancing age (Morley et al., 2001). However

a more refined definition has since been developed which defines sarcopenia as a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death (Cruz-Jentoft et al., 2010).

Sarcopenia is inextricably linked to a person's ability to live independently. As there is a reduction in FFM and an increase in FM as a result of ageing and as FFM is the tissue which enables normal body function and thus an ability to exercise and perform other normal day to day activities it plays a key role in determining a person's ability to live independently. FFM generally contributes up to approximately 50% of total body weight in young adults but declines to around only 25% by the time people reach 75 - 80 years of age (Short & Nair, 2000; Short et al., 2004). Estimates for the reduction in muscle mass do however vary although it has been reported that between the ages of 40 and 80 years there is a reduction of 30% to 50% (Doherty 2003; Faulkner et al., 2007) and a loss of up to and over 50% in those people aged 90 years and over (Baumgartner et al., 1998; Goodpaster et al., 2006).

This progressive loss of muscle mass results in a decline in skeletal muscle mass which can in turn lead to a decrease in both strength and function. It is therefore apparent that this level of loss of FFM will have an impact on function and indeed it has been shown that a reduction in FFM of as little as 10% can decrease functional ability, increase risk of infection and is also associated with increased levels of mortality (Broadwin et al., 2001; Landers et al., 2001). It has been suggested that this loss of FFM equates to an annual decline in functional ability of 1–2% after the age of 50 increasing up to as much as 3% after the age of 60 (Masanes et al., 2012; Roubenoff, 2000; Morley, 2001). Such age-related muscle loss is strongly

associated with impaired mobility, increased incidence of falls, increased morbidity and poorer quality of life (Baumgartner et al., 1998; Roubenoff, 2000) along with increased levels of frailty, reduction in strength, poor physical function and a reduced exercise capacity (Lang et al., 2010).

This loss of FFM contributes to the diagnosis of sarcopenia and it has been postulated that sarcopenia should be considered a geriatric syndrome (Cruz-Jentoft et al., 2010). Original definitions of sarcopenia referred only to the loss of skeletal muscle mass and strength seen with advancing age (Morley et al., 2001) although it is now clear that these definitions do not fully reflect the impact that these changes have at an individual level. Early studies have demonstrated that functional decline in older adults is as a result of loss of FFM. Bassey & Harries (1993) in their study of community dwelling adults aged 65 years and older (359m, 561f) living in UK found that muscle strength as measured by handgrip dynamometry (HGD) was significantly related to skeletal size (as measured by demi-span) and to total body mass in men. There was also a significant 2% decline in strength found with each year of increasing age. On follow up after 4 years, the same cohort showed a further decline in HGD of 12% in men and 19% in women. Similar results were found in a group of 847 adults (aged 20 – 100 years) with grip strength peaking in the fourth decade of life and subsequently declining with a mean reduction of 37% by the 9<sup>th</sup> decade of life decade (Kallman et al., 1990) although importantly this was not universally seen across all subjects with around 15% of people aged 60 years and over exhibiting no decline in strength during follow up. This suggests that there is significant inter-individual variability and thus there is potential to delay or even prevent the development of sarcopenia.

These studies are relatively old and may not be reflective of an older population today and so results from more recent studies need to be considered. Masanes et al. (2012) investigated the impact of the loss of FFM in a group of 200 older adults (110m, 90f). The study group who had their FFM measured using Bioelectrical Impedance (BIA) and muscle strength measured using HGD were functionally well, had no cognitive impairment and participated in regular physical activity. When compared to a younger reference group functional decline was apparent in the older adults with an annual decline in functional ability of 1 - 2% after the age of 50. The Health, Aging and Body Composition (Health ABC) Study was designed to determine the role that changes in body composition in older adults have in determining health outcomes including functional limitation and death (Delmonico et al., 2009). This study of 3,075 participants aged 70–79 years established that there is an association between FFM and strength and that both men and women lost muscle strength during the 5 year follow up period even in the presence of weight gain which in some cases included an increase in FFM. Sarcopenia has therefore been shown to increase the risk of functional loss and disability by 2 fold in men and 3 fold in women (Janssen et al., 2002b) and it is this loss of function rather than loss of muscle mass which is a more significant predictor of hospital admission, falls, fractures, gait speed and mortality (Janssen et al, 2004a; Visser et al, 2005). Indeed it has been suggested that muscle strength rather than muscle mass is the single best measure of age-related muscle change and is associated with functional limitation and physical disability in ADLs (Hairi et al., 2010). This loss of function clearly has the potential to impact on a person's ability to perform ADL and live independently and it cannot be detected by changes in weight or nutritional status. It therefore supports the need to measure not only nutritional status but also functional status in an older adult population.



In view of the impact of muscle loss on strength and function it is thought that the definition for sarcopenia suggested by Cruz-Jentoft et al. (2010) better reflects the significant impact of body composition changes with ageing. It is evident that a reduction in FFM with ageing results in impaired skeletal muscle strength and power and this in turn leads to a reduced ability to perform day to day activities such as rising from a chair, walking and climbing stairs all of which are essential for independent living and indeed may impact on health outcomes. It is important to recognise that sarcopenia can, and often does, develop without a resultant change in weight (Gallagher et al., 2000; Delmonico et al., 2009) due to the changes in body composition with ageing and the fact that it is defined not only by a loss of muscle mass but also a loss of muscle strength.

It cannot therefore be diagnosed by weight change and may be seen not only in those people who would be considered undernourished but also in those people who would be considered normally nourished or even overnourished. This therefore implies that the issue of sarcopenia has the potential to affect the whole older adult population and it is therefore important to establish the extent of the problem.

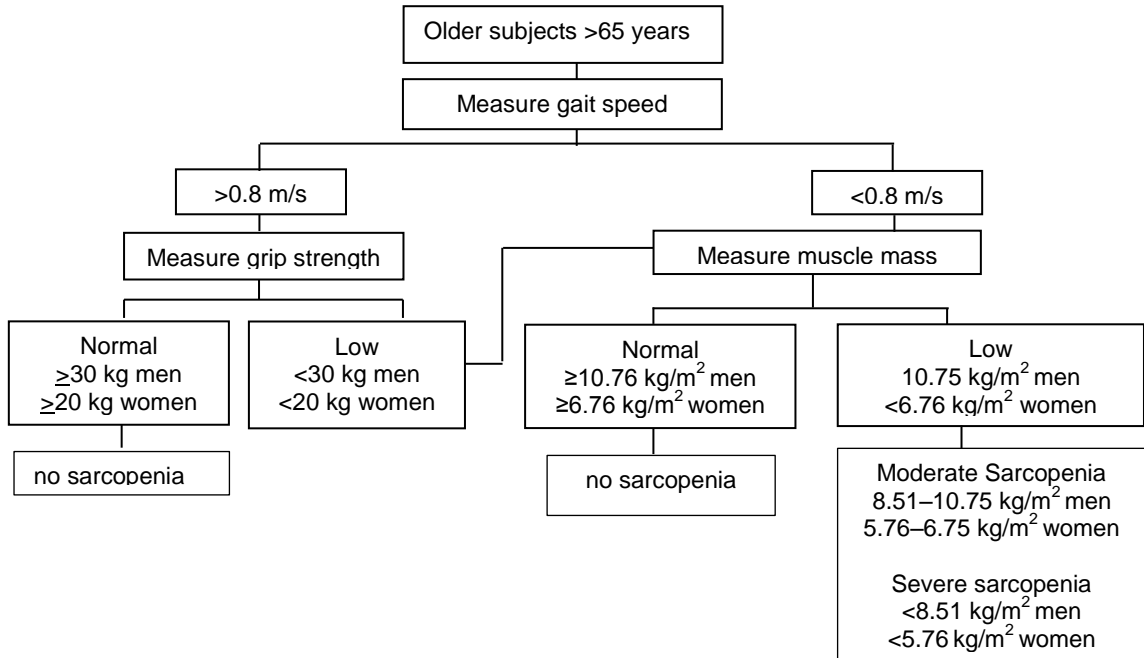
### **1.6.1 Prevalence of sarcopenia**

There has been an increase in interest in sarcopenia in recent years where a number of studies which have investigated the prevalence of sarcopenia. In the context of this literature review the focus is on healthy older adults living in the community and as such prevalence data for this population is discussed. In an early study by Baumgartner et al. (1998) the prevalence of sarcopenia in a New Mexico population was estimated to be 20% in men and 25% in women aged between 70 and 75 years. The prevalence rates increased to 50% in men and 40% in women in

the 80 years and over age group. In this study sarcopenia was defined as appendicular skeletal muscle mass less than two standard deviations (SD) below the mean of a young reference group and muscle mass was measured using upper arm anthropometry. A different study in Connecticut used an alternative definition of sarcopenia and defined it as a skeletal muscle mass more than 2 SD below the gender specific estimates of skeletal muscle mass. In this study where skeletal muscle mass was measured using DEXA the prevalence of sarcopenia was found to be 22.6% in women and 26.8% in men (Iannuzzi-Sucich et al., 2002). In addition in those people aged 80 years and over higher prevalence rates of 31.0% in woman and 52.9% in men were found (Iannuzzi-Sucich et al., 2002).

A more recent study in France estimated the prevalence of sarcopenia using BIA as a measure of muscle mass in 218 healthy older adults aged 60 - 78 years. The estimated prevalence of sarcopenia in this French population was found to be 12.15% in men and 23.6% in women (Tichet et al., 2008). This study used a similar definition of sarcopenia which was defined as a value below the mean minus 2 SD of the skeletal mass index (i.e. muscle mass x 100/weight) distribution of the population. A similar study of Taiwanese people also using BIA to estimate skeletal muscle mass and where sarcopenia was defined as the skeletal mass index of 2 SD or more below the normal gender-specific means for young people found the prevalence of sarcopenia to be 23.6% in men and 18.6% in women (Chien et al., 2008). At the time of these studies there were no agreed definitions for sarcopenia and as such no cut-offs for muscle mass and muscle strength had been agreed. This may in part explain some of the differences in prevalence rates found. It has since been suggested that consistent criteria should be utilised to define sarcopenia and these have since been developed by the European Working Group on Sarcopenia in Older People (EWGSOP) (Cruz-Jentoft et al., 2010). These criteria

involve measuring FFM (using upper arm anthropometry or BIA), muscle strength using HGD and muscle function as determined by gait speed. The results are compared to agreed cut-offs and the suggested algorithm is shown in figure 1.1.



**Figure 1.1 Diagnostic Criteria for sarcopenia (adapted from Cruz-Jentoft et al., 2010)**

The most recent study on prevalence rates has been undertaken in a UK population (Patel et al., 2013) and this study utilised the European Consensus criteria set by Cruz-Jentoft et al. (2010). The prevalence of sarcopenia among community dwelling older men (n=765) was found to be only 4.6% and among community dwelling older women (n=1,022) it was found to be 7.9%. It is unclear whether these much lower prevalence rates are a result of clearer diagnostic criteria or whether the UK population has a much lower prevalence rate (although this seems unlikely due to low levels of activity in the older adult population (The Scottish Government, 2011) along with high levels of undernutrition and frailty (Russell & Elia, 2014)). It may also be that the differences in prevalence rates, not only reflects different methodologies, but also differences in body composition which occur with

ethnicity (Wagner & Heyward, 2000; Wang et al., 2011). Despite these studies, current prevalence rates are not clearly evident and it may be that repeating the earlier studies would yield different results although it is not clear whether prevalence rates would increase or decrease. It is however clear that sarcopenia is a significant problem and as the diagnosis is based on muscle strength and function it can also exist in an overweight or obese population a phenomenon known as sarcopenic obesity.

### **1.6.2 Sarcopenic obesity**

As muscle loss and strength occur with age irrespective of weight change it is possible for a person to be overweight or obese and still have the signs of sarcopenia (Prado et al., 2008). Whilst there is evidence to demonstrate that a higher BMI is not always detrimental particularly in older people, overweight and obesity do not preclude the development of sarcopenia. Indeed there is increasing evidence of high levels of sarcopenic obesity in the older adult population (i.e. those people who have a high BMI but a low FFM and muscle strength). This may have even more significant consequences for an older person as the lower FFM and strength has an increased work burden to facilitate carrying an increased mass. This therefore has the potential to impact more significantly on a person's ability to perform ADLs due to the increased workloads required.

Sarcopenic obesity develops when there is an increase in body weight with an over accumulation of fat alongside the normal loss of FFM seen in ageing. This results in an overweight or obese population who are functionally impaired. This deterioration in function is seen alongside an increase in body mass resulting in an increased burden when performing normal day to day activities. This is evident in studies

which have shown sarcopenic obesity to be more strongly related to disability than either sarcopenia or obesity alone (Baumgartner et al., 2004). In this study of 451 older men and women who were followed up over an 8 year period results showed that those people who had sarcopenic obesity at baseline were two - three times more likely to report onset of disability related to ADLs than those people who were sarcopenic (without obesity) or obese subjects (without sarcopenia) or those with normal body composition. The impact of sarcopenic obesity on the health of older adults is therefore potentially significant. In the context of an ageing population along with a population in Scotland who are increasingly overweight and obese the impact of a deterioration in function and thus an inability to live independently may have significant economic consequences in terms of increased levels of care to support the population. It is therefore important that functional capacity is considered when assessing older people alongside the determination of nutritional status.

There are a number of cheap but reliable functional tests which can be utilised within a community setting to support information obtained from nutritional assessment. These parameters together provide a greater depth and breadth of information about older adults. Whether a person has sarcopenia or sarcopenic obesity they both have the potential to significantly influence functional status and it is therefore vital that not only is nutritional status measured but functional ability should also be measured alongside this. This will obviously enable a diagnosis of sarcopenia to be made but will also provide information about a person's ability to perform ADL.

## **1.7 MEASURING FUNCTIONAL STATUS**

There are a number of measures for functional status which when used as a battery of assessments can provide a comprehensive picture of a person's functional status. These include Handgrip Dynamometry (HGD), sit to stand (STS) and six minute walk (6MW) tests.

### **1.7.1 Handgrip Dynamometry (HGD)**

Ageing results in a loss of FFM and it has been shown that as FFM is lost, so strength and function will also decline (Janssen et al., 2002b; Goodpaster et al., 2006; Delmonico et al., 2009). HGD is positively correlated with both BMI and FFM but improvements in strength as measured by HGD have been shown to occur without increases in FFM or changes in BMI (Vernon & Hill 1998). HGD can therefore indicate changes in strength and function across a range of people of different nutritional status and body compositions (Martin et al., 1985; Heimbürger et al., 2000). Muscle strength is a more important marker of muscle quality and thus function than muscle mass. It is this functionality of the muscle rather than muscle size which determines muscle function and influences survival (Wang et al., 2005, Gale et al., 2006).

A number of studies have shown that muscle strength plays an important role in terms of predicting functional limitation and ill-health. In a prospective study of 3,075 men and women where muscle area and fat infiltration of muscle were measured by CT along with markers of strength it was found that only muscle attenuation (i.e. fat infiltration) and muscle strength could independently predict subsequent mobility loss with ageing (Visser et al., 2005). These results are supported by a separate study of 2,292 American men and women aged 70–79 years of age where a strong association between muscle strength (which included HGD measurements) and mortality was found with the crude hazard ratio (HR) for mortality based on grip

strength being 1.36 (95% CI 1.13,1.64) for men and 1.84 (95% CI 1.28,2.65) for women (Newman et al., 2006). More recently a study of 1,705 community dwelling older adults had muscle strength measured by HGD, skeletal mass measured by DEXA and levels of disability recorded and it was shown that muscle strength was the best measure of both age-related muscle change and functional impairment (Hairi et al., 2010).

The evidence to support measuring muscle strength is compelling although when considering muscle quality which influences strength some consideration has to be given to FM. A study of 2,307 older men and women found that in those people who had a greater FM there was a greater decline in FFM and it was this increased FM which was associated with lower muscle quality and also predicted faster rates of loss of FFM (Koster et al., 2011). It is therefore likely that preventing the accumulation of FM has the potential to maintain muscle quality which may in turn reduce disability and mobility deficits. Measuring FFM and FM alone will not then provide information about strength and function and so alternative more reliable measures need to be utilised. HGD has the potential to do this as HGD is a cheap, reliable, easy to perform measure and has been shown to be an accurate measure of muscle strength (Roberts et al., 2011).

Whilst HGD is a single task, and there is an obvious association with upper body strength, it has been shown to be correlated with overall body strength (Tietjen-Smith et al., 2006). HGD can be used to characterise overall muscle strength as it correlates with elbow flexion strength (men  $r=0.638$ ,  $p<0.001$ , women  $r=0.672$   $p<0.001$ ), knee extension strength (men  $r=0.524$ ,  $p<0.001$ , women  $r=0.514$   $p<0.001$ ), and trunk extension strength (men  $r=0.515$ ,  $p<0.001$ , women  $r=0.541$   $p<0.001$ ) giving an approximation of total body muscle strength (Rantanen et al., 1994). This is true for

the entire adult population including the oldest old (Tietjen-Smith et al., 2006). As a result it has been used in epidemiological studies of healthy individuals to measure strength and function (Bohannon, 1998; Rantanen et al., 2003). Although hand grip is primarily used as a measure of strength and endurance (Rantanen et al., 2003) there is a positive correlation seen with FFM and functional ability measured by HGD ( $r=.39$ ,  $p=.0005$ ) (Payette et al., 1998). It therefore also provides an indication of a person's ability to perform activities such as opening containers, lifting weights and the ability to hold onto handrails and to climb stairs (Skelton et al., 1994). It is this muscle strength ability which may be more important than aerobic fitness for independent living. Indeed in a study of 555 adults, aged 85 years, who were followed up prospectively, those who had a lower handgrip strength at baseline, had poorer functional ability and an accelerated decline in both ADL and cognitive ability (Taekema et al., 2010). There appears to be a linear relationship between handgrip strength and incident disability for ADL and as such HGD plays a role in predicting accelerated dependency in ADL.

There is an obvious role for measuring HGD to predict functional ability and an ability to perform ADL but perhaps more importantly it can also be shown to be an accurate predictor of mortality in the older adult (Rantanen et al., 2003). This has been confirmed more recently by Newman et al. (2006) and Cawthon et al. (2009). The study by Cawthon et al. (2009) showed that HGD acts as a surrogate measure of overall physical functioning which in turn consistently predicts health-related outcomes such as premature mortality, disability, and other health-related complications among middle-aged and older adults. This study which included more than 3,000 older adults found that participants with the weakest grip strength were at greater risk of hospitalisation. Further data from a systematic review of the use of HGD as a predictor of outcomes in older people showed that low grip strength was a



consistent predictor of death and with the exception of two studies which recruited participants with rheumatoid arthritis, a high grip strength was a consistent predictor of survival across all ages (Bohannon, 2008). The results from this systematic review were conclusive although it should be noted that there were some inconsistencies in results between genders within the studies included in the systematic review. This may have been due to lack of detail within some studies around methodology and this could explain some of these inconsistencies. In the same systematic review all studies examining the relationship of grip strength with future disability demonstrated that low grip strength was associated with a greater risk of functional disability. Indeed a key finding of this systematic review was that in many of the studies which included grip strength it was a consistent predictor of outcomes.

Since the publication of that systematic review further research has provided evidence to support these findings. In a group of 555 Dutch older adults (361f, 194m) aged 85 years and over those with the lowest handgrip strength at baseline had the highest rates of all-cause mortality at follow-up (Ling et al., 2010). In those people who had the greatest loss of handgrip strength over the follow up period there was also an increased risk of all-cause mortality irrespective of baseline measurements. Whilst handgrip strength can be utilised to predict outcomes it also has a predictive value in terms of recovery in older people. In a sample of 504 patients (120m, 384f, mean±sd age 85.3±5.5 years) who had undergone hip fracture surgery, grip strength was directly associated with the probability of both incident and persistent walking recovery (Savino et al., 2013). There is therefore great interest in the use of HGD as a marker of muscle strength and the role this plays in predicting functional limitations.

Handgrip measurements can be used as an important marker not only of strength and function but also to predict outcome. These studies therefore confirm that measuring HGD in an older population can act as an inexpensive, reliable screening measurement for assessing deterioration in muscle strength, functional ability and ability to perform ADL and thus potentially to live independently. There are a number of other factors in addition to changes in muscle mass and quality which negatively influence handgrip strength in a healthy older population including inflammation (Qureshi et al., 2002; Rantanen et al., 2003; Wang et al., 2005; Hamer & Molloy 2009; Schaap et al., 2009), and low levels of physical activity (Kuh et al., 2005). These associations may help to explain the relationship between handgrip and outcomes and indeed further support the use of HGD as a screening measure in an older adult population.

Due to its ease of use and portability HGD is commonly used as a simple bedside tool because it is a valid surrogate measure of overall muscular strength. Its role in this has been acknowledged within the diagnosis of sarcopenia as it is one of the accepted diagnostic markers (Cruz-Jentoft et al., 2010). The interpretation of HGD measurements requires reference or normative values for comparison and there have been several suggested cut-offs for normal handgrip levels published. In a study of 4,000 older adult Chinese people, HGD was found to be a suitable indicator of frailty within the community setting and in this study, cut-off values of 28 kg for older men and 18 kg for older women were recommended (Auyeung et al., 2014). The purpose of this study was to screen for frailty and as such these cut-offs have been suggested with this in mind. This is the most recently available data and it encompasses a large number of participants but whether these values are appropriate for the UK population is not clear. There are known differences in body composition across different ethnic groups (Wagner & Heyward, 2000; Wang et al.,

2003) and it is feasible that there are differences in functional abilities as a result. It may therefore be more appropriate to use the cut-offs suggested by Cruz-Jentoft et al. (2010) when considering sarcopenia and sarcopenic obesity. These cut-offs are <30 kg men and <20 kg for women. These are appropriate for their diagnostic value for sarcopenia but this does not apply to the entire older adult population and for comparison to normal values across the population. Normative values from Bohannon et al. (2006) may therefore be more appropriate. This meta-analysis of grip strength measurements has consolidated the data available and those relevant to older adults are shown in table 1.3.

**Table 1.3 Consolidated grip strength values for males and females (adapted from Bohannon et al., 2006)**

Age range (years)	Males		Females	
	Left (kg) mean (95% CI)	Right (kg) mean (95% CI)	Left (kg) mean (95% CI)	Right (kg) mean (95% CI)
60 - 64	38.7 (33.4,44.0)	41.7 (36.8,46.7)	23.0 (18.6,27.3)	25.9 (22.2,29.6)
65 - 69	38.2 (32.0,44.4)	41.7 (35.4,47.9)	22.9 (19.6,26.2)	25.6 (22.5,28.8)
70 - 74	36.2 (30.3,42.1)	38.2 (32.0,44.5)	22.5 (19.1,25.8)	24.2 (20.7,27.8)
75+	29.8 (24.8,34.7)	28.0 (12.7,31.0)	16.4 (14.7,18.1)	18.0 (16.0,19.9)

It is suggested that the lower limit of the 95% confidence interval can serve as a reasonable threshold for determining impaired muscle function (Bohannon et al., 2006). HGD provides important information about strength and function but does not provide an overall picture in terms of functional ability and performance in ADL and complementary measures will provide additional value when measuring function in older adults.

### **1.7.2 Sit to stand test (STS)**

The use of other sub maximal physical performance tests such as the sit to stand test (STS) has been suggested as an appropriate indicator of physical fitness in older adults (Schaubert & Bohannon, 2005). It is commonly used with older adults to determine a person's level of transfer function and the test has been shown to be

an indicator of lower extremity strength (Bohannon, 2002; Janssen et al., 2002c; Ritchie et al., 2005; Nordin et al., 2008). As it is a measure of lower limb strength it provides added value to measurements obtained from HGD. It is a reliable and valid measure in an ageing population and has been generally accepted as an indicator of functional status in older adults (Ritchie et al., 2005). Indeed it has been demonstrated to be a useful tool in both research and within the practice setting as it is considered a measure of not only functional ability but also an indicator or proxy of lower limb strength, balance and mobility (Lord et al., 2002). The motion of standing from a seated position is a key component of many daily activities e.g. rising from a chair and walking, getting out of a car or bath etc. and as such is a particularly useful measure in older adults (Janssen et al., 2002c). Indeed as the number of sit to stand motions performed each day by an older adult may be as many as 50 (Bohannon et al., 2008) it is seen as a critical determinant of a person's ability to live independently and it is a particularly important skill to maintain in ageing populations. An inability to perform the sit to stand motion leads to impaired function, mobility and impairment in ADL and in extreme cases even death (Guralnik et al., 1995). The STS clearly provides important information about a person's functional ability and it has the advantage of being a quick and inexpensive measure which does not require either a skilled practitioner or any specific training (Sterky & Stegmayr, 2005). Due to the positioning of the person undertaking the test, the test itself includes components of both upper and lower limb function and the test is considered to have both convergent construct (the extent to which the same trait is measured by different methods (Carmines & Zeller (1979)) and discriminate validity (the extent to which traits are distinct (Carmines & Zeller 1979)) as a result of its association with knee extension force and leg press force (Whitney et al., 2005).

The use of STS in an older population has the potential to highlight those people who may have a greater need for assistance as lower STS scores have been reported in older individuals who report a greater need for assistance with ADL (Bohannon, 2002; Ritchie et al., 2005). It is therefore a key measurement although there are a number of different STS tests available for use. All the tests are based on the quantification of the number of repetitions completed in either a given period of time or the time taken to perform a set number of repetitions (Bohannon, 2002). The variations in the tests include the sit to stand 5 (STS5), where the time to complete 5 repetitions is recorded, the sit to stand 10 (STS10), where the time to complete 10 repetitions is recorded, and the sit to stand 60 (STS60) where the number of repetitions completed in 60 seconds is recorded. Each test has a slightly different purpose with the STS5 and STS10 being considered in part indicators of muscle strength, and the STS60 an indicator of muscle endurance and fatigability (Bohannon, 2002).

The STS5 test has been shown to accurately reflect lower limb strength (Lord et al., 2002) and is therefore widely used particularly among older adults due to its shorter duration and thus enabling the majority of older adults to complete the test (Ganacher et al., 2012). As a one off measurement STS5 can be applied easily in many settings and provides an objective measure of lower limb muscle strength which is also a reflection of lower limb function and overall functional ability (Guralnik et al., 1994).

The time taken to perform the test can then be compared with normative values for the population. As there have been a number of studies which have used the STS5 in older adults Bohannon (2006) has reviewed the data and produced a meta-analysis of normative values for people aged 60 years and over. Data has been

categorised by age group but not by gender as there was no apparent differences in performance between men and women. Normative values are shown in table 1.4 with the upper 95% CI being used as the cut-off time for worse than average performance (Bohannon, 2006).

**Table 1.4 Meta-analysis of sit to stand performance times in older adults (adapted from Bohannon, 2006)**

sit to stand time (s)			
age (years)	n	mean time (s)	95% CI
60 - 99	20617	12.1	12.1,12.1
60 - 69	4184	11.4	11.4,11.4
70 - 79	8450	12.6	12.6,12.6
80 - 89	344	12.7	10.7,14.8

STS5 will be used within this study and unless otherwise stated STS will refer to the STS5 test. This test is clearly simple to perform and provides detail of lower limb function but due to its short duration does not reflect endurance. Endurance is also important in terms of functional ability as whilst it is important that a person can rise from a chair to enable them to function around their own homes a level of endurance will enable them to engage in additional activities and may enable them to leave their home and walk to the shops etc. Additional measures to complement the STS and HGD can therefore provide greater depth of information about a person's functional ability.

### **1.7.3 Six minute walk**

An additional submaximal measure of function which is commonly used in an older population is the six minute walk test (6MW) and this provides some detail about endurance ability making it an excellent complement to the STS. The 6MW is a quick and inexpensive performance based measure and although the gold standard for evaluation of exercise capacity is deemed to be maximal exercise testing on a treadmill or bicycle a submaximal test such as the 6MW can also be useful (Steele, 1996). It may even be more useful in an older adult population where consideration

of ADL is more important than performance per se. The 6MW has been shown to be associated with maximal exercise capacity and subjective functional status questionnaires (Steele, 1996; Bittner, 1997). The test is adapted from the 12 minute walking test which was introduced in 1968 as a guide to physical fitness and it was subsequently found that reducing the time of the walk to 6 minutes rather than the original 12 did not reduce the utility of the test (Butland et al., 1982).

The test evaluates both the global and the integrated responses of all the bodily systems involved during exercise and activity, and is influenced by the pulmonary and cardiovascular systems, the circulatory systems and muscle metabolism (American Thoracic Society, 2002). It does not however provide specific information on the individual function of each of these systems or provide an indication of causes of any exercise limitation. As it is self-paced, the 6MW assesses the submaximal level of functional ability and most people will not achieve maximal exercise capacity during the 6MW; but rather the test determines the person's own intensity of exercise and this is probably more useful as a measure in older adults. Another key advantage of the 6MW test is that participants are permitted to stop and rest during the test which again may be important in a population who are potentially functionally impaired. Whilst these may be seen as limitations in the test for some groups this is a relative strength in some situations as is the case for a healthy older adult population as most ADL are performed at submaximal levels of exertion. As such the 6MW may better reflect functional exercise level for daily physical activities (American Thoracic Society, 2002).

The test is well tolerated, reflective of ADL, safe, easy to administer, well accepted and does not require expensive equipment (Guyatt et al., 1985) and as it is an objective measure is likely to be more reproducible than functional status

questionnaires. It also has the ability to detect small but clinically significant changes in a person's exercise capacity (Steele, 1996; Bittner 1997). The 6MW therefore has an obvious role in assessing functional status in older adults and as it is time limited rather than distance dependant it can measure function in a spectrum of abilities of older adults from those who are highly functioning to those who have some degree of disability (Bohannon, 2006). Rikli & Jones (1998) originally validated the test in healthy ambulatory older adults where they found the test to be reliable and valid as a measure of physical endurance and overall physical function. Since this time guidance has been provided in terms of the use of the 6MW (Enright et al., 2003a) where it is reported that the 6MW is safer, easier to administer, better tolerated, and better reflects ADL than other walk tests. As the 6MW is self-paced older adults are probably less likely to push themselves through their limits of tolerance and as such the test is more likely to truly reflect their day to day capabilities.

The 6MW is used to measure the maximum distance that a person can walk in 6 minutes and like many functional tests there is a learning effect when the test is performed on two successive days, with a mean 15% improvement in distance walked (Leach et al. 1992) but this effect is not important when determining cross-sectional correlations (Enright & Sherrill, 1998). There are a number of factors which affect the performance in the 6MW in healthy older adults. In a study of 2,281 older adults who performed the 6MW the mean $\pm$ sd distance walked was 344 $\pm$ 88 m with gender, older age, greater weight, larger waist and weaker grip strength all impacting on the distance walked. In view of this age and gender should be acknowledged in normative values.



There have been a number of studies which have provided data for the development of normative values for the population. Lipkin et al., (1986) reported a mean±sd distance of 683±8 m walked although this was based on a small sample (n=10) who were also relatively young (36 - 62 years) and these results are unlikely to reflect normal ability of an older adult population. This is one of the problems with normative values for the 6MW as there are no established large scale studies which have produced reference data for the 6MW.

Enright & Sherrill (1998) have devised gender specific equations for adults for the 6MW based on age, height, and weight. These equations are based on data from subjects aged 40 - 80 years where a median 6MW distance recorded was 576 m for men (n=117) with a median age of 59.5 years and a median distance of 494 m for women (n=173) who had a median age of 62 years. Regression equations were developed after excluding participants who were over 80 years of age, obese, who had a history of CVA, had hypertension, poor pulmonary function (FEV <70%) or who were smokers as these all influence performance in the 6MW. The equations developed are most likely indicative of predicted performance in those older adults who would be considered healthy. These equations predict the distance a person would be expected to walk during the test and are shown in table 1.5.

**Table 1.5 Reference equations for 6MW distance (m) in health adults (Enright & Sherrill, 1998)**

<b>Gender</b>	<b>Prediction equation to estimate distance walked in 6MW test</b>
Male:	$6MW = (7.57 \times ht \text{ (cm)}) - (5.02 \times age \text{ (y)}) - (1.76 \times wt \text{ (kg)}) - 309 \text{ m}$  Alternative equation using BMI (kg/m <sup>2</sup> ): $6MW = 1140 \text{ m} - (5.61 \times BMI) - (6.94 \times age \text{ (y)})$  When using either equation, subtract 153 m for the Lower Limit of Normal
Female	$6MW = (2.11 \times height \text{ (cm)}) - (2.29 \times weight \text{ (kg)}) - (5.78 \times age \text{ (y)}) + 667 \text{ m.}$  Alternative equation using BMI (kg/m <sup>2</sup> ): $6MW = 1017 \text{ m} - (6.24 \times BMI) - (5.83 \times age \text{ (y)})$  When using either equation, subtract 139 m for the Lower Limit of Normal

These equations enable a prediction of the expected distance travelled in the 6MW test at an individual level but they should be used with caution as they account for only 40% of the distance travelled in the 6MW. Following the development of these equations normative values have been produced to provide guidance on expected values of the distance walked within the 6MW test at a population level (Steffen et al., 2002). This data are summarised in table 1.6. Clearly this reference data lacks currency but despite encouragement from the American Thoracic Society (ATS) (2002) for researchers to publish reference data for the 6MW test in a range of populations, larger more recent studies are not available and as such this is the best data currently available for comparison.

**Table 1.6 6MW distances: means, standard deviations and confidence intervals by age and gender (m) (Steffen et al., 2002)**

Age (y)	Gender	n	mean distance (m)	sd	95% CI (m)
60–69	Male	15	572	92	521,623
	Female	22	538	92	497,579
70–79	Male	14	527	85	478,575
	Female	22	471	75	440,507
80–89	Male	8	417	73	356,478
	Female	15	392	85	345,440

Although the numbers in this study were small the participants were community dwelling and were chosen based on their ability to function independently in the community and without assistive walking devices. This group are therefore likely to provide a more realistic comparison for the older population who live independently and based on the descriptive characteristics of the study population they appeared to have few medical co-morbidities, were self-reliant in ADL and were independently mobile. Steffen et al. (2002) believe that the data represents a range of older adults who are fairly active and have fairly good health and as such the data provided can act as a guide for the expected performance within this test. It should be noted that the data should only act as a guide as there are differences in performance in the 6MW with people who are of short stature, between genders, who are older, who

are heavier and those with reduced muscle mass tending to perform less well in terms of distance walked (Enright et al., 2003b). Only some of these factors are accounted for within the predictive equations and the normative data.

Guidance for the administration of the 6MW has been produced by the ATS (2002) and to enable comparisons across populations this guidance should be followed. Part of the guidance suggests the use of the BORG scale to determine dyspnoea and fatigue during the test but this is more commonly used when considering specific pathologies such as COPD and is not always required when measuring baseline distances within the 6MW or indeed in healthy populations.

The use of a range of functional tests along with markers of nutritional status provide depth and breadth of detail about a person's FM, FFM and functional ability and measuring these parameters together provide an overall picture of nutritional status, body composition, functional ability, risk of disability, functional decline and mortality. They can also be used to determine baseline information to enable the prevention or delay of sarcopenia or sarcopenic obesity developing or progressing. There are two main factors which influence the ageing process and the development of sarcopenia and these are diet and physical activity.

## **1.8 THE ROLE OF DIET IN THE AGEING PROCESS**

In view of the impact muscle loss has on a person's strength and ultimately function it is important to endeavour to minimise this inevitable loss as a result of ageing. It has been shown that well recognised lifestyle behaviours influence both FFM and muscle strength. In particular age, adult body size, nutrition and physical activity play a role (Paddon-Jones et al., 2008; Vincent et al., 2002).

### 1.8.1 Protein

In addition to the changes in BMI and well described changes in body composition in terms of FFM loss there are alterations in protein synthesis and turnover with ageing which will also influence body composition. As people age protein synthesis decreases and protein turnover slows and there is an age-related resistance to the anabolic effects of dietary protein resulting in overall muscle atrophy (Breen & Phillips, 2011; Haran et al., 2012). In view of this the amount of protein a person eats may help attenuate some of the muscle loss seen in ageing and indeed may help promote protein synthesis if eaten in adequate amounts. There is a growing body of evidence to suggest that older adults have higher protein requirements as a result of this age-related resistance to the anabolic effects of dietary protein (Paddon-Jones et al., 2008). Indeed studies have shown that targeted daily protein consumption in older people can slow or even prevent muscle protein catabolism and thus maintain levels of FFM (Paddon-Jones, 2006; Paddon-Jones et al., 2004a). In particular high biological value (HBV) protein (i.e. that primarily from animal sources) can enhance muscle synthesis in older adults (Paddon-Jones et al., 2004a; Paddon-Jones et al., 2004b) although protein consumption in isolation of other nutrients is likely to be ineffective and a mixed diet and in particular in combination with carbohydrate can reduce muscle catabolism (Volpi et al., 2000)

Currently the recommendation for protein intakes in older adults in the UK is 0.75 g/kg body weight (g/kgBW) and this was derived in 1991 on the basis of estimates of the amount of high-quality egg or milk protein required for nitrogen equilibrium as measured by nitrogen balance (DoH, 1991). This value is based on providing adequate protein to prevent deficiency rather than ensuring optimal protein intakes to prevent the development or progression of sarcopenia or frailty. These recommendations were developed prior to our increased awareness of sarcopenia

and as such it may well be that current recommendations for protein intakes in older adults may no longer reflect the growing evidence base. Indeed even relatively early studies have suggested that recommendations for protein intakes are inadequate. Campbell et al. (2001) investigated the impact a strict protein controlled diet had on body composition. This was a small study (4m, 6f) and participants were provided a diet which met the Recommended Daily Amount (RDA) in the USA for protein along with adequate energy intakes to maintain energy balance. Over the 14 week intervention period, weight and body composition was maintained although thigh circumference and urinary nitrogen both decreased suggesting a metabolic adaptation to lower than normal protein intakes. Although this study was conducted in a small number of participants and protein intakes met the RDA for the USA population the results would be transferable to a UK population where the DRV is set at a similar level. A recent report of the Health Aging and Body Composition Study (Houston et al., 2008) found that protein intake played an important role in preserving FFM at a population level. This study measured changes in body composition and dietary intake in more than 2,000 adults aged 70 - 79 years with mean daily protein intakes of 70.8 g in men and 60.9 g in women which are well above the UK Reference Nutrient Intake (RNI) for protein. After adjusting for confounding covariates (smoking, alcohol intake, activity) those participants who had the lowest protein intakes i.e. 56 g/d or 0.8 g/kg/d had 40% more FFM loss over the 3 year study period compared to those people who had the highest protein intakes of 91 g/d or 1.2 g/kg/d) again suggesting that higher protein intakes are beneficial in older people.

Evidence is however conflicting as in a large study of 4,000 Chinese men and women aged 65 years and over it was found that dietary intake and in particular protein, as measured by semi-quantitative food frequency questionnaire, was not

associated with reversing sarcopenia over a 2 year period. The mean $\pm$ sd protein intake in this study was 76.5g $\pm$ 33.5 g/day which is well in excess of the current Dietary Reference Value (DRV) for protein for both men and women in the UK (You et al., 2004). The main focus of this study was reversibility of sarcopenia and it may have been that FFM loss was decreased and the development of sarcopenia was lessened or delayed although this is not reported. As a result of studies like these described there are now suggestions that protein intakes in the elderly should be around 1.2 g/kgBW (Gaffney-Stomberg et al., 2009) or indeed as high as 1.5 g/kgBW (Wolfe et al., 2008). Whether this amount of protein is appropriate for the entire older adult population is unclear. With increasing levels of overweight and obesity providing protein based on weight could result in exceptionally high protein intakes and some correction for obesity may be appropriate. However as protein is the most satiating of all nutrients (Stubbs et al., 1996) it may be that these high protein intakes could result in increased satiation and protein intakes could become self-limiting in obesity. It should also be noted that although protein is a key nutrient in the management and prevention of sarcopenia it must be provided alongside adequate energy intakes and even then this may not be enough to combat sarcopenia and FFM loss may occur regardless of energy balance (Rolland et al., 2011).

It is therefore clear that ensuring adequate dietary protein is consumed may benefit improved functionality but the timing and delivery of protein should also be considered. Clearly from a normal day to day living perspective the most practical way to ensure the promotion of skeletal muscle protein anabolism is to include a moderate amount of protein and in particular high biological value protein (HBV) (i.e. rich in essential amino acids (EAA)) at each meal time. The distribution of protein across the day is key to this and there is evidence that suggests the provision of 25–

30 g of HBV protein (equivalent to approx. 10 g EAA) at each mealtime is necessary to maximally stimulate skeletal muscle protein synthesis (Symons et al., 2007). It is therefore not unreasonable to suggest that the ingestion of this amount of protein at each meal could be a useful strategy to maintain muscle mass in the elderly. Based on the RNI current recommendations for a 70 kg person represents 53 g protein/day which if distributed evenly across three meals equates to 18 g protein/meal which in turn equates to 5 - 8 g EAA when provided as HBV protein. This would not meet current evidence to support the provision of 10 g of EAA at each mealtime. As EAA are primarily responsible for muscle synthesis (Volpi et al., 2003) it is critical in managing muscle wastage in ageing and Paddon-Jones et al. (2004b) support intakes of EAA at around 10 - 15 g at each meal time and indeed have shown that low doses i.e. <7.5 g (approx. RNI levels) are inadequate to stimulate muscle synthesis in older adults. These suggested requirements for protein consumption are of concern as protein consumption tends to decrease with age (DoH, 2012). The reasons for this are not clear although there are a number of potential causes such as greater expense (particularly of HBV protein sources such as meat and fish), increased satiety which occurs in ageing but could be exacerbated by the fact that protein is known to be the most satiating macronutrient (Stubbs & Elia, 2001), alterations in dentition/chewing status and physiological changes in digestion in older adults.

Protein evidently plays an important role in the prevention and management of muscle loss as a result of ageing however it is not the only nutrient which plays a role with a recent upsurge in interest in the role of vitamin D within the ageing process.

### 1.8.2 Vitamin D

Whilst protein has been identified as a key nutrient in managing sarcopenia it is not the only nutrient to play a role. Over recent years there has been emerging interest in the role vitamin D has in muscle function and strength. Vitamin D is a pro-hormone produced in the skin through ultraviolet irradiation of 7-dehydrocholesterol (DeLuca, 2004). It is biologically inert and must be metabolized to 25-hydroxyvitamin D<sub>3</sub> in the liver and then to 1,25-dihydroxyvitamin D<sub>3</sub> in the kidney before being utilised by the body (DeLuca, 2004). If there is inadequate sunlight then dietary vitamin D is required. It is well established that vitamin D plays a pivotal role in bone health (Kulie et al., 2009) but increasing intakes is also considered important in terms of muscle mass and muscle strength. A number of observational studies have therefore investigated the role of serum vitamin D (measured as 25OHD) concentration and functional ability.

The results from these observational studies are conflicting. A number of studies have shown an association between lower serum vitamin D levels and poorer physical functioning. Bischoff-Ferrari et al. (2004) measured physical performance by an 8 foot walk test and the STS test and found that in a group of 4,100 ambulatory US citizens aged 60 - 90 years those with a higher serum vitamin D levels (40 - 94 nmol/L 25(OH)D) performed better in the physical functioning tests irrespective of habitual activity levels. A study in Sweden supports these findings where it was established that in a group of 986 Swedish women those with a poorer vitamin D status had poorer physical functioning ability as measured by gait speed, the Romberg balance test and thigh muscle strength (Gerdhem et al., 2005). Furthermore as part of the InCHIANTI Study 976 people aged 65 years or older were assessed for physical performance using a short physical performance battery and handgrip strength. In those people with serum vitamin D levels indicative of



vitamin D deficiency (<25 nmol/L) or vitamin D insufficiency (< 50 nmol/L) poorer performance was seen in both the short physical performance score and the HGD measurements in both men and women (Houston et al., 2007). These results appear conclusive in terms of the role of vitamin D and physical functioning however conflicting evidence exists. A study of 311 American men and 396 American women aged 22 - 93 years (mean±sd age 56±19 years) found no consistent association between serum vitamin D levels and muscle strength as measured by HGD and isometric knee extension force (Marantes et al., 2011). Interestingly however this study did find that in subjects younger than 65 years, there was an association between low vitamin D levels and low levels of FFM. The impact of this for later life in these people is not known but it appears that this has the potential to result in poorer functional ability with ageing. The findings of this study are supported by an additional study of 1,219 American men aged 30–79 years where serum vitamin D levels were measured along with physical functioning by HGD and a composite physical function score (chair stand and walking speed). This study also found no association between vitamin D levels 25(OH)D and HGD or physical functioning scores (Ceglia et al., 2011). The mechanism of the role of vitamin D status in influencing functional status is therefore inconclusive but it appears that vitamin D does play some role within this. Further research is however required to determine exactly what the role is.

Although observational studies have not provided conclusive evidence as to the relationship between vitamin D and muscle function the UK the Scientific Advisory for Nutrition (SACN) have developed a position statement on the topic of vitamin D (SACN, 2007). Vitamin D status is influenced primarily by a person's exposure to sunlight and as UV radiation and thus vitamin D synthesis varies with latitude exposure to adequate amounts of sunlight within the UK and in particular Scotland is

limited. Indeed it is only during the months of April – October where sunlight is at an appropriate wavelength to synthesize vitamin D in Scotland. During the winter months the UK population relies on body stores of vitamin D to meet their requirements. With ageing there also tends to be a reduction in the amount of skin which is exposed to sunlight reducing vitamin D synthesis further and it is therefore advised that all adults aged 65 years and over should receive a vitamin D supplement to enable them to meet requirements of 10 µg/day (SACN, 2007). It is not known whether this routine supplementation is happening and if not this may then influence muscle function. An additional consideration is that vitamin D status is also influenced by levels of adiposity with lower serum vitamin D levels seen in obese individuals and in those individuals with higher levels of total body fat (Snijder et al., 2005; Hypponen & Power, 2006). The implications for the UK, with the increasing incidence of overweight and obesity is therefore significant and consideration of the entire diet is therefore vital to ensure optimal nutritional status.

### **1.8.3 Dietary intakes in older people**

There is clear guidance for dietary and nutrient intakes within the UK along with healthy eating guidance (DoH, 1991) although there is evidence in Scotland that this is not adhered to (The Scottish Government, 2011). Dietary intakes change as we age as a result of a number of factors including ill health, chronic medical conditions, poor dentition, drug-nutrient interactions, mobility and physical difficulties e.g. arthritis and poor economic status. These problems can result in dietary intakes deteriorating which has a resultant impact on body composition. Macronutrient intake is a major influence on body weight and indeed body composition with high energy intakes in a sedentary population resulting in increased fat stores and weight gain and reduced intakes resulting in weight loss and depleted fat and muscle stores. Guidance produced by COMA (DoH, 1991) provides detail of the

recommended diet for the UK population as a whole and specific consideration is given to the dietary needs of an older adult population by the British Nutrition Foundation (Stanner et al., 2009). These recommendations are however in the main the same as those for the entire adult population. The consumption of a diet in line with these has the potential to maintain or normalise body weight which will in turn aid the prevention of many age related disorders including T2DM, HT, CVD and osteoporosis (WHO, 2004). These disorders are also influenced not only by body composition (as previously discussed sections 1.2, 1.3, 1.4) but also oxidative stress. The quality of the diet and in particular its impact on a person's antioxidant status may play a role in reducing this oxidative stress.

#### **1.8.4 Antioxidants**

Oxidative stress has been shown to be increased as body fat increases and is associated with increased levels of CVD and T2DM. A significant positive correlation between plasma antioxidant concentrations and physical performance and strength in the elderly has been shown. Higher dietary intakes of antioxidants, especially vitamin C, have been found to be associated with greater skeletal muscular strength (Cesari et al., 2004).

In terms of healthy ageing, antioxidants play a useful role as epidemiological studies have shown that consumption of anti-oxidant rich foods e.g. fruit and vegetables is associated with a lower incidence of CVD, ischemic stroke, cancer, and other age related chronic diseases (Arts & Hollman, 2005; Voko et al., 2003) and a reduced risk of dementia (Devore et al., 2010) in adults. It has been known for some considerable time that low vegetable intakes in men are associated with increased coronary heart disease (CHD) (Liu et al., 2001) and that higher intakes of fruit and vegetables in women is also associated with a reduced CHD risk (Liu et al., 2000).

This reduction in risk as a result of higher fruit and veg intakes may be partially explained by the energy density of fruit and vegetables being relatively low and higher consumptions may displace foods of higher energy density i.e. foods which are high in fat and saturated fat (and thus help to prevent weight gain). Whilst this is a beneficial effect the fact that fruit and vegetables are rich sources of antioxidants, plant sterols and non-starch polysaccharides may also be important as these all have a role in preventing CVD through maintaining endothelial function (McCall, et al., 2009; Gylling et al. 2013)

The increased risk of CVD in ageing may be due to loss of endothelial function which in turn may be as a result of both a pro-inflammatory state and oxidative stress. Oxidative stress can occur with ageing due to the production of reactive oxidative species (ROS) and free radicals both of which can impact on endothelial function (Oakley & Tharakan, 2014). The free radicals generated through increased levels of oxidative stress are subsequently scavenged by antioxidants and as such these antioxidants are vital to reduce CVD risk by limiting the amount of lipid peroxidation possible. A further concern is that abdominal obesity is also associated with endothelial dysfunction which is seen more commonly in older adults and in obese populations like the Scottish population. The mechanisms for this are likely to include insulin resistance and inflammation which in turn influence levels of oxidative stress. To prevent oxidative stress there are a number of physiological mechanisms which take place to prevent the damaging effects of ROS and these mechanisms are supported by the ingestion of rich sources of antioxidants (primarily fruit and vegetables). It is well established that micronutrients tend to have a greater antioxidant capacity than other nutrients and in particular vitamins A, C and E along with selenium are considered to have particular strengths as antioxidants. Clearly these nutrients are generally not consumed in isolation but rather in combination

with each other and so measuring each individually is generally not considered a good reflection of overall total antioxidant capacity. It may be then that in those people with abdominal obesity, increased plasma antioxidants levels could play a positive role in reducing cardiovascular risk. It may also be worthwhile determining antioxidant status to allow better more targeted dietary advice.

### **1.8.5 Measuring antioxidant status**

There are a number of methods capable of measuring antioxidant status but one of the most frequently used is the ferric reducing antioxidant capacity of plasma (FRAP) as first described by Benzie & Strain (1996). The FRAP assay is a method used to measure total antioxidant capacity based on the reduction of ferrous ions. FRAP provides more biologically relevant information than that provided by individual antioxidant measurements (Ghiselli et al., 2000) whilst also describing the dynamic equilibrium between pro-oxidants and antioxidants in the plasma. FRAP can be used as a viable measure of antioxidant capacity of both plasma and foodstuffs. When measuring the antioxidant capacity of plasma FRAP can provide an overall picture of an individual's antioxidant status and has been used in a number of studies for this purpose (Kolomvotsou et al., 2013; Kappus et al., 2011). It was however a study by Cao et al. (1998) which was one of the first to use FRAP as a means of measuring antioxidant capacity of plasma and this study found it to be simple and convenient in terms of its operation. There are some considerations in the interpretation of results obtained from FRAP analysis. FRAP does not measure the SH-group-containing antioxidants and is performed at very low pH which does not reflect biological conditions. It does however have advantages in that it can determine antioxidant activity directly in whole plasma and is not dependent on enzymatic or non-enzymatic methods to generate free radicals (Pulido et al., 2000). Normative values have not been published for FRAP levels in

an older adult population and so it is not possible to compare individual results to population norms however there is still the opportunity to have an overview of the antioxidant status of a person relative to others. Measuring AOS is therefore important as a change in this has the potential to induce a low grade inflammatory state which is also associated with a number of NCDs.

## **1.9 INFLAMMATION**

A chronic low grade inflammatory state is thought to be present as a result of ageing due to both a dysregulation of the immune system with age, and an altered redox state (i.e. a change in antioxidant status). It manifests itself by increased levels of pro-inflammatory cytokines and these are associated with not only increasing age but also increasing levels of adiposity and low levels of physical activity. The InCHIANTI study measured pro-inflammatory cytokines in a representative sample of the general population (Ferrucci et al., 2005) and found that inflammatory markers including C-reactive protein (CRP) increased with age in both men and women and even after adjusting for cardiovascular risk factors and morbidity, age continued to be a significant predictor of higher CRP in women although not in men. These increased CRP levels have a subsequent impact on mortality levels. In a UK study of 16,850 participants, those with lower levels of CRP tended to be younger, leaner, more physically active, less likely to smoke, have lower cholesterol levels, lower blood pressure and lower prevalence of diabetes (Ahmadi-Abhari et al., 2013). Unsurprisingly then higher levels of CRP were associated with increased risk of all-cause mortality. It is therefore fairly conclusive that inflammation plays a role in ageing, age related disorders, morbidity and mortality.

Whilst age is an important determining factor for levels of inflammation other lifestyle factors are also important. It is well documented that inflammation places a role in

the onset and development of a number of age related disorders including atherosclerosis (Libby et al., 2002), CVD (Ridker, 2000), T2DM (Lee et al., 2009) and obesity (Fröhlich, 2000). These diseases are influenced heavily by nutritional status and in particular overweight and obesity as well as having a clearly defined association with low levels of physical activity and sedentary behaviour. This relationship between NCD and inflammation may be partially explained by higher levels of abdominal adiposity as in a sample of 387 older women (i.e. those aged over 60 years of age) it was established that those people with a normal CRP level had lower WC levels and even after correcting for BMI this association remained, suggesting CRP levels are independent of BMI (Sasaki et al., 2007). Overnutrition and central adiposity therefore have a clear link with low grade inflammation however this is also true of people who have a poorer nutritional state.

Whilst inflammation is linked to overnutrition and increased levels of abdominal adiposity resulting in a link with CVD and T2DM, perhaps more surprisingly it has also been shown to play a role in the development of undernutrition and therefore has the potential to impact the entire older adult population. Undernutrition is a common problem in an ageing population with the incidence being estimated at between 29 - 61% (Corish & Kennedy, 2000) and it can occur as a result of wasting and/or sarcopenia. Wasting occurs as a result of poor dietary intake attributable to either disease or psychosocial factors and sarcopenia is an intrinsic part of the ageing process (Hickson, 2006) and is defined as a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death (Cruz-Jentoft et al., 2010). Wasting and sarcopenia both result in a reduction of FFM and as previously discussed this loss of FFM will have a resultant impact on functional ability causing increased frailty and increased levels of inflammatory markers have

been found in those people who are undernourished or frail. Hubbard et al. (2009) categorised 89 older adults for frailty using criteria described by Fried et al. (2001) and measured inflammatory markers and it was found that with increasing frailty both CRP and tumour necrosis factor  $\alpha$  (TNF $\alpha$ ) increased significantly. Following adjustment for multiple covariates (age, gender, BMI, smoking, number of co-morbidities and medications) it was found that these covariates did not account for any of the observed differences in levels of inflammatory markers. Those people who were less frail and thus had lower inflammatory markers were not unsurprisingly more likely to live independently.

The elevated cytokine levels seen in ageing (Yeh & Schuster, 1999) resulting in loss of FFM is often termed cachexia of ageing (Roubenoff, 1999). As it is possible that this inflammation plays a role in the development of age related disorders it is vital that this is considered within the ageing process. This is particularly the case as low grade inflammation has implications in terms of functional ability as it has been demonstrated that the pro-inflammatory state affects muscle and may be involved in muscle breakdown which in turn can lead to sarcopenia (Barbieri et al., 2003). This study measured interleukin-6 (IL-6) and found this to be associated muscle function ( $r=-.14$ ,  $p<.005$ ) and handgrip ( $r=-.17$ ,  $p<.001$ ). When tested in linear regression modelling IL-6 was found to be an independent variable. Whilst this study did not measure CRP the pro-inflammatory state is normally also associated with raised CRP levels and it therefore seems likely that the same associations would be found with CRP. More recently Vasunilashorn et al., (2013) established that in a group of 1,006 older adults who were found to have a pro-inflammatory state (which included a raised CRP) there was loss of ability to walk 400 m over a 6-year follow up period. These results suggest that low grade inflammation influences a decline in physical function. As similar functional declines are seen in sarcopenia, inflammation may be



an important determinant of not only overweight and obesity but also in the development and progression of sarcopenia (Roubenoff et al. 2003).

As inflammation has been linked to nutritional status and age related disorders and to a decline in functional ability it is unsurprising that it has also been associated with mortality in older adults (Harris et al., 1999). Levels of IL-6 and CRP (both markers of inflammation) were measured in a group of 1,293 healthy older adults who were followed up prospectively over a mean time of 4.6 years. It was found that in those people who had higher levels of IL-6 at baseline there was a twofold greater risk of death (RR=1.9; (95% CI 1.2,3.1)) and in those with raised CRP at baseline there was also found to be an increased risk of mortality although to a lesser degree (RR=1.6 (95% CI 1.0,2.6). Where both inflammatory markers were increased there was a 2.6 greater likelihood of mortality and these results were similar across cardiovascular and non-cardiovascular events. More recent studies have confirmed these findings with Reuben et al., (2002) measuring levels of CRP in 870 healthy older adults aged 70 - 79 and in those people who had high levels of inflammatory markers including CRP the adjusted OR for 3 and 7 year mortality were 6.6 (95% CI 2.6,16.6) and 3.2 (95% CI, 1.6,6.4) respectively, compared to those people with no elevated inflammatory marker. Low grade inflammation is therefore seen in both over and under nutrition and perhaps surprisingly has also been reported in healthy older adults (Thomas, 2007) suggesting this may a normal part of the ageing process.

Reassuringly there does however appear to be the possibility of reversing the inflammatory state as physical activity, independent of weight loss, is inversely related to CRP levels (You et al., 2004). Importantly the type of activity appears to be unimportant as inflammatory markers have been shown to be lower in older

adults who are active through non-sedentary behaviour as well as through exercise when compared to sedentary older adults (Boekholdt et al., 2006). It seems therefore that it is movement rather than the intensity of the activity which is important in preventing or reducing inflammation. More recently a study by Martins et al. (2010) confirmed these findings when the effects of aerobic and strength based physical activity interventions on levels of CRP in older men and women were investigated. The study participants were randomly assigned to an intervention of either aerobic activity or strength training for 16 weeks followed by 16 weeks without any intervention and in both groups functional fitness improved along with CRP levels decreasing. In the aerobic exercise group CRP levels decreased by 10% following the exercise intervention (end of intervention i.e. 16 weeks) and by 51% at final follow up (32 weeks) and in the strength training group CRP decreased by 11% after the exercise intervention (16 weeks) and by 39% at final follow up (32 weeks) demonstrating a prolonged effect of activity. These reductions in CRP levels also appeared to be associated with improvements in strength as measured by chair stand and arm curl and reduction in adiposity as measured by BMI and WC. Increasing physical activity per se may therefore be important as it has been suggested that reduced systemic inflammation may be one of the mechanisms through which physical activity leads to reduced cardiovascular risk (Boekholdt et al., 2006).

There is a large body of evidence to support the use of physical activity in reducing inflammatory markers. One study of 50 older adults (11 men, 39 women mean±sd age 68±5.5 years) who were randomly allocated to receive an intervention of either resistance training or aerobic exercise found that after a 12 week intervention there was a 50% reduction in the number of people with elevated CRP who participated in resistance training and an 85.7% reduction in the number of people with elevated

CRP who participated in aerobic activities (Wanderley et al., 2013). This supports the role of aerobic activity as a means of reducing inflammatory markers but it is reassuring that exercise per se has a beneficial effect. It may be however that older adults are not able to participate in exercise and so the role of habitual activity has also been investigated.

Habitual activity levels (measured by accelerometer) and CRP levels were measured in 1,253 community-dwelling older adults living in Germany and a dose–response relationship was found with daily walking duration and CRP and so even low intensity activity may be beneficial in older adults (Klenk et al., 2013). These results should be interpreted with caution as not all studies are consistent with these findings. In a study in the UK of 505 older adults (mean±sd age 59±10 years and mean±sd BMI 29.5±4.7 kg/m<sup>2</sup>) in those women who had increased levels of sedentary behaviour (as measured by sitting time) there was a positive association with increased levels of CRP although this was not found to be the case in the male participants. The association in women remained significant after additional adjustment for total moderate to vigorous intensity physical activity suggesting that the influencing factor may be sedentary behaviour (Yates et al., 2012) rather than physical activity. The reason for the differences in CRP levels between genders is not clear but in view of the findings from the previous studies it may be as a result of exercise type between the men and women although this is not reported so cannot be confirmed. It may also be as a result of differences in baseline fitness levels as this also plays a role in inflammation.

It has been established that in postmenopausal women who were prescribed a year long exercise intervention there was a statistically significant reduction in CRP levels in the intervention group after 12 months. It also appeared to be the case that as

activity levels were increased further so CRP levels decreased further and this was particularly true in women with higher baseline levels of fitness (Friedenreich et al., 2012). The Health, Aging and Body Composition Study found similar results. In a group of 3,075 men and women where physical activity levels were measured by questionnaire and CRP levels were measured it was found that the cohort had a median (IQR) CRP level of 1.67 (0.99–3.11) mg/L and in those people who participated in up to 180 minutes exercise each week had a median (IQR) CRP level of 1.6 (0.2–30.8) mg/L and for those who participated in more than 180 minutes of activity each week a median (IQR) CRP level of 1.3 (0.2–85.2) mg/L was found (Colbert et al., 2004).

In T2DM and in the presence of metabolic syndrome there are also encouraging results as it appears that markers of inflammation can be reduced in those people participating in increasing levels of either high intensity activity or a combination of resistance and aerobic exercise. This reduction in CRP was seen irrespective of weight loss (Balducci et al., 2010). It should be noted however that whilst there was no weight loss there was a reduction in WC and thus abdominal adiposity in both groups and this could partially explain reductions in CRP levels in the absence of weight loss. Although CRP levels can be reduced by activity irrespective of weight loss, changes in diet, body composition and weight reduction can also reduce CRP levels (Kasapis & Thompson, 2005, Nicklas et al., 2013; Tchernof et al., 2002) providing further evidence that measuring intake and considering energy balance will provide useful information about a person's overall nutritional status and may give an indication as to the expected body composition and functional status of a person.

## **1.10 ENERGY BALANCE**

Maintaining an appropriate body weight throughout adulthood will help reduce problems associated with both over and undernutrition. Energy balance is fundamental to this to ensure energy intake and energy expenditure are equivalent. Total energy expenditure (TEE) is comprised of 3 main components, resting energy expenditure (REE) which accounts for 60 - 70% of TEE, dietary induced thermogenesis (DIT), which accounts for approximately 10% of TEE and physical activity which accounts for 20 - 40% of TEE in healthy adults SACN (2011). Energy expenditure (and thus energy requirements) decrease with age due to the previously discussed changes in body composition i.e. decreased levels of FFM and increased levels of FM resulting in reduced metabolic rates. This reduction in energy expenditure can be exacerbated through changes in lifestyle and in particular reduced levels of physical activity and increased levels of sedentary behaviour (Phillips, 2003) which can result in weight gain. To maintain energy balance and to prevent increases in body weight energy intakes should reduce in line with this lowering of TEE. It is possible to either predict REE through the use of validated prediction equations (Henry, 2005) or to measure it by indirect calorimetry. Physical activity levels (PAL) can then be used in conjunction with REE to predict TEE. PAL factors can be either based on population based activity factors or be objectively measured. Population based PAL factors have been described (SACN, 2011) but these have remained relatively unchanged since 1991 (DoH, 1991) and it has long been suggested that these factors may underestimate energy expenditure in an older adult population (Roberts, 1996). As such objectively measured REE and activity levels are likely to provide greater accuracy in predicting TEE. To determine energy balance a measure of energy intake is also required.

It has long been established that overall dietary intake including energy can be measured in older adults using a food diary over a seven day period (Mahalko et al., 1985) and this provides an accurate picture of total energy, macronutrient and micronutrient intake. This can then be compared to dietary reference values (DRV) (DoH, 1991). There is some evidence to show that over and underreporting can occur with food diaries (Stubbs et al., 2014) however measuring REE will enable the accuracy of food diaries to be established. Importantly the information obtained through dietary analysis provides an insight into the known risks associated with poor diet and into the impact diet has on nutritional status.

Diet is therefore a key determinant of nutritional status, functional ability, antioxidant status and inflammation. These are all also influenced by physical activity levels as it is this alongside dietary intake which will more fully enable muscle anabolism which in turn will aid muscle function. It is therefore important that physical activity, physical functioning and dietary intakes are considered alongside each other in an older population to enable appropriate targeted advice to help prevent further muscle loss or indeed even replete some lost muscle which in turn has the potential to improve function and thus enable people to live independently for longer.

### **1.11 PHYSICAL ACTIVITY**

Physical activity is an all-encompassing term for any type of activity and has been defined by WHO (2014) as any bodily movement produced by skeletal muscle that requires energy expenditure. It therefore includes all activity associated with energy production including work related activities, leisure-time activities and exercise. It can be categorised in a number of ways but for the purposes of this literature review the definitions shown in table 1.7 will be used.

**Table 1.7 Definitions of different activity types**

<b>Activity type</b>	<b>Definition</b>	<b>Reference</b>
Aerobic Activity	Aerobic exercise (activity) involves large muscle groups in dynamic activities that result in substantial increases in heart rate and energy expenditure. Regular participation results in improvements in the function of the cardiovascular system and the skeletal muscles, leading to an increase in endurance performance	Howley, 2001
Exercise	Activity which is planned and structured	DHHS, 2008
Light activity	Activity where the metabolic equivalent is between 1.6 - < 3.0 MET	Norton et al. 2010
Metabolic Equivalent (MET)	MET is the ratio of a person's working metabolic rate relative to their resting metabolic rate. One MET is defined as the energy cost of sitting quietly and is equivalent to a caloric consumption of 1 kcal/kg/hour.	WHO, 2014
Moderate intensity activity	Activity which requires a moderate amount of effort and noticeably accelerates the heart rate. Activity at 3 - 6 METS	WHO, 2014
Physical activity	Any bodily movement produced by skeletal muscles that requires energy expenditure.	WHO, 2014
Resistance activity	Resistance exercise (activity) is designed specifically to increase muscular strength, power, and endurance by varying the resistance, the number of times the resistance is moved in a single group (set) of exercise, the number of sets done, and the rest interval provided between sets.	Howley, 2001
Sedentary behaviour	Seated or reclining postures that require low levels of energy expenditure (i.e. < 1.5 MET)	Owen et al., 2010a
Vigorous intensity activity	Activity which requires a large amount of effort and causes rapid breathing and a substantial increase in heart rate. Activity at > 6 MET.	WHO, 2014

It is well established that increasing levels of physical activity has significant health benefits across the lifespan. The purpose of this literature review is therefore to consider increases in physical activity in the context of older people and to investigate the benefits of physical activity for healthy ageing. One of these key benefits is in terms of the impact that activity has on a person's functional ability as this has the potential to prevent or delay sarcopenia

A number of cross-sectional studies (Aubertin-Leheudre et al., 2006; Baumgartner et al. 1998; Szulc et al., 2004) and longitudinal studies (Hughes et al., 2002; Rantanen et al., 1997) have shown relationships between low levels of habitual activity and the presence or the development of sarcopenia. Indeed the role of

resistance training interventions in reversing skeletal muscle mass loss and deterioration in functional ability indicative of sarcopenia and sarcopenia progression have been clearly demonstrated (Chodzko-Zajko et al., 2009). It is also well established that rates of decline in strength are higher in sedentary individuals and are twice as high in men compared to women (Gallagher et al., 1997). Targets for increasing physical activity and reducing sedentary behaviour could therefore play a potential role in public health for conditions such as muscle loss due to ageing. The movement of muscle enhances muscle synthesis and thus increased levels of habitual activity could benefit skeletal muscle function and improve ADL on which this depends. Although resistance type exercise has the greatest influence on muscle strength it may be that in an older population increasing general physical activity levels could play a role in the prevention or delaying of sarcopenia as it appears logical that this could hold benefits for skeletal muscle given that any muscle contractions are associated with anabolic effects (Lenk et al., 2010).

The relationship between skeletal muscle mass and levels of physical activity is however complex. Physical activity alters body composition by increasing muscle mass and reducing fat mass (Kuh et al., 2005). Exact measures of FM and FFM are not easily determined although Hughes et al., (2002) measured body composition by underwater weighing and recreational physical activity by questionnaire in 54 men and 75 women over a 10 year period. Results showed that higher levels of habitual physical activity attenuated the progression of sarcopenia. A separate year long study demonstrated a progressive increase in muscle mass with daily activity and showed that in older adults who walked at least 7,000–8,000 steps/day and/or spent 15–20 minutes/day participating in moderate intensity activity (i.e. less than current targets) were likely to have a muscle mass above the sarcopenia threshold (Park et al., 2010). Physical activity therefore has the potential to preserve muscle mass and



may even reverse skeletal muscle mass decline and prevent functional impairment (Chodzko-Zajko et al., 2009).

Of greatest concern to an older adult is most likely to be their ability to perform ADL and maintain their independence and whilst this and sarcopenia are inextricably linked more general consideration of the role of activity in functional ability is required. It is well established that there are a number of physiological changes associated with ageing which impact on functional ability however in many cases these are reversible with exercise (Bean et al., 2004). Encouragingly it appears that physical activity correlates positively to the functional status of older adults with more active individuals having fewer limitations than those who are less active and the evidence to support this is summarised in a review by Blair & Wei (2000). More recently a large study of 1,288 participants found a significant reduction in levels of activity with ageing and this reduction in activity was associated with a reduction in physical fitness (Milanovic et al., 2013). In this study activity was measured by self-reported questionnaire. Self-reported questionnaires have some limitations in that they are open to interpretation as they measure perceived levels of activity based on intensity i.e. sedentary behaviour, low intensity, moderate intensity and high intensity. It is difficult to objectively quantify activity levels using this methodology and so determining a dose effect of activity on fitness is difficult.

Aerobic activity slows down the progression of disability in older adults (Wang et al., 2002) and this may be as a result of improved physical functioning. A recent study of older adults found that better functional ability as measured by the Functional Fitness Test (lower and upper body strength, endurance, lower and upper body flexibility, agility/balance) was associated with increased time spent walking (over 6,500 steps/day) (de Melo et al., 2013) confirming the idea that increased levels of

activity are associated with increased levels of functional ability. This supports the premise that even low intensity activity has beneficial effects. In a further large longitudinal study of French community dwelling older adults (2,410f, 1,572m) who were disability-free at baseline found that during the 12 year follow-up, those people who developed moderate or severe disability were more likely to have participated in lower levels of physical activity (as measured by self-report) have a lower fruit and veg intake and were more likely to smoke or have recently stopped smoking (Artaud et al., 2013). Whilst function was not measured directly in this study it is reasonable to assume that as disability is a progressive process which generally sees a deterioration in function prior to the appearance of a disability there is a likelihood that poor function is also associated with these lifestyle choices.

In a study of 611 adults where activity levels were objectively measured by the Actiheart accelerometer and function was measured by gait speed there was evidence to support the finding from the previous studies as in this study those people who were more active had a faster gait speed indicating better function (Schrack et al., 2013) and this was consistent across all age groups. These results have been further confirmed by a systematic review which demonstrated that in older adults, higher levels of physical activity and in particular aerobic activity, which promotes cardiovascular fitness, was associated with reduced risk of functional limitation and disability (Paterson & Warburton, 2010). As physical activity levels have been shown to be associated with maintaining functional status over time in older adults, irrespective of age (Stessman et al., 2009) it seems possible that function can be maintained through exercise even in an older population.

The key to prevention of sarcopenia or maintaining functional ability may be a long term pattern of activity/exercise and good nutrition. Whilst physical activity plays a

key role in preventing or delaying the development of sarcopenia and this is a vital component of healthy ageing it is not the only benefit of physical activity to the ageing process. The benefits of participating in physical activity across the entire age spectrum are well documented and increasing physical activity is a key target for most developed countries. It clearly has a benefit in terms of functional ability but there are many additional health benefits associated with increasing activity levels including improving nutritional status and body composition reducing fatigue and improving quality of life (WHO, 2014). From a public health perspective increased activity also reduces levels of inflammation along with reducing risk of NCDs in particular CVD and T2DM (WHO, 2014).

## **1.12 BENEFITS OF ACTIVITY**

### **1.12.1 Physical activity, nutritional status and CVD risk**

The physiological and psychological health benefits associated with increased levels of physical activity are well documented (WHO, 2014) There is a significant body of evidence to show that increased levels of physical activity are associated with reduced risk, incidence and mortality associated with age related diseases such as CVD, obesity, HT and cancer (DHHS, 1996). The benefits of physical activity are wide reaching as it has a role to play in improving body composition (by assisting weight loss, and reducing central adiposity), reducing CVD and T2DM risk by improving central adiposity along with improving lipid profile, reducing blood pressure (and as such HT) and reducing levels of inflammation (WHO, 2014).

In terms of body composition physical activity promotes weight loss in an overweight and obese population by increasing energy expenditure. This weight loss will be primarily fat loss as FFM is retained through increased muscle anabolism as a result of increased activity levels. Moreover increasing physical activity levels will result in

a loss of central adiposity (a significant risk factor for CVD and T2DM) even in the absence of an overall weight loss. Janssen et al., (2004b) showed physical activity improves cardiovascular fitness and a reduction in central adiposity with or without weight loss and these benefits of activity were shown across a range of BMI levels i.e. 18 – 35 kg/m<sup>2</sup> which is a key message for an overweight or obese population.

In separate studies post-menopausal women were randomised to receive a 14 week intervention of either weight loss through diet, weight loss through exercise, or exercise without intentional weight loss. Whilst there was a larger reduction in total abdominal, and abdominal subcutaneous fat within the exercise plus weight loss group this reduction was also seen in the exercise without weight loss group albeit to a smaller but still significant level (Ross et al., 2004). A similar study in men (Ross et al., 2000) showed similar results. As low levels of physical activity and an increased WC have been associated with many metabolic disorders and diseases increasing levels of activity has benefits even in the absence of weight loss. This is particularly true of an older population where BMI is less reliable as a marker of nutritional status. Clearly the impact of increasing physical activity levels in an older, overweight or obese population may present challenges particularly in terms of increasing the intensity level of the activity. However whilst the guidance around increasing levels of activity is often focussed on moderate intensity activity there is evidence to show that even walking can improve cardiovascular fitness. A meta-analysis of walking intervention studies which included 18 studies (and 459,833 participants) found that in those who participated in the higher amounts of walking compared to those people who were inactive there was a lower all-cause mortality and these results were consistent for men and women (Hamer & Chida, 2008). This meta-analysis demonstrated that whilst walking pace was a stronger predictor of reduced CVD risk rather than the amount of time spent walking there is a benefit in

even slow paced walking compared to no walking as this also reduced risk. Finally this meta-analysis also confirmed there appears to be a dose–response relationship across the highest, intermediate, and lowest walking categories in relation to the outcome measures.

These relationships may have been found as walking even at slow speeds has been shown to be at moderate intensity activity in older adults (Fitzsimons et al., 2005). The fact that walking has health benefits is positive news for an older adult population who may not be able to engage in some moderate intensity activities and exercise due to poorer functional ability or co-morbidities affecting ability to participate in exercise but providing the option of walking may be a reasonable alternative. As studies have shown older people engage in more leisure based activity (Tudor-Locke & Ham 2008) which is often at low intensity, increasing activity via this route may be more achievable.

Activity across the life span is important as those people who are more active in early years and in early adulthood will have a sustained and reduced CVD risk in later life but even in those people who take up physical activity in later life reductions in CVD are evident (Rothenbacher et al., 2006). The message for the population should therefore be that increasing levels of activity at any age will provide beneficial effects and even low intensity activity such as walking could improve overall fitness, and cardiovascular health. Some of these benefits seen in CVD health are evidently associated with improvements in body composition, however there are additional benefits of activity in terms of reducing blood pressure which is key to preventing CVD especially in those people who are hypertensive. High blood pressure and the risk of HT are known to increase with age and HT is associated with increased risks of CVD and stroke (Huonker et al., 2002). Physical activity has been shown to have

positive effects in reducing blood pressure and thus reducing CVD risk although differences are seen between younger and older adults. In those people aged less than 30 years of age regular exercise is associated with lower diastolic blood pressure and elevated pulse pressure whereas in older adults (in this study those aged over 50 years) physical activity is associated with a lower systolic blood pressure and lower pulse pressure and these were both lower in older active individuals (McDonnell et al., 2013). Regular exercise therefore appears to lower large artery stiffness in older individuals although this study does confirm the benefits of activity across all ages throughout adulthood. As hypertension is a major risk factor for CVD it should be targeted as an outcome in activity strategies but there are other considerations alongside elevated blood pressure, abdominal obesity and levels of inflammation (which have been discussed previously, section 1.11). In view of the link between activity and NCDs it is therefore not surprising that there is also a relationship with mortality.

### **1.12.2 Physical activity and mortality rates**

The benefits of physical activity are extensive including having a favourable impact on mortality (Lee et al., 2010) with the greatest benefits seen when comparing sedentary adults to those who are physically active (Blair & Wei 2000) and encouragingly this is seen even if physical activity is not started until late in life (Blair, 1995). Importantly this increased risk in mortality is seen independently of cardiovascular fitness and it appears that muscle strength and function also predict both cardiovascular and all-cause mortality (FitzGerald et al., 2004; Katzmarzyk & Craig, 2002). Indeed the evidence to support greater participation in physical activity and the risk of developing and dying from a variety of different disorders has been evident for many years (DHHS, 2008). There is now considerable evidence to confirm the positive role of physical activity in health and disease and recent

systematic reviews have shown that there is an inverse dose relationship between activity and all-cause mortality in both men and women. A meta-analysis by Löllgen et al. (2009) established that there is a significantly lower association with mortality in those individuals who are physically active compared to those who are sedentary. This study showed that highly active men had a 22% lower risk of mortality (RR=0.78, (95% CI 0.72,0.84)) compared to only mildly active men and in women although the relative risk was lower it was still significant (RR=0.69 (95% CI 0.53,0.90)). These results are also true of those people considered moderately active (rather than very active) and all these results were consistent even in an older population. The duration of activity is also key to reducing all-cause mortality and a systematic review looked at this concept in greater depth (Woodcock et al., 2011) and endeavoured to establish a dose response for risk. Overall it appears that 2.5 hours each week of physical activity (i.e. equivalent to 30 minutes moderate intensity activity on 5 days) reduces risk of mortality by 19% (95% CI 15,24%) and even greater amounts i.e. up to 60 minutes each day reduces risk further by 24% (95% CI 19,29%). The issue of whether older people will be able to engage in this amount of moderate intensity activity is not clear as many older people may have functional limitations or co-morbidities which could influence this. Reassuringly a similar, albeit smaller, effect was found in studies which looked at walking alone in that participating in 2.5 hours of brisk walking per week was associated with an RR of 0.89 ( 95% CI 0.82,0.96). This is perhaps a more achievable type of activity for older adults (Woodcock et al. 2011).

The impact of activity on healthy ageing is apparent and the U.S. Advisory Committee Report has therefore concluded that there is strong evidence that physically active older adults have higher levels of functional health, lower risks of falling, and improved cognitive health (DHHS, 2008). Importantly these benefits are

also seen even if activity was started late in life (Stessman et al., 2009) and therefore encouraging physical activity at any age is important even into advanced years. The benefits of activity can be seen across the entire older age group with exercise having been shown to have some benefits in frail older people as well as those who are not frail, although in this group there is a lack of clear direction as to which exercise characteristics (type, frequency, duration) are most effective (Gine-Garriga et al., 2014). It is therefore apparent that all adults including older adults should be encouraged to increase activity levels despite the current trend for adults to reduce activity levels with age.

### **1.12.3 Levels of activity in ageing**

It is reported that globally 28% of adult men and 34% of adult women were insufficiently active in 2008 and that approximately 3.2 million deaths each year are attributable to insufficient physical activity (WHO, 2014). The picture in Scotland does not differ significantly from this with the most recent Scottish Health Survey indicating that 38% of the adult population (33% men and 42% women) were not participating in adequate amounts of physical activity (The Scottish Government, 2014). Participation in physical activity also tends to decrease with age and in Scotland only 46% of men aged 65 - 69 and 69% of those aged 75 and over were meeting guidance for physical activity and in women 48% aged 65 - 69 and 79% of those aged 75 years and over women not meeting targets for physical activity (The Scottish Government, 2014).

The picture in Scotland of older people engaging in lower levels of physical activity is not uncommon as physical activity levels have been shown to decrease with age in other populations (Troiano et al., 2008). The methodology used for determining levels of physical activity may however influence the results as the levels described



tend to be self-reported levels of activity and reflect the amount of time spent in moderate intensity activity. Whilst moderate intensity exercise is important for cardiovascular health benefits it may not reflect the type of activity undertaken by older people. A large US population based study found that when time spent walking was measured as a means of leisure time physical activity, this increased with age (Tudor-Locke & Ham, 2008). Due to the nature of walking and the fact that it is in general self-paced this may not always result in moderate intensity activity which is the determinant of whether someone is meeting targets for physical activity. It should however be noted that in this study despite it having large numbers of participants, activity was measured by self-report rather than objectively measured by accelerometer or by step count. Nonetheless these low levels of activity are of concern as physical activity is one of the main components of a healthy lifestyle and has the potential to maintain optimal health and to contribute to healthy years even in an older population.

Consideration has been given to the method of reporting activity levels in older adults and some studies have used a step counting approach. A review of published literature found that in healthy older adults, physical activity levels as measured by pedometer ranged from 2,015 - 8,938 steps/day (Tudor-Locke et al., 2009). This review also reported that generally those people who were of normal weight took more steps than those who were overweight or obese and generally men took more steps than women with the difference ranging from 497 - 1,450 steps/day. However this review, unlike the study by Tudor-Locke & Ham (2008), reported a decline in steps/day with age. The differences in findings are likely due to differences in methodologies in measuring activity levels and as such the method used to measure activity levels is important to ensure accurate data are gathered.

It should also be acknowledged however that there are many barriers to older people increasing their activity levels including poor health, pain, the physical environment and lack of knowledge and understanding of the relationship between exercise and health (Schutzer & Graves, 2004). These factors should not be overlooked when considering interventions which would enable an older person to increase their physical activity levels. As physical activity and physical fitness are closely related, with fitness being in the main, a result of activity it may be more successful to encourage older adults to maintain a higher level of physical activity through a reduction in sedentary behaviour rather than through increasing exercise levels. There is evidence to demonstrate that individuals who are regularly physically active are less likely than sedentary individuals to develop health problems (Blair et al., 2001) and so participating in lower levels of sedentary behaviour can therefore confer health benefits.

### **1.13 BENEFITS OF REDUCING SEDENTARY BEHAVIOUR**

Research into sedentary behaviour is not new. In 1953 Morris et al., (1953a; 1953b) showed that the incidence of CHD was lower in active bus conductors compared to sedentary bus drivers. There has however been growing interest in the impact of sedentary behaviour on health in recent years and it is now well established that sedentary behaviour is associated with an increased risk of diabetes and cardiovascular disease mortality (Wilmot et al. 2012). Levels of sedentary behaviour however typically increase with age with a marked increase from approximately 60 years of age onwards (The Scottish Government, 2014). There are gender differences seen generally with a greater proportion of women compared to men being more sedentary up to the age of 40 and then this reversing with more men than women being sedentary over the age of 60 (Matthews et al., 2008).

Sedentary behaviour is a separate behaviour in its own right and even individuals who currently meet recommended levels of physical activity may be susceptible to the adverse effects of prolonged bouts of sedentary behaviour (Owen et al., 2010a). Measures of sedentary behaviour have generally been derived from self-reports of a limited number of discretionary behaviours thought to be indicative of a more sedentary lifestyle (e.g., television viewing, video game-playing, and computer use). However, assessment of these behaviours provides only a partial picture of overall levels of sedentary behaviour in a typical waking day.

More recently studies have tried to determine levels of sedentary behaviour using accelerometers. Matthews et al. (2008) showed that in people aged 60 – 69 years of age the mean $\pm$ se time spent in sedentary behaviour was 8.41 $\pm$ 0.09 hours with men spending 8.80 $\pm$ 0.14 hours and women 8.08 $\pm$ 0.10 hours in sedentary behaviour. In the 70 – 85 age group the mean $\pm$ se time spent in sedentary behaviour was 9.28 $\pm$ 0.06 hours with men spending 9.52 $\pm$ 0.06 hours and women 9.11 $\pm$ 0.08 hours demonstrating not only long periods of sedentary behaviour but also increasing sedentary behaviour with age. In this study whilst habitual activity was reported, activity monitoring was not based on 24 hour recording and reported data was for a minimum of 1 day with at least 10 hours of recording. It could therefore be argued that this limited level of activity recording does not reflect habitual activity levels and as such is not completely reflective of sedentary behaviour. It is most likely that sedentary behaviour will be underestimated rather than over-estimated using these types of criteria. In addition activity levels in this study were measured using an actigraph accelerometer and the appropriateness of determining levels of activity in older adults using actigraph accelerometers has been questioned in a recent systematic review (Gorman et al. 2014).

The actigraph accelerometer measures activity levels using cut-points and to date there has been no standardisation of cut-points across research protocols and the majority of data informing cut-points has been derived from studies which include children and young adults (Gorman et al. 2014). In addition the systematic review established that there were eight different cut-points used for classifying moderate intensity activity and sedentary behaviour and that the most commonly used cut-point for moderate intensity activity (1952 counts/min) was validated in young adults (Freedson et al., 1998). Using this cut-point is not appropriate in older adults as they will expend more energy than a younger fitter person when completing the same task (Malatesta et al., 2003).

An alternative accelerometer, the *activPAL*<sup>TM</sup> overcomes some of the problems seen with the actigraph as it measures levels of activity based on posture and cadence. Whilst some data is available which reports sedentary behaviour in older adults using the *activPAL*<sup>TM</sup> accelerometer these have either not measured sedentary behaviour based on the definition or have used a combination of subjective and objective measurements. Fitzsimons et al. (2013) measured sedentary behaviour using the sedentary behaviour questionnaire (SBQ) (Rosenburg et al., 2010) and supported this data with objectively measured habitual activity levels using the *activPAL*<sup>TM</sup> accelerometer. This study found that a group of older Scottish adults, mean  $\pm$  sd age  $68 \pm 6$  years, spent a median (range) 51.8 (99.5) hours/week in sedentary behaviour and whilst not truly reflective of sedentary behaviour they spent a mean  $\pm$  sd  $17.66 \pm 1.39$  hours/day sitting and/or lying as measured by *activPAL*<sup>TM</sup> accelerometers.

A further study of a mixed group of older adults in Scotland where habitual activity including sedentary behaviours was measured using the *activPAL*<sup>TM</sup> accelerometers

recruited a group of healthy older adults with a mean  $\pm$  sd age of  $74.0 \pm 5.3$  years (Grant et al. 2010a). This group of older adults was found to be sedentary for 18 hours/day and when considering only day time activity the participants were found to be sedentary for 7 hours/day which was equivalent to 57% of the day. Whilst giving some indication of sedentary behaviour the levels found in this study are not truly reflective of sedentary time. Time asleep should not be considered sedentary behaviour (Owen et al., 2010a) and so including sleep time is not providing a true representation of sedentary behavior. Although sedentary time across 24 hours has been reported in this study there has been also an attempt to disregard sleep time and an indication of day time sedentary behavior has also been reported (i.e. 7 hours/day). This level of sedentary behaviour was calculated from data gathered by the *activPAL*<sup>TM</sup> between the hours of 8 am and 8pm. This therefore does not take into consideration time when a person was awake and sedentary before 8am or after 8pm. The sedentary behavior reported in this study is therefore likely to significantly underestimate true sedentary time.

Perhaps not surprisingly one of the most sedentary groups in the United States are adults aged 60 years and over, and they spend about 60% of their waking time in sedentary pursuits. Although these levels of sedentary behaviour are from self-reported data it is reasonable to expect similar levels across the older adult population of the UK although data to confirm this are lacking. Indeed no study to date has used the *activPAL*<sup>TM</sup> accelerometers to objectively measure sedentary behaviour across by continuously recording activity levels and excluding sleep time. Recording sedentary behaviour is however extremely important as there is emerging evidence that sedentary behaviours are detrimentally associated with chronic disease, morbidity and mortality and this is found independently of physical activity levels (Proper et al., 2011; Thorp et al., 2011). These systematic reviews provide

strong epidemiological evidence to show that sedentary behaviours, independent of physical activity, are associated with a host of poor health outcomes, including increased risk of obesity, T2DM, CVD, and premature mortality. It is important to note that these relationships have primarily been established through self-reported surrogate measures of sedentary behaviour although the use of accelerometers are increasingly used to confirm these findings (Matthews et al., 2008). Physical activity has been shown to be associated with psychological wellbeing and a small number of studies have reported that sedentary behaviour may also be adversely associated with psychological health, e.g. depression and mental wellbeing and as such potentially quality of life (Hamer & Chida, 2010; Teychenne, 2010).

The interest in sedentary behaviour and the health risks associated with it has increased in recent years as due to changes in the way we live in terms of increased technology which results in longer periods of sitting (e.g. television watching, computer use, access to cars for travel etc.) and as such there is a reduced need to be habitually active. It is therefore feasible for people to meet guidance for physical activity levels whilst still engaging in extended periods of sedentary behaviour and whether the risks of one is outweighed by the benefits of the other is not known. Most of the studies into sedentary behaviour have focussed on middle aged adults and there are limited data for the older adult population. In 2002 a study began which examined the relationship between total sitting-time and all-cause mortality in a population of older Australian women aged 76 – 81 years Pavey et al., (2012). The women were followed up over a 9 year period and sedentary behaviour was measured by self-reported questionnaire. The results of this study found that overall sitting time was significantly and positively associated with all-cause mortality. Compared to people who sat for < 4 hours/day those people who sat for 8 – 11

h/day had a 1.45 (95% CI 1.26,1.66) times higher risk of mortality and those people who sat for > 11 hours/day had a 1.65 times higher risk of death (95% CI 1.37,2.00).

A cross-sectional study of 1,914 older adults based in the USA aged 65 years and older found that the mean±sd daily time spent in sedentary behaviour (as measured by actigraph accelerometer) was 9.4±2.3 hours and only around one third of the participants would be deemed to be sufficiently active (Gennuso et al., 2013). The results also showed a strong independent positive association between sedentary behaviour and BMI ( $p<.01$ ), WC ( $p<.01$ ), CRP ( $p<.01$ ) and number of functional limitations independently of engagement in moderate intensity activity. As levels of sedentary behaviour were measured by actigraph accelerometers the data it may not be possible to compare this data to data from other studies which have used *activPAL*<sup>TM</sup> accelerometers but nonetheless the results strengthen the case for a reduction in sedentary behaviour. This may also be a more achievable target in an older population than increasing levels of physical activity and has the potential to have similar health benefits in terms of reducing morbidity and mortality whilst maintaining functional status. If the reduction in sedentary behaviour was achieved through increased amounts of walking for example there could be a consequent reduction in waist circumference and levels of inflammation.

As there is a large body of evidence to support the benefits of increasing activity and reducing sedentary behaviour recommendations have been set for the population.

#### **1.14 RECOMMENDATIONS FOR LEVELS OF ACTIVITY**

Currently all adults including those aged 65 years and over are recommended to accumulate at least 30 minutes of moderate or vigorous intensity activity on most days of the week totalling not less than 150 minutes. These recommendations are

based on World Health Organisation recommendations for physical activity (WHO, 2010b). Within these recommendations there are specific recommendations for adults aged 65 years and older with the aim of improving cardiorespiratory and muscular fitness, bone and functional health, reducing the risk of non-communicable diseases, depression and cognitive decline. These recommendations are:

- Older adults should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week or an equivalent combination of moderate- and vigorous-intensity activity.
- Aerobic activity should be performed in bouts of at least 10 minutes duration.
- For additional health benefits, older adults should increase their moderate intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous intensity aerobic physical activity per week, or an equivalent combination of moderate and vigorous intensity activity.
- Older adults, with poor mobility, should perform physical activity to enhance balance and prevent falls on 3 or more days per week.
- Muscle-strengthening activities, involving major muscle groups, should be done on 2 or more days a week.
- When older adults cannot do the recommended amounts of physical activity due to health conditions, they should be as physically active as their abilities and conditions allow.

Based on these recommendations the UK government has developed physical activity guidance for the UK population as a whole with specific recommendations for the older adult population. These DoH (2011) recommendations, which have been adopted by the Scottish Government, are:



- Older adults who participate in any amount of physical activity gain some health benefits, including maintenance of good physical and cognitive function. Some physical activity is better than none, and more physical activity provides greater health benefits.
- Older adults should aim to be active daily. Over a week, activity should add up to at least 150 minutes (2½ hours) of moderate intensity activity in bouts of 10 minutes or more – one way to approach this is to do 30 minutes on at least 5 days a week.
- For those who are already regularly active at moderate intensity, comparable benefits can be achieved through 75 minutes of vigorous intensity activity spread across the week or a combination of moderate and vigorous activity.
- Older adults should also undertake physical activity to improve muscle strength on at least two days a week.
- Older adults at risk of falls should incorporate physical activity to improve balance and co-ordination on at least two days a week.
- All older adults should minimise the amount of time spent being sedentary (sitting) for extended periods.

Variations in the recommendations do exist with the World Health Organization promoting at least 30 minutes of moderate intensity physical activity 5 days per week for older adults (WHO, 2014) whereas in the UK like the USA all older adults are advised to avoid inactivity with some physical activity considered better than none (DHSS, 2008; DoH, 2011)

In addition to the guidelines which quantify activity in terms of time, duration and intensity there are an increasing number of step-based recommendations being

produced around the world. These recommendations are based on data obtained through pedometers and/or accelerometers and are intended to supplement rather than replace current guidelines. As they are easily understood and relatively simple to measure step-based guidance may be more achievable. There is some disparity in the recommendations which are proposed throughout the world but the majority of recommendations including those set by the UK National Obesity Forum (2006) suggest that people should be aiming to achieve 10,000 steps/day. In older adults this will not always be achievable and so in a review of the published literature assessing the quantity of steps required for health benefits and in relation to moderate intensity activity it is proposed that between 7,000 – 10,000 steps/day should be encouraged in older adults (Tudor-Locke et al., 2011). In addition to these activity based recommendations there are also recommendations for sedentary behaviour.

#### **1.15 RECOMMENDATIONS IN RELATION TO SEDENTARY BEHAVIOUR**

Sedentary behaviour is not simply a lack of physical activity and so guidance documents are available specifically related to sedentary behaviour. The recommendations from WHO and many EU countries encourage populations to reduce sedentary behaviour but there are few quantified recommendations to enable people to do this (DoH, 2010). The focus of these also tends to be for children and young people (DoH, 2010). Where quantified recommendations are made they tend to follow the American Academy of Paediatric guidance to limit maximum media time to no more than 1 - 3 hours per day. These recommendations are based on a recommendation to limit television viewing but this has since been interpreted to include all screen time (DoH, 2010). These recommendations do not fully reflect the lifestyle of older adults and in relation to this population there appears to be little or no justification in guidance documents for the quantification of

sedentary behaviour and it seems that recommendations are based on expert opinion and common sense rather than a sound evidence base (DoH, 2011). The DoH (2011) have therefore suggested that in addition to recommendations for physical activity older adults should aim to minimise the time they spend being sedentary each day without a quantified target being set.

In an attempt to increase levels of physical activity and decrease levels of sedentary behaviour in the Scottish population a number of initiatives have been developed by the Scottish Government. These include:

- Let's Make Scotland More Active: A strategy for physical activity (Physical Activity Taskforce ), (The Scottish Government, 2003)
- Healthy Eating, Active Living: An action plan to improve diet, increase physical activity and tackle obesity (2008-2011) (The Scottish Government, 2008)
- Route Map for tackling obesity and associated Obesity Route Map Action Plan (The Scottish Government, 2011)

There is irrefutable evidence to suggest that older adults should engage in both increased levels of physical activity and reduced levels of sedentary behaviour. To enable this there are clear guidance statements provided as to the amount and intensity of this activity recommended. However due to the nature of the older adult population and the benefits seen with both reducing sedentary behaviour and increasing physical activity it may be that the advice has to be individually supplied depending on a person's functional ability and cardiovascular capacity. Whatever the advice, finding appropriate methodology to determine activity levels is essential to provide individual and population based information for levels of physical activity.

## 1.16 MEASURING ACTIVITY

There are a number of methods of measuring physical activity including questionnaires, heart rate monitors and accelerometers. Heart rate monitors have been widely used to measure activity levels but their efficacy at low intensities has been questioned (MacFarlane et al., 2006; Haskell & Keirnan, 2000). Self-reported activity questionnaires are also not without their problems as they are limited due to their reliance on subjective recall (McFarlane et al., 2006; Reilly et al., 2008; Atkin et al., 2012) and whilst they are cheap and easy to administer they have limited test-retest reliability and are subject to bias from perceptions of cultural norms (Atkin et al., 2012). Objective measurements of habitual behaviour from accelerometers provide more robust data.

A number of studies have attempted to objectively measure habitual activity as a means of providing information about meeting targets for physical activity and periods of time spent in sedentary behaviour. The monitoring period for accelerometer-based assessments of sedentary time has typically been 7 days (Matthews et al., 2008; Hagstromer et al., 2007; Healy et al., 2008). The rationale for 7 days of activity monitoring is suggested as it is likely that at least 7 days of monitoring may be required to obtain reliable estimates of habitual activity including habitual levels of sedentary behaviour (Matthews et al., 2002). There is however conflicting information regarding this. In young and middle age adults it has been established that the number of days to reliably predict habitual activity is five consecutive days or six randomly selected days and this produces an intraclass correlation (ICC) of .80 (Kang et al., 2009). This ICC shows a substantial level of agreement (Landis & Koch, 1977). A separate study (Tudor-Locke et al., 2005) suggests only three days of monitoring is required to produce an equivalent ICC with only a Sunday being a limiting factor in terms of habitual activity. This however may

not be reflective of an older adult population as the study participants had a mean age of 50 years and so many would have been in paid employment giving more structure to days and thus the potential for more consistent activity levels. In older adults, it has however been suggested that five days are sufficient to accurately predict average daily sedentary time by accelerometer (Hart et al., 2011). Further work is however required to examine between-day variability in sedentary behaviour patterns (e.g. weekday versus weekend) and possible seasonal variation, both of which will have implications for the monitoring period required (Atkin et al., 2012). Whether these impact on measurements of habitual activity in older adults is as yet not clear.

The methodologies used to measure habitual activity vary across studies even in studies where accelerometers are used. Studies measuring habitual activity frequently measure less than 7 days' worth of activity and generally the testing period is not entire days (i.e. 24 hours/day). Often studies base activity data on a minimum of 10 hours of recording (Matthews et al., 2008; Gorman et al., 2014, Jefferis et al., 2014) and this can result in the activity being measured being under-sampled and in particular under-sampling of sedentary behaviour which in turn may not provide a true reflection of habitual activity levels. Where studies do not ask participants to wear the accelerometer for full 24 hour periods this is taken into account by considering non-wear time where this is subtracted from the time the participants wear the accelerometer. Any non-wear time is typically calculated by selecting a period of consecutive zero counts from the accelerometer output above which it is deemed that the device must have been removed (this is different across studies). The segments of zero counts are then removed from further analysis. This is however problematic as continuous zero readings may occur for a number of reasons including when a person is sitting or lying which is indicative of sedentary

behaviour. If this is not included in the analysis then true levels of sedentary behaviour will not be calculated. Greater accuracy is more likely to be achieved by wearing the accelerometer for 24 hours/day over the measurement period.

There are a number of accelerometers available one of which is the *activPAL*<sup>TM</sup> (PAL Technologies Ltd, Glasgow). The *activPAL*<sup>TM</sup> is a simple, inexpensive method of measuring habitual activity which has been shown to be a valid and reliable measure of walking in healthy adults and importantly is not affected by the speed of walking (Grant et al., 2006). It not only provides information about the duration of stepping but it can provide more comprehensive data about other activities as it is also a valid and reliable measure of posture and motion during every day physical activities (Grant et al., 2006). The *activPAL*<sup>TM</sup> monitor classifies an individual's activity into periods spent sitting or lying, standing or stepping and it accurately distinguishes static and dynamic activities in prolonged free-living situations (Godfrey et al., 2007). It does not however differentiate further than this as it cannot differentiate between activity types. This limitation can be overcome by the use of an activity diary to support data produced from the *activPAL*<sup>TM</sup> providing a description of activities a person is participating in and thus enhancing the data collected from the accelerometer.

As there are a number of accelerometers available Feito et al., (2012) compared their validity and found that the greatest differences in accuracy between monitors was at the slowest speed of movement (i.e. < 67m/min). Importantly even at these slow speeds *activPAL*<sup>TM</sup> monitors were one of two monitors with the greatest accuracy with *activPAL*<sup>TM</sup> correctly recording 98±3% of activity. In view of these results it may be that *activPAL*<sup>TM</sup> is better able to measure levels of sedentary behaviour as well as episodes of physical activity. These findings are important

when studying an older population who are more likely to have a slower gait speed and who are likely to be more sedentary. In this same study it was established that all the devices tested recorded more than 97% of steps taken and so can be used as a good marker of overall activity levels. Levels of habitual activity have been reliably measured over a seven day period and although a number of studies which have measured habitual activity over this period have used either pedometers (Koulouri 2006, Parfitt & Eston, 2005) or questionnaires (Stewart et al., 2003), the *activPAL*<sup>TM</sup> monitor is at least as reliable and valid as either of these methods (Grant et al., 2006). This is therefore a valid and reliable measure of habitual activity and can be used in an older adult population.

There is overwhelming evidence that increasing activity levels is key to making the population healthier in terms of reducing risk of chronic long term conditions and improving nutritional status. The role of both exercise and habitual activity has been shown to be of value for a variety of reasons most of which have been discussed. The role of physical activity in the healthy ageing process is therefore not in doubt but encouraging and enabling people to engage in increased levels of activity is not without its challenges. A particular issue which is increasingly seen is that of fatigue and whilst the role of fatigue within physical activity is not clear, what is apparent is that an association exists. In a study of older adults where habitual activity was measured there was an inverse relationship with higher levels of physical activity being associated with lower levels of fatigue (general fatigue  $r=-.279$ ;  $p<.05$ ; physical fatigue  $r=-.367$ ,  $p<.05$ ; reduced activity  $r=-.320$ ,  $p<.05$ ; reduced motivation  $r=-.221$ ,  $p<.05$ ) (Valentine et al., 2011). Measuring fatigue may therefore also provide useful information in an older adult population.

## 1.17 FATIGUE

Persistent feelings of fatigue are a widespread complaint reported by older adults. Insufficient levels of physical activity have also been associated with reported fatigue in both men and women (Resnick et al., 2006). Recent literature suggests that increasing physical activity may attenuate perceptions of fatigue, at least in younger adults and cancer patients (Puetz et al., 2006; Luctkar-Flude et al., 2007). However little data exists regarding the influence of varying levels of habitual activity, and potential interactive effects of physical activity and nutritional status on fatigue in older adults.

A reduced capacity for physical activity and a reduction in muscle mass and strength will influence levels of fatigue and quality of life (Evans & Lambert, 2007). Fatigue is defined as a subjective state of overwhelming, sustained exhaustion and a decreased capacity for physical and mental work that is not relieved by rest (Poluri et al., 2005). It is often described as a normal everyday experience that most people report after lack of sleep but it is most commonly associated with disease and much of the research surrounding fatigue has taken place in the context of disease and in particular in cancer patients. This is often as a result of treatment modalities such as radio and chemotherapy. It is now however recognised as a specific geriatric entity (Liao & Ferrell, 2000) and as such interest in fatigue in healthy people is growing. Reviews of prevalence of fatigue in healthy populations suggest prevalence to be between 7 – 68% in the primary care setting (Smets et al., 1995; Lewis & Wessley 1992; Wijerante et al., 2007; Moreh et al., 2010). The large differences in prevalence are most likely attributable to differences in the working definition of fatigue, differences in methodologies used to measure fatigue, the choice of time period fatigue was measured over (e.g. present vs past week vs past month), selection of cut-offs defining fatigued compared to non-fatigued, and



characteristics of the study population (e.g. presence of co-morbid clinical or sub-clinical disease) (Smets et al., 1995; White, 2007).

In the USA the prevalence of fatigue in the general adult population (mean±sd age 45.7±16.8 years) when measured by FACT-Fatigue scale (Yellen et al., 1997), a scale which measures intensity of fatigue along with impact on ADL, is reported to be 20 – 25% (Cella et al., 2002). The US National Health and Nutrition Examination Survey (NHANES) reports gender differences in self-reported fatigue in the general population aged between 25 – 74 years with 20.4% of women and only 14.3% of men affected by fatigue although the reasons for this are not clear. Measuring the severity of fatigue also influences prevalence rates as in an ambulatory assisted living older population of the USA prevalence of fatigue, when measured by a modified Piper fatigue scale (Piper et al., 1998), has been found to be as high as 98% when measuring mild fatigue but drops markedly to 7% when measuring severe fatigue (Liao & Ferrell, 2000). These studies were performed in an American population and in the UK prevalence rates have been reported to be lower. In a study undertaken in general medical practice in England, which investigated the prevalence of chronic fatigue (defined in this study as fatigue for 6 months or longer) fatigue was found in only 8% of subjects aged between 64 - 75 years (Aggarwal et al., 2006). It is possible that as this study was looking at chronic fatigue it is likely that the study population was reflective of people who had co-morbidities and as such the prevalence rate may not be truly reflective of the general population. Indeed many people will experience fatigue for shorter periods of time albeit that this fatigue may be of a greater intensity, but even these short episodes of fatigue can impact significantly on day to day activity and potentially ADL. It is possible therefore that this study by Aggarwal et al. (2006) may be underestimating the prevalence and impact of fatigue across the general population as a whole as in

those people who have prolonged chronic fatigue perceptions of levels of fatigue may be different to that of a healthy individual.

A further survey of 705 nondisabled 70 year old Danish men and women measured fatigue as tiredness in ADL using the Mob-T Scale (Avlund et al., 1993) which is a six-item self-report scale focussing on tiredness associated with mobility related tasks. The participants were asked if they felt tired after performing ADL and 49% of men and 53% of women reported tiredness associated with one or more daily activities (Schultz-Larsen & Avlund, 2007). These high prevalence rates may be due to being asked about tiredness as many people will feel tired after performing day to day tasks but it could be argued that this is not fatigue. As this study measured tiredness in mobility even if this is fatigue it does not take into consideration other aspects of fatigue such as mental fatigue and motivation to participate in activities. In a similar survey in the primary care setting in Australia a sample of equal numbers of male and female ambulatory participants aged 60 years and older (mean±sd age 73.4± 6.9 years) fatigue was measured by self-reporting on six somatic items used to predict prolonged fatigue i.e. muscle pain after activity; needing to sleep longer; prolonged tiredness after activity; poor sleep; poor concentration; and tired muscles after activity. In this study a total of 27% of participants reported fatigue although 17% of the total sample was considered to have fatigue associated with co-morbidity and only 10.5% had fatigue alone (Wijeratne et al., 2007). As study participants were recruited from depression education seminars this may influence the prevalence of domains of mental fatigue and so as a result may not truly reflect levels of fatigue in a healthy older adult population.

Finally a large survey of community dwelling older adults across 10 European countries assessed prevalence of frailty but also considered fatigue in the context of exhaustion (Santos-Eggimann et al., 2009). Fatigue was measured as a positive response to the question, "In the last month, have you had too little energy to do things you wanted to do? (yes/no)". The results show that across the 10 countries 37.6% of people indicated a level of exhaustion. When considering exhaustion based on age 22% of subjects aged 50 - 64 years and 37% of subjects aged 65 years and older reported feeling exhausted in the past month (Santos-Eggimann et al., 2009) suggesting levels of fatigue increase with age. However it could be argued that a one off question related to tiredness is not fully reflective of fatigue.

It may therefore be more appropriate to measure fatigue across a number of domains rather than just as tiredness. A large study of German men (n=2,771) aimed to do this and this study supports the notion that levels of fatigue increase with age (Beutel et al., 2002). Participants were grouped by age and fatigue was measured using the Multi-dimensional Fatigue Inventory (MFI) (Smets et al., 1995) which measures five domains of fatigue by 5 point Likert scales (mental fatigue, physical fatigue, general fatigue, reduced motivation, reduced mobility) and significant increases in levels of fatigue were seen across each of the domains of fatigue with increasing age. In a similar study of German female participants (n=2,182) similar results were found (Beutel et al., 2004). These results are supported by an Israeli study which found prevalence of fatigue to be 29%, 53%, and 68%, at ages 60, 70 and 80 respectively and the prevalence was higher in women compared to men (Moreh et al., 2010).

Other studies however have found conflicting results and it has been shown that rather than fatigue increasing with age it actually decreases with advancing age. In

the previously described study by Aggarwal et al. (2006) fatigue prevalence was lower in 64 – 75 year old subjects compared to three other age categories (36 - 44, 45 - 53 and 54 - 63 years) but was not lower than in the 18 - 35 age group. As this study measured chronic fatigue it may be that expectations of fatigue differ between older and younger people providing some explanation for the conflicting results. This is supported by a survey of 2,991 Swedish women where the prevalence of self-reported fatigue over the preceding 3 months was highest in the youngest age group (35 - 39 years) and lowest in the oldest age group (60 - 64 years) (Bardel et al., 2009). There are also studies which are inconclusive in their findings in that in a survey of 1,350 people in the USA using an established internet polling panel, fatigue was measured using components of the FACT-Fatigue Scale (Yellen et al., 1997). The results of this survey found that there was no difference in reporting of fatigue between different age groups (Stone et al., 2008).

The conflicting results from these studies may be partially explained by the fact that when asking someone who is aged 20 - 30 about the overall feelings relating to their health they will be describing a very different health state than someone aged 70 - 80 years of age being asked the same question and the perceptions may result in a change in response over time. It may also be that as fatigue is a self-reported entity in that older people or people with a chronic condition may tolerate greater levels and prolonged episodes of fatigue compared to younger or healthier counterparts. Although it is unclear whether fatigue increases or indeed decreases with age what is apparent is that fatigue appears to be a significant problem even in healthy adults and the implications of this in terms of physical activity and a person's ability to meet physical activity recommendations requires further investigation.

The prevalence of fatigue is also of concern as increased levels of fatigue are associated with poorer health outcomes including disability and mortality and due to this there is a growing interest in fatigue as an early marker of age-related declines in health and functional abilities. Ekmann et al. (2012) have shown that fatigue in healthy middle aged adults could be a marker for subsequent hospitalisation due to non-fatal ischaemic heart disease among non-smokers (possibly as a result of age related cardiovascular functional decline). It is however not always possible to find a medical cause for fatigue. Indeed in a Dutch sample (n=10,296) who consulted their family practitioner complaining of tiredness, no medical diagnosis causing the fatigue could be found in 43.2% (95% CI  $\pm$  1%) of the sample (Kenter et al., 2003). Whether there is an organic cause or not what is apparent is that fatigue could play a role in determining a person's level of activity. In a study which used baseline data from the InCHIANTI study (n=1,055) participants aged 65 years and older (mean $\pm$ sd age 74.5 $\pm$ 7.0 years) were assessed for fatigue using two questions from the Centre for Epidemiologic Studies-Depression scale (CES-D) (Vestergaard et al., 2009). Results show that the prevalence of fatigue was higher in women than in men (29.1% vs 15.3%) and that fatigue was associated with older age in men, but not in women. Both men and women who were fatigued had poorer self-rated health, quality of sleep, poorer functional performance including poorer handgrip strength and slower walking speed and had significantly greater disability in terms of function, mobility, and ADL compared with their non-fatigued counterparts. This clearly has the potential to impact on activity levels.

A further longitudinal study of 75 year old Danes found that tiredness with one or more 6 daily activities, predicted nearly twice the risk of hospitalisation and need for care at home at age 80 years and over (Avlund et al., 2001). In addition sustained tiredness between the ages of 75 - 80 years was associated with a 1.7-fold greater

risk of functional disability and a 2.2-fold greater risk of death during the following 5 years (Avlund et al., 2003). To further demonstrate the association between fatigue and disability a study by Gill et al. (2001) aimed to estimate the rate and causes (health related and non health related) of restricted activity among community-living older adults. In the 754 participants who took part in the study, fatigue was reported as the main cause of restricted activity. Clearly it is not possible to determine whether restricted activity is caused by fatigue or whether other co-morbidities exist which may result in decreased activity and increased levels of fatigue. However, Avlund et al. (2006), found that fatigue as measured by self-reported tiredness was a predictor of adverse events such as the onset of disability, future hospitalization, and use of home care help in a sample of 419 older non-disabled participants.

A study by Stenholm et al. (2010) which investigated insomnia and levels of fatigue among older adults aged 65 years and older found that those with a shorter sleep time ( $\leq 6$  hours) had a higher OR for mobility limitations in women aged 65 years or older (OR=1.68, (95% CI 1.02,2.75)) although this was not the case for older men. Sleeping disorders or insomnia was independently associated with both decreased walking speed and mobility limitation in men aged 55 years or older but only with mobility limitation in women aged 65 years or older. Whilst this study was based primarily on length of sleep it could be argued that shorter episodes of sleep results in greater levels of fatigue and so it may be possible to extrapolate these results.

Function also plays a role in a person's ability to participate in adequate physical activity and whilst there is relatively little research on the relationship between function and fatigue Hardy and Studenski et al. (2008a) assessed the association of general fatigue with functional ability over a 3 year period in older primary care patients. In this study fatigue was measured as tiredness and community dwelling,

cognitively intact participants aged 65 years and over were recruited from two primary care units. Of the 496 individuals (mean±sd age 74±5.6) included in the study 212 reported feeling tired most of the time and of those who were tired 16% said their function was not affected, 29% said their function was affected a little, 29% said moderately and 26% said quite a lot. The impact of fatigue on daily activities and thus potentially physical activity is strengthened by evidence which shows that fatigue is also a predictor of mortality (Hardy & Studenski 2008a; Ekman et al., 2012; Moreh 2010) and it appears that those people who report higher levels of fatigue have poorer general health which may then result in lower levels of activity. There is clearly much conflicting data reported about levels of fatigue and the most likely reason for this is due to differences in defining fatigue along with a diverse range of methodologies for assessing fatigue. To make this data more meaningful consistent methodology would be helpful.

There are many methods used to measure fatigue but most are questionnaire based and rely on self-reporting. Some fatigue scales are uni-dimensional and these tend to consider severity of fatigue only. Alternative scales exist which acknowledge that there may be different domains of fatigue and this may provide a better overall picture of fatigue. This is probably true for an older population where you may expect higher levels of physical fatigue but not necessarily higher levels of mental fatigue. One such multi-dimensional scale is the Multi-dimensional Fatigue Inventory (MFI) (Smets et al., 1995) which measures five domains of fatigue with higher scores indicative of increased levels of fatigue. This was initially developed for use within a cancer population but has since been validated across a number of groups including for use within a healthy population (Lin et al., 2009). The interpretation of the scores obtained would however have greater value if they can be compared against normative data for a similar population.

There are limited data on normative values for levels of fatigue within the general population however a recent study attempted to describe expected levels of fatigue in a healthy population (Hinz et al., 2013). In this study 1,500 healthy individuals completed the MFI along with other measures of fatigue and questions related to their socioeconomic and health status with a particular focus on chronic disease. In this study of Colombian residents the mean±sd fatigue score was 44.3 ± 14.1 and this was then stratified by age category. Overall it was found that women had higher levels of fatigue than men for all age groups and levels of fatigue increased with age. This study presented mean±sd levels of fatigue for the population based on totals of each of the domains of fatigue but this is not recommended by the developer of the questionnaire (Smets et al., 1995) who suggests that overall fatigue can be determined by using the general fatigue domain within the questionnaire. However the study also presents normative data for each of the individual domains of fatigue across age group which can then be used for comparisons. The data for the over 60 age group are shown in table 1.9.

**Table 1.8 Normative values for levels of fatigue in adults aged over 60 years as measured by MFI (adapted from Hinz et al., 2013)**

	mean±sd scores for domains of fatigue					
	general fatigue	physical fatigue	reduced activity	reduced motivation	mental fatigue	total
male	9.6±3.1	9.8±3.1	9.7±3.1	8.8±3.1	9.6±3.3	47.5±13.1
female	10.6±3.5	10.6±3.7	10.2±3.6	9.5±3.3	9.7±3.5	50.7±15.5

The study presents data for an older adult population but considers all people over 60 years of age having similar levels of fatigue. This may not be appropriate in view of the previously discussed evidence suggesting fatigue increases with age. Indeed in this study fatigue was found to increase with each decade from 18 years onwards and it may well be that this continues to be found with each decade after the age of 60 years. If this is the case this normative data may underestimate the predicted



levels of fatigue in an older old population. A further consideration is that this study was undertaken in a Columbian population and as such may not to truly reflect a UK older adult population however no other normative data exists for the UK population using the MFI. Only one European study has tried to describe normative data and this was undertaken in a German population (Schwarz et al., 2003) which may better reflect a UK population. In this study of 2,038 adults aged 14 – 92 years who completed the MFI, 293 males and 373 females were aged 60 – 92 years of age. This study confirms that fatigue increases with age although the normative data from this study again considers the older adult population as anyone aged 60 years and over and as such does not take into consideration increasing levels of fatigue with age after the age of 60. The results from this study are shown in table 1.8.

**Table 1.9 Normative values from levels of fatigue in adults aged over 60 years as measured by MFI (adapted from Schwarz et al., 2003)**

	mean±sd scores for domains of fatigue				
	general fatigue	physical fatigue	reduced activity	reduced motivation	mental fatigue
male	10.1±3.7	10.3±4.3	10.3±4.0	9.1±3.3	8.7±3.5
female	10.8±3.7	11.1±4.2	10.5±4.0	9.9±3.5	9.2±3.4

There are clearly differences between the two sets of normative values and it is unclear which values are most reflective of a UK population however they both provide some guide for making comparisons.

As discussed earlier it is acknowledged that fatigue has been recognised as a prevalent symptom in the general population for many years however it is now being considered more widely across this population to determine its association and influence on general health and wellbeing including its relationship with levels of physical activity and sedentary behaviour.

## **1.18 SUMMARY**

The role of physical activity in healthy ageing is clear and has the potential to influence a person's ability to live independently. It is however linked to many other factors which also influence the ageing process including nutritional status, functional ability, dietary intake and levels fatigue. To date there have been no studies in a healthy older adults population which have looked at the relationship of all of these parameters with habitual activity levels and in particular physical activity and sedentary behaviour.

## **1.19 AIMS AND OBJECTIVES**

Despite an extensive search of the literature no studies were found which have looked at the relationship of physical activity and a combination of other parameters associated with healthy ageing and so the aims and objectives of this study were as follows:

### **1.19.1 Aims**

1. To determine the relationship of levels of habitual activity with nutritional status, functional ability, inflammation, dietary intake, and levels of fatigue in older adults.
2. To inform physical activity targets for the ageing population to optimise functional status.

### **1.19.2 Objectives**

1. To determine levels of habitual activity in older adults using accelerometers and activity diaries.
2. To establish if older adults meet current targets set for levels of activity.

3. To measure nutritional status and body composition of older adults using BMI, waist circumference (WC), mid upper arm circumference (MUAC) and tricep skinfold (TSF).
4. To determine functional status of older adults using handgrip dynamometry (HGD), sit to stand (STS) and six minute walk (6MW) tests.
5. To determine dietary intakes of older adults using an unweighed seven day diet diary.
6. To measure levels of inflammation using high sensitivity CRP (hsCRP) and antioxidant status using ferrous reducing antioxidant capacity of plasma (FRAP).
7. To determine level of fatigue in older adults using the multi-dimensional fatigue inventory (MFI).
8. To establish whether associations exist between levels of habitual activity and nutritional status, functional status, dietary intakes, antioxidant status, levels of inflammation and levels of fatigue.

### **1.19.3 Research Hypothesis**

It is hypothesised that statistically significant relationships will be found between measures of habitual activity and nutritional status, functional status, dietary intake, anti-oxidant status, levels of inflammation and levels of fatigue. Specifically it is hypothesised that higher levels of sedentary behaviour will be positively associated with BMI and measures of adiposity (WC and TSF), antioxidant status, levels of inflammation, and levels of fatigue. It is hypothesised that sedentary behaviour will be negatively associated with fat free mass (MAMC) and functional ability (HGD and 6MW). Due to the nature of the measurement of the STS in that quicker times are indicative of better function it is hypothesised that a positive association will be found between this parameter and sedentary behaviour. Due to the nature of the

relationship between sedentary behaviour and physical activity it is hypothesised that the converse relationships will be found between physical activity and nutritional status, functional status, antioxidant status, inflammation and levels of fatigue.

## **CHAPTER 2: MATERIALS & METHODS**

The purpose of this study was to determine the relationship of levels of habitual activity with nutritional status, functional status, dietary intake, levels of inflammation and fatigue in older adults. Additionally the study aimed to inform physical activity targets for the ageing population to optimise functional status. The methodology to achieve these aims is described below.

### **2.1 PARTICIPANTS, ETHICAL APPROVAL AND RECRUITMENT**

Ethical approval was obtained from Queen Margaret University, Edinburgh (QMU) and recruitment began in May 2009. When applying for ethical approval a number of aspects were considered. In particular participant burden was considered due to the significant number of parameters which were measured. To minimise the burden of the study for the participants, measurements were split across two separate measurement sessions ensuring that each session lasted a maximum of one hour. In addition as participants were required to be fasted for the second measurement session the researcher travelled to the participant at a time which was convenient to them and as early in the morning as requested by the participant. Whilst participants completed the functional tests they were observed at all times by the researcher to ensure they did not become unwell or injure themselves and as a further measure an appropriately trained first aider was in the vicinity during testing. The researcher was a trained phlebotomist and so risks associated with taking blood were reduced for both the participant and the researcher. Where any abnormal results were found e.g. high blood pressure participants were advised to seek guidance from their GP. These measures ensured that the ethical aspects of the study were managed appropriately.

### **2.1.1 Participants**

This was a cross-sectional study design which recruited healthy, adults aged 65 years and over from a variety of social settings within Lothian including churches, social clubs, lunch clubs, leisure facilities and voluntary organisations. Social settings were targeted in an attempt to recruit a representative sample of older adults in terms of activity levels, dietary intake and nutritional status. Potential recruitment sites in East Lothian, Midlothian and the City of Edinburgh were identified by a search of the yellow pages, an internet search and local knowledge and a wide range of potential recruitment sites was established. These included but were not exclusive to local churches, bowling clubs, leisure centres, bingo halls, social groups for older people including Probus groups, lunch clubs, golf clubs, the University of the Third Age, WRVS groups and charity shops. Where email addresses were available introductory emails about the study were sent to the appropriate contact and where these were not available a formal letter was written and sent by post.

The introductory email or letter explained the purpose of the study and requested permission to advertise the study to group members. Following receipt of permission the study was then advertised to group members. Where possible, group members were contacted directly. This occurred by either emailing the membership with information about the study or preferably the researcher attended group meetings to provide information about the study directly to group members. Where the researcher attended meeting the format was either an education session around diet, activity and/or healthy ageing followed by information about the study or to only provide information about the study. Direct contact by attending meeting was preferred by the researcher as this provided a greater opportunity to discuss the study and enhance recruitment opportunities. In addition to the direct contact a

range of other measures was also utilised. Where a central location was available for potential advertising, posters and leaflets were placed there for all visitors to see. Posters and leaflets were provided both electronically and in paper form as and when required. In addition contact with group members was made through mediums such as group newsletters. Where the group secretaries preferred that potential participants were not contacted directly by the researcher but were happy to distribute study information themselves appropriate information was provided to facilitate this. Where information was distributed by email, this provided an opportunity to send out reminder emails about the study to enhance recruitment further.

Any potential participant who was interested in volunteering for the study contacted the researcher directly and they were provided with an information sheet and given the opportunity to ask questions prior to informed, written consent being obtained.

### **2.1.2 Inclusion and exclusion criteria**

Inclusion criteria for the study were healthy adults aged 65 years and over who were living independently in their own home (including sheltered housing and warden aided accommodation). Participants were required to be ambulatory with or without walking aids and to be cognitively intact. Cognitive function was assessed prior to full inclusion in the study by screening participants using the mini mental state examination MMSE (Folstein et al., 1975) which is a commonly used instrument for screening for cognitive decline. The MMSE is a short validated questionnaire which provides measures of orientation, attention, immediate and short-term recall, language, and the ability to follow simple verbal and written commands and thus the presence of cognitive impairment can be indicated. It has a total possible score of 30 and following a comprehensive review of the literature related to the MMSE

Tombaugh & McIntyre (1992) recommend the following cut off levels to classify cognitive ability:

24 – 30: no cognitive impairment

18 – 23: mild cognitive impairment

0 – 17: severe cognitive impairment

The cut off for inclusion into this study was therefore set as a score of 24 or greater.

To meet the aims of the study a substantial number of parameters were measured. Due to the volume of parameters measured these were completed during two separate appointments at least 8 days apart. This reduced participant burden, enabled recording of seven days of activity and dietary intake and enabled clarification of the food diary and the activity diary as and where required. The structure of the research is shown in figure 2.1.



## 2.2 STRUCTURE OF RESEARCH

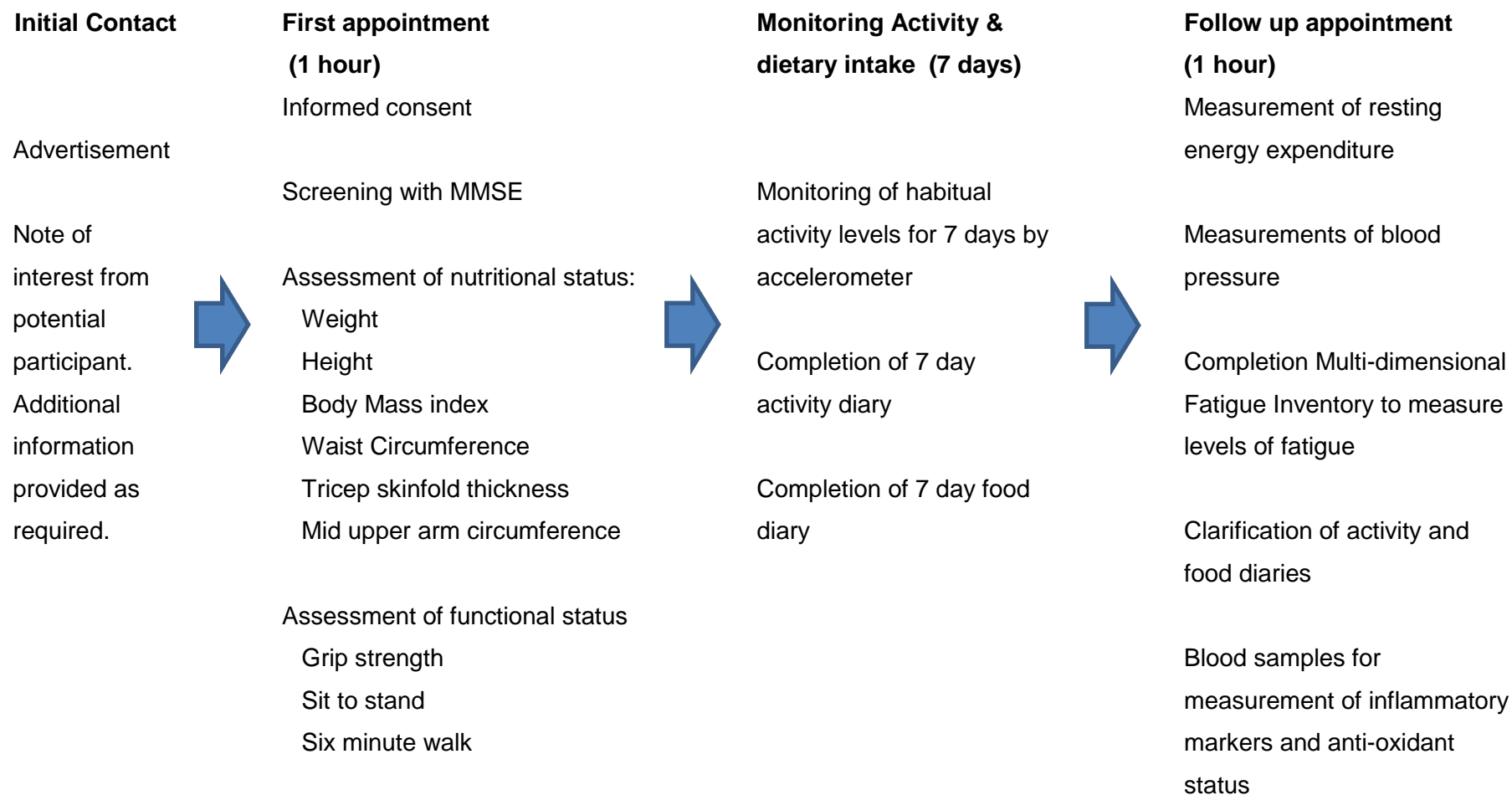


Figure 2.1 Structure of research study

## **2.3 FIRST APPOINTMENT**

Following recruitment to the study the first appointment was arranged with the participant and this appointment normally took place at QMU with the participants travelling there at a time which was convenient to them. Where participants preferred not to travel to QMU the researcher travelled to the participant if there was access to a quiet, flat, straight uninterrupted 20 m walkway to undertake the testing. If a 20 m walkway was not available then it was not possible to undertake all the measurements and the participants were then asked to travel to QMU.

### **2.3.1 Nutritional status**

It is well recognised that there is no definitive single method available to assess nutritional status (Hrnciarikova et al., 2006) and thus this study used a number of methods concomitantly i.e. weight (kg), height (m), body mass index (BMI ( $\text{kg}/\text{m}^2$ )) waist circumference (WC) (cm) and upper arm anthropometry (mid upper arm circumference (MUAC) (cm), tricep skinfold thickness (TSF) (mm) and mid arm muscle circumference (MAMC) (cm)). All nutritional parameters were measured at the first appointment using standard protocols which are described below. Appropriate consideration was given to health and safety for hand washing and cleaning of equipment i.e. scales, stadiometer, calipers etc.

The following parameters were measured at the first appointment in the order stated below and were recorded on a standardised proforma.

#### *2.3.1.1 Height (m)*

Height was measured using a Leicester Height Measure portable stadiometer (range 20 - 207 cm) with an accuracy of 0.1 cm. Participants were required to

remove their shoes and stand with their feet together, heels touching, and with the buttocks and upper part of the back touching the stadiometer scale without leaning on it and with their arms hanging loosely by their sides. The head was placed in the Frankfort plane prior to measurements being taken. The Frankfort plane was achieved by lowering the participants head to ensure the edge of the eye socket was in the same horizontal plane as the tragion (the notch superior to the tragus of the ear) ensuring that when aligned the vertex was the highest point of the skull (Norton & Olds, 1999). Participants were asked to keep their eyes focused on a point straight ahead and to breathe in deeply. The headplate was then lowered until it was touching the vertex of the skull and the measurement was taken before expiration. This measure of height was used in combination with weight for the subsequent calculation of body mass index (BMI  $\text{kg}/\text{m}^2$ ).

#### *2.3.1.2 Weight (kg)*

Weight was measured to provide a general description of body size and total mass (fat free mass (FFM) plus fat mass (FM)). Participants were weighed in light indoor clothing with their shoes removed. Weight was measured to the nearest 0.1 kg using calibrated electronic Seca stand on scales which had an accuracy of 0.01 kg. Coupled with height this measurement was used to calculate BMI ( $\text{kg}/\text{m}^2$ ).

#### *2.3.1.3 Body Mass Index (BMI) ( $\text{kg}/\text{m}^2$ ).*

BMI ( $\text{kg}/\text{m}^2$ ) is a measure of the weight of a person scaled according to their height. As it does not differentiate between components of body composition it acts only as a crude measure of mass and body size. BMI ( $\text{kg}/\text{m}^2$ ) is calculated using the equation weight (kg)/height ( $\text{m}^2$ ). As has been previously discussed (section 1.2) it is generally accepted that in the adult population a BMI range of 18.5 – 25  $\text{kg}/\text{m}^2$  is normal (WHO, 2006). However this is not the case for an older person (Wynn &

Wynn, 1995, Beck & Ovesen 1998). In the very old i.e. those aged over 80 years an increased BMI ( $\text{kg/m}^2$ ) may have some protective effect as it has been demonstrated that in people aged 84 - 88 years mortality is increased when BMI is  $<22 \text{ kg/m}^2$  but not when BMI is  $>30 \text{ kg/m}^2$  which is the usual cut off for obesity (Rajala et al., 1990). It has therefore been suggested that a more appropriate cut off for overweight in those people aged 65 years and over is a BMI  $> 27 \text{ kg/m}^2$  (Wynn & Wynn, 1995) or a BMI of  $29 \text{ kg/m}^2$  (Beck & Ovesen 1998). Indeed Beck & Ovesen (1998) suggest that a BMI range of  $24 - 29 \text{ kg/m}^2$  is healthy for older adults. There is adequate evidence to demonstrate that a higher BMI up to  $29 \text{ kg/m}^2$  is acceptable for most people aged 65 years and over and in view of this a BMI range of  $24 - 29 \text{ kg/m}^2$  has been considered normal in this current study.

#### *2.3.1.4 Waist circumference (WC) (cm)*

Waist circumference (WC) (cm) is a simple measure used to identify the accumulation of excess visceral fat (Lean et al., 1995) and thus identify cardiovascular and metabolic risk. It provides additional information to support BMI in terms of providing some detail of body composition. It is possible to have a normal BMI whilst also having an increased WC and as such be at increased CVD risk despite being apparently of normal weight. Measuring WC was therefore important and to ensure accurate measurements the protocol published by the International Society for the Advancement of Kinanthropometry (ISAK) for measuring WC (cm) was followed (Norton & Olds, 1999).

A flexible, Lufkin W606PM steel tape was used to measure WC. The bony landmarks of the lower costal rib and the iliac crest were located and the measurement was taken at the narrowest point between these anatomical points. If no obvious narrowing was visible then the measurement was taken at the mid-point

between these two landmarks. The researcher stood in front of the participant to locate the narrowing and the tape was placed touching the skin in a horizontal plane around the abdomen with attention being paid to ensure the tape measure was parallel to the floor. Participants stood relaxed, with arms folded comfortably across the chest and the measurement was made at the end of normal expiration ensuring that the tape measure was adjacent to but not compressing the skin (Norton & Olds 1999). WC measurements were made to the nearest 0.1 cm.

### **2.3.2 Body Composition Measurements**

Upper arm anthropometry provides additional information to BMI ( $\text{kg/m}^2$ ) and WC (cm) by allowing a determination of body composition through the prediction of fat mass (FM) from tricep skinfold thickness (TSF) and fat free mass (FFM) from mid arm muscle circumference. The prediction of FFM in particular is important in older people as this is likely to influence functional status and thus influence a person's ability to perform activities of daily living (ADL). As there is growing concern about the health risks associated with the loss of FFM with ageing it is important to measure this within the study population. Protocols published by ISAK were also used for upper arm anthropometry (Norton & Olds, 1999) and measurements were standardised to the right side of the body (Norton & Olds, 1999). Comparisons between the left and right sides of the body have shown that there is either no significant difference in skinfold thickness (Womersley & Durnin, 1973) or that the differences, although statistically significant, are of no clinical significance (Martorell et al., 1988). Standardising the measurements to the right side of the body will therefore not affect the results of the study.

### *2.3.2.1 Mid upper arm circumference (MUAC) (cm)*

As the arm contains both subcutaneous fat and muscle, mid upper arm circumference (MUAC) (cm) can be used to indirectly estimate FM and FFM together (Heyward & Wagner, 2004). MUAC (cm) was measured using a flexible Lufkin W606PM steel tape measure. The point of measurement for MUAC is the midpoint equidistant from the acromiale and radiale. Participants were asked to stand and assume a relaxed position, arms hanging freely by their sides. Their palms faced their thighs and their shoulder girdle was in a mid position in order to allow identification of the acromiale and the radiale.

The acromiale is the point at the superior and external border of the acromion process of the scapula. This was located by the researcher positioning themselves behind the right side of the participant. The spine of the scapula to the corner of the acromion was palpated and the straight edge of a pencil was then applied to the lateral external border of the scapula to identify the most lateral part of the border of the acromion process. The most superior, lateral margin was located with the side of the thumb and marked with a hypoallergenic pencil.

The radiale is the point at the proximal and lateral border of the head of the radius. This was located by the researcher again being positioned at the right side of the participant. The right thumb was used to palpate downward in the lower portion of the lateral dimple of the right elbow. If necessary, participants were asked to pronate or supinate their forearm to produce a rotary movement of the head of the radius. The position was then marked with a hypoallergenic pencil. Once identified the linear distance was measured between the acromiale and radiale landmarks with the arm relaxed and extended at the side, avoiding any curvature surface of the arm. A horizontal mark using a hypoallergenic pencil was placed at the midpoint

between these two landmarks. The mark was then projected around to the posterior surface of the arm as a horizontal line (to allow the measurement of the tricep skinfold).

In order to obtain the MUAC, participants continued to assume a relaxed position with arms hanging by their sides. The participants arm was abducted slightly to allow the steel tape measure to be passed around the arm. The tape was placed perpendicular to the long axis of the arm when the subject was standing erect. The circumference was measured at the marked level of the mid acromiale - radiale line. The MUAC was measured to the nearest 0.1 cm.

MUAC (cm) measures both FM and FFM and so to determine FM, the TSF (mm) can be measured which in combination with the MUAC allows for the calculation of mid arm muscle circumference (MAMC (cm)) which is an indirect measure of FFM.

#### *2.3.2.2 Tricep skinfold thickness (TSF) (mm)*

Tricep skinfold thickness was measured to 0.2 mm using Harpenden skinfold calipers. The Harpenden calipers were calibrated by Harpenden prior to commencing the study and again at the end of the study. The tricep skinfold site is the most widely used single skinfold site for estimating total fat mass stores operating on the assumption that subcutaneous fat stores at this point are representative of whole body fat stores (Brodie & Hutcheon 1998).

The participant was asked to assume a relaxed position with the right arm hanging by the side but this time with the shoulder joint slightly externally rotated and the elbow extended at the side of the body. The skinfold was raised parallel to the long axis of the arm at the site of the posterior mid acromiale - radiale line. The skinfold

was grasped and raised at the marked line so that a double fold of skin plus the underlying subcutaneous adipose tissue was held between the thumb and index finger of the left hand. The nearest edge of the contact faces of the calipers were applied 1 cm away from the edge of the thumb and finger. The measurement was recorded two seconds after the full pressure of the calipers was applied (Kramer & Ulmer, 1981). This approach was used as adipose tissue is compressible and a constant recording time enables test/retest comparisons to be made while controlling for this known compressibility (Martin et al., 1985). Two measurements were taken and the mean value recorded.

#### *2.3.2.3 Mid arm muscle circumference (MAMC) (cm)*

Mid arm muscle circumference (MAMC) is considered to be an estimate of fat free mass (FFM) and is commonly used to reflect whole body FFM stores (Jackson & Pollock, 1976). It represents the circumference of the inner circle of muscle mass surrounding a small central core of bone (Gurney & Jelliffe, 1973). It does have some limitations in that it does not take into account inter-subject variation in the diameter of the humerus relative to the MAMC (Frisancho, 1981). Despite this, it is widely used as a marker of FFM as it is considered an accurate reflection of this body compartment. MAMC is derived from the measurements of MAC and TSF as described above using the following equation:

$$\text{MAMC (cm)} = \text{MUAC (cm)} - (\pi \times \text{TSF (mm)}) \text{ (Frisancho, 1990)}$$

#### **2.3.3 Reliability of upper arm anthropometry**

It is widely acknowledged that there is the potential for intra-observer error when measuring the circumference and skinfolds of the upper arm (Ellis, 2001). If any error exists it is possible to calculate the technical error of measurement (TEM) (Ulijaszek & Kerr, 1999) thus providing an objective measure of the error associated



with a single observer. This was calculated for this study. To enable this to be calculated repeated measurements are required on a minimum of 20 subjects (Norton & Olds, 1999, pp. 82).

The TEM was calculated from measurements taken in the study population. This study measured MUAC on each participant once only but to provide repeated measurements the first 10 men and first 10 women recruited to the study had MUAC measured twice on the first study visit using methodology described above with the mid point of the upper arm marked separately for each of these measurements. As TSF was measured twice on all subjects with the mean result being used measuring for the TEM did not veer from this. Following 2 measurements of MUAC and TSF the TEM was then calculated. This involved calculating a one-way ANOVA to determine the mean error square and the TEM was then calculated by using the equation described by Ulijaszek & Kerr (1999).

$$\text{TEM} = \sqrt{\text{MSe}} \text{ (where MSe is the mean error square)}$$

This is reported as an absolute value and the percentage error is also calculated. In addition an intraclass correlation (ICC) is also calculated to establish the correlation between successive measurements on the same subject (Norton & Olds, 1999 chapter 13).

Following measurements of nutritional status and body composition, functional status was then measured.

#### **2.3.4 Functional performance**

Functional status is directly related to nutritional status and body composition as FFM influences a person's functional ability with higher levels of muscle mass generally indicating better functional ability. However FFM alone does not

determine functional ability as muscle strength also plays a key role in influencing functional status. In view of this functional status should be measured alongside nutritional status to provide an indication of muscle mass (i.e. FFM) and muscle strength. It is these together which will at least in part determine a person's ability to live independently.

#### *2.3.4.1 Hand grip dynamometry (HGD)*

Handgrip strength was measured using an analogue dynamometer (Grip-A 5001, Takei Scientific Instruments Co. Ltd) with a measuring range 0 - 100 kg which was calibrated at the start and the end of the study. Prior to each individual measurement the dynamometer was adjusted to the hand size of each participant and correct grip size was achieved when the second joint of the participant's forefinger was bent through 90°. The non-dominant arm was used. Measurements were made with subjects standing with their arm hanging by their side and standardised instructions as described by Mathiowetz et al. (1984) were used. The researcher demonstrated the technique and participants were told:

'I want you to hold the handle like this and squeeze as hard as you can'.

Following correct positioning of handgrip for each participant the researcher said

'Are you ready? Squeeze as hard as you can'.

As the participant started to squeeze, the researcher said

'Harder, harder, and relax'.

In line with protocol three measurements were taken to the nearest 1 kg and the mean of the three measurements was used as this has the highest test-retest reliability (Hamilton, 1994).

Handgrip strength provides an indication of upper body strength and whilst it is also related to lower body strength (Tietjen-Smith et al., 2006) additional measures of

lower body strength which are reflective of ADL provide additional information. In view of this additional functional parameters were also measured in this study.

#### *2.3.4.2 Timed Sit to Stand*

The ability to stand-up from a seated position is an important functional task performed several times throughout the day. The sit-to-stand (STS) movement is biomechanically demanding, and requires greater lower extremity joint torque and range of motion than walking or stair climbing (Berger et al., 1988). As such it is a prerequisite for upright mobility and is an important factor for independent living. Timed chair standing has been shown to be a reliable and valid test that reflects older adults' lower extremity muscle force, balance, and functional mobility (Ferrucci et al., 1997). It has been shown to be a reliable and valid measure of strength in an ageing population (Ritchie et al., 2005, Judge et al., 1996) and has been accepted as an indicator of functional status in older adults (Gross et al., 1998).

To perform the test a straight back chair with no arms and a standard seat height of 44.5 cm as recommended by Csuka & McCarty (1985) was used. The chair was placed against a wall to stop the chair from moving and the participant sat in the middle of the chair with their back straight, shoes on, feet flat on the floor and arms crossed at the wrists and held against the chest. The researcher demonstrated the technique prior to the participant performing the test. Participants were then invited to undertake one sit to stand movement prior to the test to allow them to familiarise themselves with the height of the chair and the movement required for the test. They were told that they should squat over and touch the chair with their bottom in the sitting phase and to fully extend their knees in the standing phase (Koufaki et al., 2006). Having completed the familiarisation trial, participants were then told that should they feel unwell or unable to continue the test would be discontinued.

The researcher provided the following instructions according to standardized laboratory protocol (Whitney et al., 2005):

“I want you to stand up and sit down 5 times as quickly as you can when I say 'Go'. You should finish in the seated position after completing 5 full sit to stand movements”.

On the verbal signal of 'go' the participant rose to a full stand, and then returned to a fully seated position repeating this five times until returning to a fully seated position (Whitney et al., 2005). Timing commenced at the 'go' signal and stopped when the participants had completed the five sit to stands and had returned to the seated position. The time required to complete all five sit to stand movements was recorded to the nearest 0.1 second using a hand held stop watch. If participants were not able to complete the test at the first attempt they were offered the opportunity to rest until they felt able to try again and then when able were asked to follow the procedure above for a second time. If they did not want to try a second time or failed to complete the test i.e. failed to complete 5 complete sit to stand transitions at a second attempt this was recorded as a non-completion.

The STS five test measures a person's ability to rise from a chair and is reflective of function however due to the relatively short nature of the test it does not provide an indication of endurance related to functional ability. In view of this an additional measure was performed to provide an indication of endurance and in this instance the measurement was the six minute walk (6MW) test.

#### *2.3.4.3 Six minute walk (6MW) (m)*

The six minute walk (6MW) test is a widely used sub-maximal exercise test which correlates well with maximal exercise capacity and subjective functional status

questionnaires (Steele, 1996; Bittner, 1997). The test is well tolerated, reflective of activities of daily living, safe, easy to administer, well accepted by participants and does not require expensive equipment (Guyatt, 1985; Solway et al., 2001; Casanova et al., 2011).

Guidance on methodology has been published by the American Thoracic Society (2002) and this was followed in this study. In brief the following methodology was used. The 6MW (m) was performed indoors along a long, flat, straight, enclosed corridor with a hard surface that is seldom travelled. The walking course was 20 m in length and the turnaround points were marked with cones. Chairs were also placed at these points to facilitate rests should they be required. Participants were asked to wear comfortable clothing and appropriate comfortable walking shoes. If they usually walked with a walking aid they were asked to use this during the test. Participants were also advised not to exercise vigorously within 2 hours of the start of the test.

Participants were supervised during the test and were provided with standard instructions to complete the test. Participants were told “The object of this test is to walk as far as possible for six minutes. You will walk back and forth in this hallway. Six minutes is a long time to walk, so you will be exerting yourself. You may become out of breath or become exhausted. You are permitted to slow down, to stop, and to rest as necessary. You may lean against the wall or sit while resting, but resume walking as soon as you are able. You will be walking back and forth around the cones. You should pivot briskly around the cones and continue back the other way without hesitation. Now I’m going to show you. Please watch the way I turn without hesitation.” One lap was then demonstrated by the researcher. Participants were then asked “Are you ready to do that? I am going to keep track of

the number of laps you complete. Remember that the object is to walk as far as possible for 6 minutes, but do not run or jog. Start now, or whenever you are ready.”

After the first minute the participants were told: “You are doing well. You have 5 minutes to go.” With four minutes remaining the participants were told: “Keep up the good work. You have 4 minutes to go.” With three minutes remaining the participants were told: “You are doing well. You are halfway there.” With two minutes remaining the participants were told “Keep up the good work. You have only two minutes left.” With only one minute remaining the participants were told: “You are doing well. You have only 1 minute to go.” With 15 seconds from completion the participants were told: “In a moment I’m going to tell you to stop. When I do, just stop right where you are and I will come to you.” When the six minutes were complete the participant was told: “Stop, please remain where you are.” This point was marked with a beanbag. The total distance travelled was calculated by counting the number of 20 metre laps completed and adding the distance covered in the final lap which was measured to the nearest 0.1 m using a Draper 44238 trundle wheel. Any rest period was also noted.

The initial appointment provided an opportunity for nutritional status, body composition and functional status to be measured. The appointment lasted up to an hour which provided adequate time to answer any questions, obtain informed consent and undertake the measurements. Following completion of the measurements the participants were then given instructions on the next stage of the study which involved monitoring habitual activity and dietary intakes over seven consecutive 24 hour periods.

## **2.4 MONITORING HABITUAL ACTIVITY AND DIETARY INTAKE**

Following the initial measurements participants were asked to record levels of activity by use of an *activPAL*<sup>TM</sup> accelerometer and activity diary along with dietary intakes using an unweighed food diary for seven consecutive 24 hour periods.

### **2.4.1 Activity monitoring**

Activity was monitored over seven consecutive 24 hour periods commencing immediately at the end of the first appointment. This length of monitoring was chosen as it provides an accurate reflection of habitual activity in older adults (Tudor-Locke et al., 2005). Habitual activity was measured using an accelerometer to measure time spent sitting and lying (min), time spent standing (min) and time spent stepping (min). In addition the total number of steps taken was measured and the intensity of the activity was also recorded to give an indication of the length of time participants spent in moderate intensity activity (activity at MET > 3). For the purposes of this study and due to the nature of the study participants, moderate intensity activity is all activity at MET > 3 and so could include vigorous intensity activity. Finally sedentary behaviour (activity when awake but seated or reclining and at MET < 1.5) was also calculated as both absolute time (min) and as a percentage of time awake.

Alongside the accelerometer participants were requested to complete an activity diary to provide an indication of time asleep to enable sedentary time to be calculated. In addition types of activities participants engaged in which would be considered moderate intensity but which may not have been identified by the accelerometer (i.e. upper body activity) could also be established.

#### 2.4.1.1 Measuring habitual activity using an accelerometer

The *activPAL*<sup>TM</sup> accelerometer (PAL Technologies Ltd, Glasgow) is a lightweight (15 g) single unit uni-axial accelerometer which measures 53 x 35 x 7 mm. It classifies an individual's activity into time (in seconds) spent sitting and lying, spent standing and spent stepping. The monitor also records steps and cadence in real time and as a result provides additional information regarding number of steps taken along with the metabolic equivalents (METs) of the activity enabling determination of both amount of activity and level of intensity associated with activity. *ActivPAL*<sup>TM</sup> accelerometers have been shown to be a valid and reliable measure of habitual activity (Grant et al., 2006; Godfrey et al., 2007). Importantly *activPAL*<sup>TM</sup> accelerometers have been shown to have high level of accuracy even at slow speeds as they have been shown to correctly record 98%±3% of activity along with more than 97% of all steps taken (Feito et al., 2012).

The monitors have a 4 megabyte memory and can store data for more than seven days. They were charged via a USB port on a computer and were activated to record data immediately prior to participants attaching them for the study. Participants were asked to wear the *activPAL*<sup>TM</sup> monitor continuously for seven consecutive 24 hour periods thus providing data on habitual activity for one full week. The *activPAL*<sup>TM</sup> monitor is placed on the mid-point of the anterior thigh as per the manufacturer's guidance (see figure 2.2).





**Figure 2.2: Participant wearing *activPAL*<sup>TM</sup> accelerometer**

The monitor was secured between two 10 x 12 cm waterproof dressings (Tegaderm Film 3M) which enabled the monitors to be worn continuously for the seven day recording period. As the monitors were sandwiched between waterproof dressings participants were permitted to shower. Those participants who preferred to bathe or participated in underwater activities such as swimming were asked to remove the *activPAL*<sup>TM</sup> for the duration of that activity and then replace it between two fresh waterproof dressings immediately after drying themselves. On completion of the seven consecutive days of activity monitoring the *activPAL*<sup>TM</sup> could be removed by the participant.

When the *activPAL*<sup>TM</sup> was returned the data was downloaded automatically onto a computer which had been uploaded with the *activPAL*<sup>TM</sup> software and the data was saved automatically as a .cfg and a .pal file. This permits the activity to be viewed

diagrammatically using the *activPAL*<sup>TM</sup> software and to be converted into excel files to enable analysis of the data.

#### 2.4.1.2 *ActivPal*<sup>TM</sup> output

The *activPAL*<sup>TM</sup> output is available in 3 formats:

1. Graphical display of daily activity with summary variables.
2. Summary excel files for each recorded 24 hour period with time spent sitting and lying, spent standing and spent stepping recorded per 15 second epoch. Number of steps and number of sit to stand transitions were also recorded per 15 second epoch. A summary of these variables is also available for each minute and thus each hour the monitor was worn and therefore for each 24 hour period.
3. Summary excel files which include data on accelerometer counts and METS in each 15 second epoch were also available. Again this is then available for each minute, hour and 24 hour period. The *activPAL*<sup>TM</sup> provides an indirect estimate of METs based on steps and is calculated from the following equation:

$$\text{MET/H} = (1.4 \times \text{activity duration (h)}) + (4 - 1.4) \times (\text{cadence}/120) \times \text{activity duration (h)}$$

#### 2.4.1.3 *Graphical output*

The *activPAL*<sup>TM</sup> output can be displayed graphically summarised by 15 second epoch, by minute, by hour, by 24 hour period and by week (figure 2.3). The graphs are colour coded with sitting and lying coloured yellow, standing coloured green and stepping events graded from red to orange depending on step rate. Higher step rates and thus higher intensity activity are shown in orange. These outputs were used for describing activity to participants and a copy of these along with summary

data of time spent in each activity type along with total number of steps for each 24 hour period and the mean activity for the seven day period was provided to each participant.

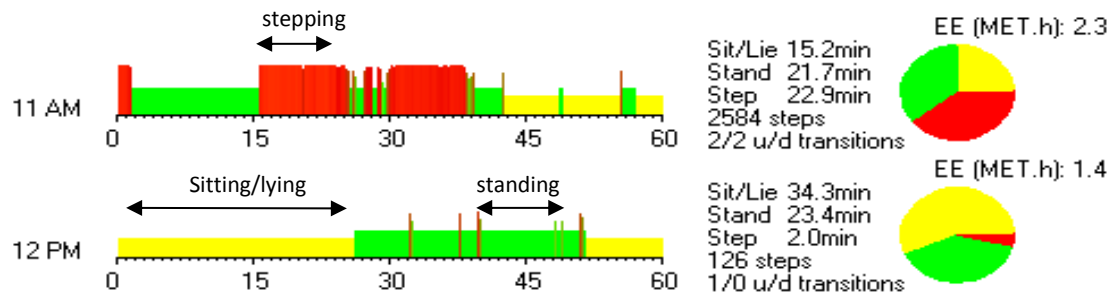


Figure 2.3 *ActivPAL™* graphical output in hours

#### 2.4.1.3 Summary results

The excel file obtained after downloading the data allows time spent sitting and lying, time spent standing and time spent stepping to be calculated for each 24 hour period and across the whole recording period. These calculations are based on the activity in each 15 second epoch of the recording period. Total number of steps and energy expenditure based on METs was also calculated for each 24 hour period. All data obtained from the *activPAL™* over the seven day recording period was included in the analysis. The only non-wear time which would have influenced the results would be if a participant bathed and thus removed the *activPAL™* (which would not influence results of habitual activity) or if a participant had gone for a swim and removed the *activPAL™* during that time. Daily totals were then used to provide mean time spent in each activity, mean number of steps and mean MET throughout the recording period. Mean time in each activity was compared to guidance targets for levels of activity in an older population. The day to day variation in levels of activity was also noted.

In addition to total time spent in activity at MET > 3 the amount of time in activity at MET > 3 in blocks of at least 10 minutes was calculated to enable comparison to recommendations for levels of activity. To do this the researcher reviewed each activity file for each 24 hour period for each participant. The researcher reviewed the data in 15 second epochs and manually counted each episode of moderate intensity activity which lasted for at least 10 minutes. Where episodes of activity lasted for at least 10 minutes these were counted as episodes of 10 minutes, 15 minutes, 20 minutes, 25 minutes and 30 minutes. It is acknowledged that small amounts of moderate intensity activity may not have been counted e.g. 12 minutes of activity would be counted as 10 minutes of activity. To be included in the analysis episodes of activity at MET > 3 had to be continuous.

#### *2.4.1.4 Activity Diary*

Although the *activPAL*<sup>TM</sup> provides comprehensive information on activity levels the data provided does not differentiate between the types of activities which participants engaged in. To provide additional information regarding types of activities participants were asked to complete an activity diary (Appendix 1) for the same time period as the *activPAL*<sup>TM</sup> monitoring. Whilst activity diaries are typically broken down into 15 minute segments with individuals recording their activity in each of these 15 minute blocks (Koebnick et al., 2005) the activity diary used in this study was divided into 30 minute blocks. As participants were recording activity for 7 consecutive days it was felt that 15 minutes may have been too intensive and lead to non completion. The activity diary was therefore divided into 30 minutes blocks over each 24 hour period and the participant was required to record the type of activity they had participated in during each 30 minutes over the same seven consecutive 24 hour periods which the *activPAL*<sup>TM</sup> monitor was worn.

The data recorded in the activity diary was a crude record of the activity throughout the recording period. The primary purpose of the activity diary was to enable sedentary time to be calculated however it was also used as a supplement to the accelerometer data to identify activities which could not be recorded by the *activPAL*<sup>TM</sup> (i.e. upper body movement e.g. ironing, decorating and swimming). These activities were noted to establish if any the participant was engaging in activities which would be considered moderate intensity (i.e. MET > 3) which were not recorded by the *activPAL*<sup>TM</sup> monitor and thus provide an indication of any potential under-reporting of activities.

The activity diaries were also reviewed to establish if participants met the recommendation of participating in muscle-strengthening activities on 2 or more days a week (DoH, 2011). Any activity which is considered either definitely muscle strengthening or potentially muscle strengthening as described in the Scottish Health Survey (The Scottish Government, 2012) was counted as strength based activities and it was noted whether participants met the recommendation, did some strengthening activities but did not meet the recommendation or if they did not strengthening activities at all.

#### *2.4.1.5 Sedentary behaviour*

Sedentary behaviour is behaviour where a person is awake and sitting or reclining and engaging in activity which results in low energy expenditure i.e. at MET < 1.5 (Owen et al., 2010a). The activity diary was therefore utilised to establish waking time and the accelerometer data provided detail on participant positioning and MET. This together could then be used to provide an accurate measure of sedentary behaviour across the recording period. This could then be reported as absolute time

(min) but also as a percentage of the time the participant was awake to allow meaningful comparisons between participants.

To do this the activity diary was used to establish the time each participant was asleep and this was confirmed using the output data from the *activPAL*<sup>TM</sup>. Any sleep time was then excluded from calculations for sedentary behaviour. Where a participant went to bed to listen to the radio or to read (as noted on the activity diary) this was not counted as sleep time and was included within sedentary time. Having established sleep time, the data in 15 second epochs for all time awake was then reviewed and any activity where the participant was awake, sitting or lying and at MET < 1.5 was considered sedentary. To do this data in the excel spreadsheet was sorted to identify that which was at MET < 1.5 and all 15 second epochs of sedentary behaviour were then totalled to provide a daily time in sedentary behaviour and was reported to the nearest whole minute. This absolute time was then converted to a percentage of awake time to enable meaningful comparisons.

Levels of activity provide an indication of energy expenditure (from predicted resting energy expenditure and physical activity levels (PAL) based on the mean daily MET of the participants) and this along with dietary intake provided an indication of energy balance. In addition as dietary intake profoundly influences nutritional status, body composition and functional status measuring this provided useful information about the participants in the study.

#### **2.4.2 Dietary intake**

To determine normal dietary intakes of the participants they were asked to record their dietary intake during the same seven consecutive 24 hour period that activity was monitored using an unweighed seven day diet diary. Written instructions were

given to all participants for completion of the food diary and this was supported by a verbal explanation of what was required along with an opportunity for the participants to ask any questions. Participants were asked to record all food and drink which was consumed (even if it was just a small amount) and they were asked not to change their eating habits over the recording period. In addition they were provided with guidance on recording as much detail as possible about the food and drink which was consumed including types and brands of food, where the food was purchased, if it was an own brand, portion sizes (as weights, volumes or handy measures) and cooking methods. They were also encouraged to provide food labels where they could.

When the food diaries were returned the researcher checked the content of these with each individual participant and clarified aspects of the information e.g. cooking methods, ingredients of home cooked food, potential missing meals or drinks etc. where required. Portion sizes were clarified using the Food Standard Agency photographic atlas of food portion sizes (Nelson, 1997).

The food diaries were analysed using a dietary computer analysis programme, WinDiets Research (Univation Ltd 2005), to obtain estimates of total energy intake (kcal) and macronutrient intake i.e. fat (g), saturated fat (SFA) (g) polyunsaturated fat (PUFA) (g), monounsaturated fat (MUFA), protein (g and g/kgBW), carbohydrate (CHO) (g), sugar (g), non-milk extrinsic sugar (NMES) (g) and alcohol (g). In addition and in line with recommendations for healthy eating, intakes of macronutrients were also calculated as contribution of each nutrient to percentage energy intakes. Other selected micronutrient intakes relevant to the study were also assessed using WinDiets (Univation Ltd 2005), i.e. vitamin C (mg) and vitamin D

( $\mu\text{g}$ ) as these have been shown to be associated with functional ability in the older adult population (Stanner et al., 2009).

At the end of the period of monitoring activity and dietary intake participants were invited to a follow up appointment where additional measurements were taken to measure resting energy expenditure (REE), blood pressure and fatigue. In addition two blood samples to measure antioxidant status and levels of inflammation were also taken.

## **2.5 APPOINTMENT 2**

Due to the nature of the testing participants were required to be fasted prior to the testing and so this appointment had to take place first thing in the morning. The participant could therefore choose for this appointment to either be at QMU or at a location convenient to them. The participants were required to be fasted to enable resting energy expenditure to be measured. This was used to confirm the dietary analysis and to check for potential over or under-reporting.

### **2.5.1 Energy Expenditure**

Total energy expenditure (TEE) comprises of 3 main components, resting energy expenditure (REE) which accounts for 60-70% of TEE, dietary induced thermogenesis, which accounts for approximately 10% of TEE and physical activity levels (PAL) which accounts for 20-40% of TEE in healthy adults. As the *activPAL*<sup>TM</sup> accelerometers provide data on physical activity levels including MET, measuring REE enabled the prediction of TEE for each participant. This was then utilised in conjunction with dietary intake to determine energy balance and give an indication of the accuracy of the diet diaries.



REE is an expression of the rate at which oxygen is used by body cells or the calculated equivalent heat production by the body, in a fasting subject at complete rest (Levine, 2005). The conditions required to accurately measure REE are for a person to be completely rested (before and during measurements), lying down but fully awake, fasted for at least 10 – 12 hours, in a thermo-neutral environment (22-26°) and free from emotional stress (Levine, 2005). Fulfilling all these criteria is however difficult. These conditions were however adhered to where possible. Participants were asked to fast overnight drinking only water in the morning and they were asked to rest prior to testing. Testing took place either at QMU or in the participants own home shortly after they had wakened. As participants had to be rested the preferred location was the participants own home to prevent an increase in energy expenditure as a result of travelling to QMU. The appointment time was chosen by the participant to allow them to remain fasted without too much discomfort.

REE was measured using a Fitmate Calorimeter (Cosmed Company, Rome) which was calibrated prior to the start of the study. The calorimeter is a small (20 x 24 cm) metabolic analyser designed for measurement of oxygen consumption and energy expenditure during rest and exercise. It uses a turbine flow meter for measuring ventilation, a galvanic fuel cell oxygen sensor for analysing the fraction of oxygen in expired gases, and incorporates an innovative sampling technology that allows the FitMate to retain the performance of a metabolic cart with a standard mixing chamber. REE is calculated from oxygen consumption using a fixed respiratory quotient (RQ) of 0.85, and estimated grams of urinary nitrogen using a modified Weir equation. The Weir equation measures REE in the following way:

$$\text{REE} = (\text{O}_2 \text{ consumed (litre)} \times 3.941 + \text{produced CO}_2 \text{ (litre)} \times 1.11) \times 1440 \text{ min/d}$$

Participants were asked to lie in a supine position and wear a mask which covered their nose and mouth and were asked to breathe normally. The mask enabled oxygen consumption and carbon dioxide production to be measured. To enable the participants to fully relax and for breathing to stabilise the calorimeter measured breathing (including number and depth of breath), oxygen consumption and carbon dioxide production for five minutes initially and then these measurements were discarded. Following this, the calorimeter measured oxygen consumption and carbon dioxide production for a further 15 minutes and these 15 minutes of testing was used to determine REE. This timeframe has been established to be adequate to determine a reliable measure of REE whilst minimising participant burden (Compher et al., 2006). If participants felt uncomfortable they were informed that they could stop the test at any time by letting the researcher know that they wished to halt the test.

During the REE measurements the researcher downloaded the data from the *activPAL*<sup>TM</sup> to ensure seven consecutive days of activity had been recorded. This also provided an opportunity to compare the activity diary data with the data from the accelerometer and to identify any inconsistencies which could then be discussed with the participant following completion of the testing should this be required.

As the participants were rested for measuring REE at the end of this test blood pressure was then measured.

### **2.5.2 Blood pressure**

Raised blood pressure provides an indication of cardiovascular disease (CVD) risk. As CVD is linked to ageing and increased visceral adiposity, measuring blood pressure alongside markers of nutritional and functional status provides additional

information to determine the health status of a person. To determine normal blood pressure this should be measured when a person is at rest. Blood pressure was measured following European Society of Hypertension recommendations (O'Brien et al., 2003). An Omron M10-IT upper arm automated sphygmomanometer was used. Positioning of the participant for blood pressure monitoring followed guidance of the American Heart Association (Pickering et al., 2005).

Participants were asked to remove clothing which covered the location of cuff placement and they were asked to sit in a chair with their legs uncrossed and with their back supported. Their left elbow and forearm rested on a table with the blood pressure monitor cuff at the level of the right atrium of the heart i.e. the midpoint of the sternum or the fourth intercostal space. A standard cuff with a bladder measuring 12 x 26 cm was placed around the upper arm and 1 - 2 cm above the antecubital fossa in line with the brachial artery. The cuff was tightened to the point where 2 fingers could still be inserted comfortably between the cuff and the participant's arm. The display on the blood pressure monitor was placed facing away from the participant's line of sight to prevent the reading causing sudden changes in blood pressure.

The participant was instructed to relax as much as possible and not to talk during the measurement procedure with the first measurements taken 5 minutes after positioning. The monitor was then switched on and as the sphygmomanometer was automated the cuff continued to inflate until the brachial artery was occluded. Systolic and diastolic measurements were then recorded automatically by the blood pressure monitor. Blood pressure was then measured twice more with at least one minute between each measurement. In line with British Hypertension Society guidance (Williams et al., 2004) the first measurement was discarded and an

average of the two subsequent systolic and diastolic measurements was then taken and recorded as the participant's normal blood pressure.

Fasting blood samples were required for the participants and so whilst the participants were fasted they were asked to provide two blood samples. The researcher was trained in phlebotomy as part of the NHS Lothian training programme and these procedures were followed. To collect the blood samples each participant was asked to sit in an upright position with their chosen arm outstretched and supported by a cushion. A 21G (Greiner Bio-One, Brunel Way, Stroudwater Business Park, Stonehouse, GL10 3SX) hypodermic needle was inserted into a suitable vein in the antecubital fossa. Blood (approx. 10 ml) was withdrawn into an Ethylenediaminetetraacetic acid (EDTA) vacuette (Greiner Bio-One) and a further blood sample (approx. 10 ml) was withdrawn into a lithium heparin (LH) vacuette (Greiner Bio-One). The blood samples were inverted several times in the respective vacuettes to ensure anticoagulation of the blood and were then processed in preparation for analysis (see later).

Following the measurement of REE, blood pressure measurements and provision of blood samples participants were permitted to eat and drink if they wished. Participants were then asked to complete the questionnaire to measure levels of fatigue.

### **2.5.3 Fatigue**

Fatigue was measured using the Multi-dimensional Fatigue Inventory (MFI) (Smets et al., 1995) which is a 20 point questionnaire to measure fatigue. It was initially developed to measure fatigue in a cancer population but it has since been validated

in a healthy population (Lin et al., 2009). Permission to use the questionnaire was sought from and granted by the developer.

The questionnaire is self-administered and measures five domains of fatigue: physical fatigue, mental fatigue, reduced motivation, reduced activity and general fatigue. Each domain is measured by a separate subscale within the questionnaire with each subscale consisting of 4 questions all of which use a five-point Likert scale. General fatigue includes general statements about fatigue and decreased functioning and was designed to encompass both physical and psychological aspects of fatigue. Physical fatigue concerns physical sensations related to fatigue. Mental fatigue pertains to cognitive functioning, including difficulty concentrating. Reduced activity refers to the influence of physical and psychological factors on levels of activity. Reduced motivation relates to lack of motivation for starting any activity. Scores on each subscale range from 4 - 20, with higher scores indicating greater levels of fatigue.

## **2.6 BLOOD PROCESSING AND ANALYSIS**

The EDTA and LH vacuettes (Greiner Bio-One) containing anti-coagulated blood were centrifuged (Jouan) at 3000 rpm for 5 minutes at 4 °C to produce plasma. Plasma was then aliquoted into 1.5 ml eppendorf tubes (Fisher Scientific) and stored at -80 °C at QMU, awaiting antioxidant capacity analysis using FRAP (Benzie & Strain, 1996) at QMU and high sensitivity CRP (hsCRP) analysis at the laboratories at the Royal Infirmary of Edinburgh (RIE).

### **2.6.1 Antioxidant capacity**

The analysis for antioxidant capacity was completed by the researcher in the laboratories at QMU. A number of laboratory methods can be used to quantify the

levels of phenolic compounds and their antioxidant abilities in foods, beverages and biological samples. The Standard Operating Procedure (SOP) used at Queen Margaret University and described below is one method for assessing reducing agents based on electron transfer assay. The methodology was first described by Benzie & Strain (1996) and measures the ferric-reducing antioxidant capacity of plasma (FRAP). The FRAP assay is a colorimetric assay used to measure the ability of a sample to reduce the straw-coloured ferric-2, 4, 6-tri-2-pyridyl-s-triazine (TPTZ-Fe<sup>3+</sup>) complex to the blue-coloured ferrous-2, 4, 6-tri-2-pyridyl-s-triazine (TPTZ-Fe<sup>2+</sup>) form under acidic conditions (Benzie and Strain, 1996). The assay has the advantage of directly measuring the concentration of reductants in any given sample (Halvorsen et al., 2002).

Ferrous sulphate (0.278 g) was weighed and dissolved in 1 L of distilled water to give a 1 mM stock solution. The stock was serially diluted in phosphate buffer saline (PBS) to give the following standard concentrations: 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 mM Fe<sup>2+</sup>. A 300 mM acetate buffer solution (pH 3.6) was also prepared by dissolving 3.1 g sodium acetate and 16 ml of glacial acetic acid in 1 L of distilled water. Following this Ferric-2, 4, 6-tri-2-pyridyl-s-triazine was prepared. A 10 mM TPTZ solution was prepared by dissolving 0.031 g TPTZ in 10 ml of 40 mM hydrochloric acid (HCl). Alongside this a 20 mM ferric chloride solution was prepared by adding 0.054 g of ferric chloride in 10 ml distilled water.

A working ferric-reducing capacity of plasma (FRAP) solution was then prepared by combining 100 ml of 300 mM acetate buffer (pH 3.6) with 10 ml ferric chloride, 12 ml distilled water followed by 10 ml of TPTZ. The TPTZ solution was added drop-wise giving a straw coloured working FRAP solution. Any traces of a blue colour were suggestive of contamination with a reducing compound indicating the need to

discard the solution. The working FRAP solution was then kept in a water bath at 37°C.

After preparation of all the solutions the ferric-reducing capacity of plasma was measured. This was done by adding the 6 µl of standard or diluted sample to a 96-well microplate, followed by 200 µl sample of FRAP reagent. The plate was left to incubate in an oven at 37°C for 4 minutes and absorbance was then read at 600 nm using a Dynex Technologies MRX microplate reader (Dynex Technologies Ltd, Worthing, UK). Results were expressed in mmol Fe<sup>2+</sup> per litre. To determine FRAP the amount of Fe<sup>2+</sup> produced was calculated using the following calculation:

$$[\text{FRAP}] = p [\text{Abs sample} - b] / m$$

where p = dilution factor of original sample, Abs sample = abs at 600 nm, b = intercept from standard curve and m = slope from standard curve).

### **2.6.2 Measuring levels of inflammation**

Analysis of hsCRP was undertaken at the Royal Infirmary Edinburgh (RIE). Samples were removed from the -80°C freezer at QMU and placed into ice which was held in a polystyrene box to ensure the samples remained frozen. The samples were then immediately transported to RIE and stored again at -80°C at the RIE until they were analysed. The process and equipment for this analysis is not known.

## **2.7 STATISTICAL ANALYSIS**

The power calculation for the multiple regression analyses, has been calculated on a sample size of 200 participants, allowing for 25% attrition (through illness, non attendance, non functionality of equipment etc.). This would provide a sample of 150 to undertake the analysis. With 3 - 5 predictors in the model studying main effects at 80% power, and a two-sided significance level of 0.05, an effect size of

0.11 to 0.13 could be estimated. With these parameters a 95% confidence interval around  $R^2$  of approximately 0.01 to 0.2, would be achieved (Soper, 2006)

Descriptive statistics were used to describe the characteristics of the population. Means and standard deviations were used to describe the parametric data (i.e. markers of nutritional status, functional status, dietary intake and levels of habitual activity). Medians and interquartile ranges (IQR) were used to describe the non parametric data (antioxidant status and levels of fatigue). A Shapiro-Wilk test was performed to assess for normality of distribution of the data and to inform statistical comparisons.

Independent samples t-Tests or Mann Whitney  $U$  test were used to examine differences between the female and male participants as appropriate and one sample t-Tests were used to examine differences between normative data and the study population. A one-way ANOVA in conjunction with an intraclass correlation analysis (ICC) was used to determine the technical error of measurement (TEM) for upper arm anthropometry. In addition an ICC was used to assess the reliability of the measurements of habitual activity.

Two tailed Pearson's correlation coefficient analysis was used to determine associations between habitual activity and nutritional status, functional status, and dietary intake. Spearman's Rho correlation analysis was used to determine relationships between levels of habitual activity and non-parametric data (antioxidant status and levels of fatigue). Partial correlation analysis was used to control statistically significant relationships for age and gender.



Statistical analysis was performed using the statistical package for social sciences (SPSS versions 17.0 and 19.0). Results with  $p < .05$  were considered statistically significant.

## **CHAPTER 3: RESULTS**

The purpose of this study was to determine the relationship of levels of habitual activity including sedentary behaviour with nutritional status, functional ability, dietary intake, inflammation and fatigue in older adults. Additionally the study aimed to inform physical activity targets for the ageing population to optimise functional status. The results described below will therefore describe the study population in terms of the demographics, nutritional status and body composition. Body composition measurements were compared to normative values as appropriate and where available. The functional status of the study population is also described and compared to normative values for an older adult population. Habitual activity levels of the study population are presented in terms of mean daily time spent sitting or lying (min), mean daily time spent standing (min) and mean daily time spent stepping (min) along with the mean daily number of steps. In addition the mean daily time participants spent in moderate intensity activity (min) and sedentary behaviour (min) plus the percent time spent in sedentary behaviour are presented. The results of the questionnaire assessing levels of fatigue will also be described and these results will be compared to population norms. Finally the association of levels of habitual activity with nutritional status functional status, dietary intakes, levels of inflammation and levels of fatigue has been established and is reported.

### **3.1 RECRUITMENT**

Participants were recruited from a range of social settings within Lothian including churches, social clubs, lunch clubs, bowling clubs, golf clubs and voluntary organisations. Social settings were targeted in an attempt to recruit a representative sample of older adults in terms of activity levels, dietary intake and nutritional status. Potential recruitment sites in East Lothian, Midlothian and the City of Edinburgh

were established by a search of the yellow pages, an internet search and local knowledge and a range of potential recruitments sites was identified as previously discussed (section 2.1.1). The types of recruitment sites are shown in table 3.1 along with the number of venues contacted by email and letter.

**Table 3.1 Potential recruitment sites**

<b>Setting</b>	<b>Number of Sites contacted</b>
Churches	63
Bingo halls	4
Bowling clubs	26
Golf clubs	17
Lunch clubs	24
Leisure centres	9
Probus Clubs	1
Community Halls	4
Race course	1
Older peoples forum	1
Libraries	3
Private Gyms/health clubs	8
Walking groups	4
Community groups	4
Healthy Ageing Groups	2 main contacts for all groups
University of Third Age	3 branches
Local shops	16
WRVS	1 main contact for WRVS across Lothian

Due to the nature of the recruitment strategy the potential size of the study population is not known and the total number of posters and leaflets displayed and distributed is also not known. It is however anticipated that a wide sector of the older adult population across Lothian could potentially have seen the advertising literature for the study.

Despite the wide range of potential recruitment sites and the extensive advertising opportunities, only 44 people volunteered to take part in the study. Following screening using the MMSE (Folstein et al., 1975) and discussion of the inclusion and exclusion criteria it was established that all volunteers met the inclusion criteria for the study and these volunteers were subsequently recruited to take part. All of the 44 participants completed the study.

### 3.2 PARTICIPANT DEMOGRAPHICS

Participants were recruited from a variety of geographical areas across the Lothians and the study sample consisted of 21 male and 23 female participants with a mean±sd age of 72.8±5.5 years. To determine whether the participants were representative of the Scottish population they were categorised by the postcode of their residence and level of deprivation was determined using the Scottish Index of Multiple Deprivation (SIMD) (The Scottish Government 2012). The SIMD is the Scottish Government's official tool for identifying those places in Scotland suffering from deprivation. It incorporates several different aspects of deprivation, combining them into a single index. It divides Scotland into 6,505 small areas, called datazones, each containing around 350 households. The Index provides a relative ranking for each datazone, from 1 (most deprived) to 6,505 (least deprived). For this study the datazones have been categorised by quintiles with quintile 1 indicating highest levels of deprivation and quintile 5 indicating lowest levels of deprivation. The results for the study population are shown in table 3.2

Table 3.2: Levels of deprivation of study participants categorised by SIMD

Quintile	All n=44	Males n=21	Females n=23
1 (data zones 1 – 1301)	3/44 (7%)	3/21 (14%)	0/23 (0%)
2 (datazones 1302 – 2602)	1/44 (2%)	0/21 (0%)	1/23 (4%)
3 (datazones 2603 – 3903)	9/44 (20%)	2/21 (10%)	7/23 (30%)
4 (datazones 3904 – 5204)	19/44 (43%)	12/21 (57%)	7/23 (30%)
5 (datazones 5205 – 6505)	12/44 (27%)	4/21 (19%)	8/23 (35%)

In addition to level of deprivation health status was also established. At the initial interview participants were asked to report any relevant current or previous medical conditions which may influence the results of the study i.e. conditions which would impact on habitual activity levels and dietary intakes. Of the 44 participants, 18 (41%) reported no co-morbidities (12 women (53%), 6 men (29%)). A variety of other conditions were reported by the remaining participants (table 3.3) some of who

reported more than one co-morbidity. Four participants (3m, 1f) reported having type 2 diabetes (T2DM) all of these participants were taking anti-hypertensive medications. In addition a further two female participants reported either having been diagnosed with hypertension or to take ant-hypertensive medication. The female participant with T2DM also reported increased cholesterol levels and one of the male participants with T2DM reported having angina. All participants reported that they did not perceive that these conditions influenced the amount of physical activity they participated in on a daily basis.

**Table 3.3 Relevant current and past medical history of participants**

Disorder	Number of participants		Comment
	men	women	
Type 2 Diabetes	3	1	The female participant also reported HT and hypercholesterolaemia
CVD			
Coronary artery bypass graft	1		
Arterial fibrillation		1	
Angina	1		Single episode
Arrhythmia	1		Also reported HT and T2DM
Hypercholesterolaemia		1	One female participant also reported T2DM and hypercholesterolaemia
Hypertension	3	3	
surgery			
Total mastectomy		1	
Partial colectomy	1		
Respiratory disorders			
asthma	2		
Bone health			
osteoarthritis	3	3	
osteoporosis		1	
Knee replacements	3	1	7 knee replacements between these participants
Hip replacements	2	1	5 hip replacements between these participants
spondylitis		1	
Gastro-intestinal Disorders			
Hiatus hernia	1	1	
Oesophageal dilatation		1	
Other			
Polymyalgia rheumatic	1		
Trigeminal Neuralgia	1		

Prior to undertaking the statistical analysis a Shapiro-Wilk test was performed to assess for normality of distribution of the data and to inform statistical comparisons (Field, 2009). This determined that for the entire study population body mass index

(BMI) ( $\text{kg}/\text{m}^2$ ), handgrip dynamometry (HGD) (kg), sit to stand (STS) (s), six minute walk (6MW) (m) and high sensitivity C-reactive protein (hsCRP) (mg/L) were not normally distributed. In the male participants HGD (kg), STS (s) and mean daily time stepping (min) were not normally distributed whilst in the female group waist circumference (WC) (cm) and STS (s) were not normally distributed. Appropriate non-parametric analysis was therefore performed with these parameters i.e. data are described using medians and IQR and when comparing men and women Mann Whitney *U* test was performed

### 3.3 NUTRITIONAL STATUS OF PARTICIPANTS

Participant demographics and nutritional status are shown in table 3.4. Height was not recorded for one male participant and WC was not recorded for two female participants due to omissions by the researcher. Blood pressure was not measured for one male and three female participants due to the equipment not working.

**Table 3.4 Participant characteristics and nutritional status with comparison between genders**

	All		Males		Females		p
	n	Mean±sd	n	mean±sd	n	Mean±sd	
Age (years)	44	72.8 ± 5.5	21	72.2 ± 5.6	23	73.3 ± 5.5	.524
Weight (kg)	44	75.5 ± 12.8	21	83.7 ± 9.8	23	68 ± 10.5	<.001
Height (m)	43	1.68 ± 0.1	21	1.75 ± 0.1	22	1.61 ± 0.6	<.001
BMI ( $\text{kg}/\text{m}^2$ )	43	26.8 ± 2.8	21	27.4 ± 2.4	22	26.2 ± 3.0	.83
WC (cm)	42	93.6 ± 12.4	21	100.9 ± 9.4	21	86.4 ± 10.9	<.001
MUAC (cm)	44	29.7 ± 2.5	21	30.1 ± 4.0	23	29.4 ± 0.4	.365
TSF (mm)	44	16 ± 6.1	21	12 ± 3.8	23	20 ± 5.0	<.001
MAMC (cm)	44	24.6 ± 2.9	21	26.3 ± 2.8	23	23 ± 1.9	<.001
Systolic BP	40	135 ± 14.1	20	135 ± 13.1	20	135 ± 14.8	.609
Diastolic BP	40	83 ± 6.6	20	81 ± 7.4	20	83 ± 6.3	.822

As BMI was not normally distributed for the whole study population and WC for the women was not normally distributed this data are also described as medians and IQR to better describe the data and these results are shown in table 3.5.

**Table 3.5 Median and interquartile ranges for parameters found to be not normally distributed with comparison between genders**

	All n=43 median (IQR)	Males n=21 median(IQR)	n	Females median (IQR)	p
BMI (kg/m <sup>2</sup> )	26.2 (24.5,28.4)	26.5 (25.8,29.1)	22	25.7 (23.7,27.7)	.448
WC (cm)	91.8 (81.7,104.8)	98.5 (91.8,108.8)	21	81.8 (79.2,91.3)	.002

The mean±sd age of the group confirms that an older adult population have been recruited and as such the results obtained are indicative of the older adult population. The mean±sd BMI of the group was 26.8±2.8 kg/m<sup>2</sup> indicating that the group were of good nutritional status and from this crude measure, would be considered normally nourished for an older adult population.

The results were analysed for the whole study population and also by gender with differences between genders established using an independent t-Test for all parameters. There were no significant differences in age (p=.524), BMI (p=.83), mid upper arm circumference (MUAC) (p=.365), Systolic Blood Pressure (SBP) (p=.609) and Diastolic Blood Pressure (DBP) (p=.822) between the male and the female participants. The male participants however had a statistically significantly higher weight (83.7±9.8 kg vs 73.3±5.5 kg, p<.001), height (1.75±0.1 vs 1.61±0.6 m, p<0.001), WC (100.9±9.4 vs 86.4±10.9 cm, p<.001), and mid arm muscle circumference (MAMC) (26.3±2.8 vs 23±1.9 cm, p<.001) and a statistically significantly lower tricep skinfold thickness (TSF) (11.8±3.8 vs 20.1±5.0 mm, p<.001) compared with the female participants. As BMI in all participants and WC for the female participants were not normally distributed differences between the male and female study populations was established using a Mann-Whitney *U* test. There was no statistically significant difference in BMI (p=.448) when comparing median values, however as expected the male participants had a statistically significantly higher median (IQR) WC (98.5 (91.8 - 108.8) vs 81.8 (79.2 - 91.3) cm, p=.002) compared to the female participants.

BMI is a crude marker of nutritional status and is frequently used to categorise a person's weight relative to their height which in turn can give an indication of overall nutritional status in terms of undernutrition, normal nutrition and overnutrition. Therefore in order to determine the nutritional status of the study population in terms of both nutritional status and nutritional risk (for both over and undernutrition) participants were categorised by BMI status. Traditional cut-offs for BMI are unlikely to be appropriate in an older adult population due to significant changes in body composition as a result of ageing (section 1.2). Despite this being the case, traditional cut-offs as reported by WHO (2006) are regularly referred to for the older adult population and so the study population have been categorised using these cut-offs. To provide a more comprehensive comparison the study population have also been compared to the cut-offs more appropriate for older adults (Beck & Ovesen, 1998). The results of both comparisons are shown table 3.6.

**Table 3.6 Participants categorised by BMI using traditional and older adults cut-offs**

	Under weight		Normal weight		Overweight and obese	
	Traditional BMI cut -off <18.5 kg/m <sup>2</sup>	Older adult BMI cut-off <24 kg/m <sup>2</sup>	Traditional BMI cut -off 18.5-24.9 kg/m <sup>2</sup>	Older adult BMI cut-off 24-29 kg/m <sup>2</sup>	Traditional BMI cut -off 25+ kg/m <sup>2</sup>	Older adult BMI cut-off 29+ kg/m <sup>2</sup>
All	0/43 (0%)	5/43 (12%)	12/43 (28%)	30/43 (70%)	31/43 (72%)	8/43(19%)
Male	0/21 (0%)	0/21 (0%)	3/21 (14%)	16/21 (76%)	18/21 (86%)	5/21 (24%)
Female	0/22 (0%)	5/22(22%)	9/22 (41%)	14/22 (64%)	13/22 59%)	3/22 (14%)

When considering BMI cut-offs for older adults (Beck & Ovesen, 1998) fewer participants were categorised as overweight or obese compared to proportions when with using traditional cut-offs. Within the female study population 5/21 (24%) participants were considered to have low BMI potentially indicating nutritional risk. BMI in isolation lacks detail in terms of determining a person's CVD risk. In view of this the participants were also categorised by WC to determine CVD risk (NICE, 2006). The results are shown in table 3.7.



**Table 3.7 Participants categorised by cardiovascular risk using waist circumference**

	no risk ≤94 cm men ≤80 cm women	increased risk 94-102 cm men 80 - 88 cm women	substantially increased risk >102 cm men >88 cm women
Males	6/21 (29%)	8/21 (38%)	7/21 (33%)
Females	7/21 (33%)	7/21 (33%)	7/21 (33%)

### 3.4 RELIABILITY OF UPPER ARM ANTHROPOMETRY MEASUREMENTS

There is an acknowledgement that potential intra-observer error exists when measuring the circumference and skinfolds of the upper arm (Ellis, 2001). It is however possible to determine what, if any, error exists when undertaking these measurements by calculating the technical error of measurement (TEM) (Ulijaszek & Kerr, 1999). This provides an objective measure of the error associated with a single observer or across a number of observers. When measuring the TEM of a single observer (i.e. the intra-observer error), the same observer performs repeated measurements on a number of subjects. The population of interest should be acknowledged and as such the TEM should be calculated from measurements taken from subjects similar to that of the test population. The required number of subjects to establish the TEM is normally not less than 20 (Norton & Olds, 1999 pp. 82). In view of this and to ensure the measurements were reliable for older adults, the TEM for this study was calculated from measurements taken from the study population.

The study design required MUAC to be measured only once but to enable the TEM to be calculated, the first 10 men and first 10 women to be recruited to the study had MUAC measured twice on the first study visit. The mid point of the upper arm was marked separately for each of these measurements. As part of the study protocol TSF was measured twice on all subjects with the mean result being used and so measuring for the TEM did not veer from this. Following two measurements of

MUAC and TSF, the TEM was then calculated. This is done by initially calculating a one-way ANOVA to determine the mean error square and this then enabled the TEM to be calculated by using the equation:

$$\text{TEM} = \sqrt{\text{MSe}} \text{ (where MSe is the mean error square) (Ulijaszek \& Kerr, 1999).}$$

The TEM is reported as an absolute value and the percentage error is also calculated. In addition an intra-class correlation (ICC) is also calculated to establish the correlation between successive measurements on the same subject (Norton & Olds, 1999, chapter 13).

The TEM of the researcher for MUAC measurements was calculated to be 0.1 cm (0.36%) and the TEM for the TSF measurement was calculated to be 0.17 mm (1.1%). The ICC was calculated using a two factor random effects model and type consistency  $\text{ICC}_{(3,2)}$  (McGraw and Wong, 1996; Shrout & Fleiss, 1979). The  $\text{ICC}_{(3,2)}$  for the MUAC was 0.999 and for the TSF was 1.0. These calculated TEMs are well within normal accepted levels (Norton & Olds, 1999, chapter 13) and the ICC shows excellent reliability between measurements (Kang et al., 2009). The TEM and ICC therefore together indicate that the anthropometric measurements within this study are a true reflection of the participant's FM and FFM.

### **3.5 FUNCTIONAL STATUS**

Functional status of the participants was measured using HGD, STS and 6MW. The results of these functional tests are shown in table 3.8. As HGD, STS and 6MW are not normally distributed for the whole sample and HGD and STS are not normally distributed for the male participants, these results are shown as median (IQR). Differences between the male and female participants were established using a Mann-Whitney *U* test.

**Table 3.8 Functional status of participants with comparison between genders**

	All n=44 Median (IQR)	Males n=21 Median (IQR)	Females n=23 Median (IQR)	p
HGD (kg)	26.5 (20,38)	38 (33.5,44.5)	20 (17.8,24)	<.001
STS (s)	12.6 (11.1,16.8)	12.4 (11.2,17.4)	13.3 (11,15.4)	.546
6MW (m)	463 (355,550)	436 (319,557)	477 (360,547)	.357

There was no significant difference found between the male and female participants for STS ( $p=.546$ ) and 6MW ( $p=.357$ ) tests however the male participants had a significantly higher median (IQR) HGD (38 (33.5,44.5) vs 20 (17.8,24) kg,  $p<.001$ ) compared to the female participants.

### 3.5.1 Handgrip Dynamometry

As HGD is a measure of strength and is associated with function it has particular value in an older adult population. Bohannon et al., (2006) has therefore reviewed the literature surrounding HGD in adults in an attempt to provide normative data to enable comparison of individuals. A meta-analysis of grip strength measurements consolidated the available data and as a result consolidated grip strength values for the adult population have been produced. These are reported as means and 95% CI and are gender specific due to established differences in grip strength between men and women. Normative values for different age categories of adults are provided with three age ranges for older adults (i.e. 65 - 69, 70 - 74 and 75 years and older) and these are shown in table 3.9.

**Table 3.9 Consolidated grip strength values for males and females (adapted from Bohannon et al., 2006)**

Age range	Males		Females	
	Left (kg) mean (95% CI)	Right (kg) mean (95% CI)	Left (kg) mean (95% CI)	Right (kg) mean (95% CI)
65-69	38.2 (32.0,44.4)	41.7 (35.4,47.9)	22.9 (19.6,26.2)	25.6 (22.5,28.8)
70-74	36.2 (30.3,42.1)	38.2 (32.0,44.5)	22.5 (19.1,25.8)	24.2 (20.7,27.8)
75+	29.8 (24.8,34.7)	28.0 (12.7,31.0)	16.4 (14.7,18.1)	18.0 (16.0,19.9)

These normative values can be used to indicate nutritional risk within an individual and it suggested that the lower limit of the 95% CI can serve as a reasonable

threshold for determining impaired muscle function (Bohannon et al., 2006). The grip strength of the participants relative to normative values is shown in table 3.10.

**Table 3.10 HGD measurements of the participants compared to normative data (Bohannon et al., 2006)**

	<b>Males (n=21)</b>	<b>Females (n=23)</b>
HGD < lower 95% CI	1/21 (5%)	5/23 (22%)
HGD within 95% CI	10/21 (48%)	10/23 (43%)
HGD > upper 95% CI	10/21 (48%)	8/23 (35%)

Of the male participants 1/21 (5%) and of the female participants 5/23 (22%) are considered at nutritional risk based on handgrip measurements alone.

### 3.5.2 Sit to Stand

A further measure of function is the sit to stand (STS) test and normative data are also available to allow comparison. Normative data takes into consideration changes in STS performance with ageing and as a result normative values are available for 60 - 69 year olds and for 70 - 79 year olds although not for people aged 80 years and over (Bohannon, 2006). As there is no difference in normative values based on gender, the results of the STS for the study sample were compared to this normative data based on age only. The results of this comparison are shown in table 3.11.

**Table 3.11 STS measurements of the participants compared to normative data (Bohannon, 2006)**

<b>age band</b>	<b>n</b>	<b>STS norm (s) (Bohannon 2006)</b>	<b>STS (s) mean±sd</b>	<b>p</b>
60-69 years	15	11.4	12.4±3.9	.333
70-79 year	24	12.6	15.3±5.8	.033

Differences between STS performance times for the study population and normative values were established using a one-sample t-Test. There was no statistically significant difference found between the 60 - 69 year old participants in the study sample and the expected norms for this population (p=.333), however the 70 - 79

year study population had a statistically significantly higher mean±sd STS time than the normative values (15.3±5.8 vs 12.6 s, p=.033).

### 3.5.3 Six minute walk

In addition to HGD and STS the distance walked during the 6MW test was also measured in the study sample to provide additional information about functional status. Normative values for the 6MW test are available for comparison (Steffen et al., 2002). As there are established gender differences in performance in the 6MW test, normative values are provided based on this. In addition the distance walked within the 6MW tends to decrease with age and so normative values also take this into consideration. All 44 participants completed the 6MW test without taking a break or having a rest during the test. The performance of the study population during the 6MW test is shown in table 3.12. This has been compared to normative values using a one-sample t-Test and the results for this comparison are also shown in table 3.12.

**Table 3.12 6MW measurements of the participants compared to normative data (Steffen et al., 2002)**

age band	gender	n	6MW norm (m) (Steffen et al., 2002)	Study population mean±sd 6MW (m)	p
60 - 69 years	male	8	572	483±100	.039
	female	7	538	543±43	.739
70 - 79 years	male	11	471	421±122	.205
	female	13	417	454±99	.205

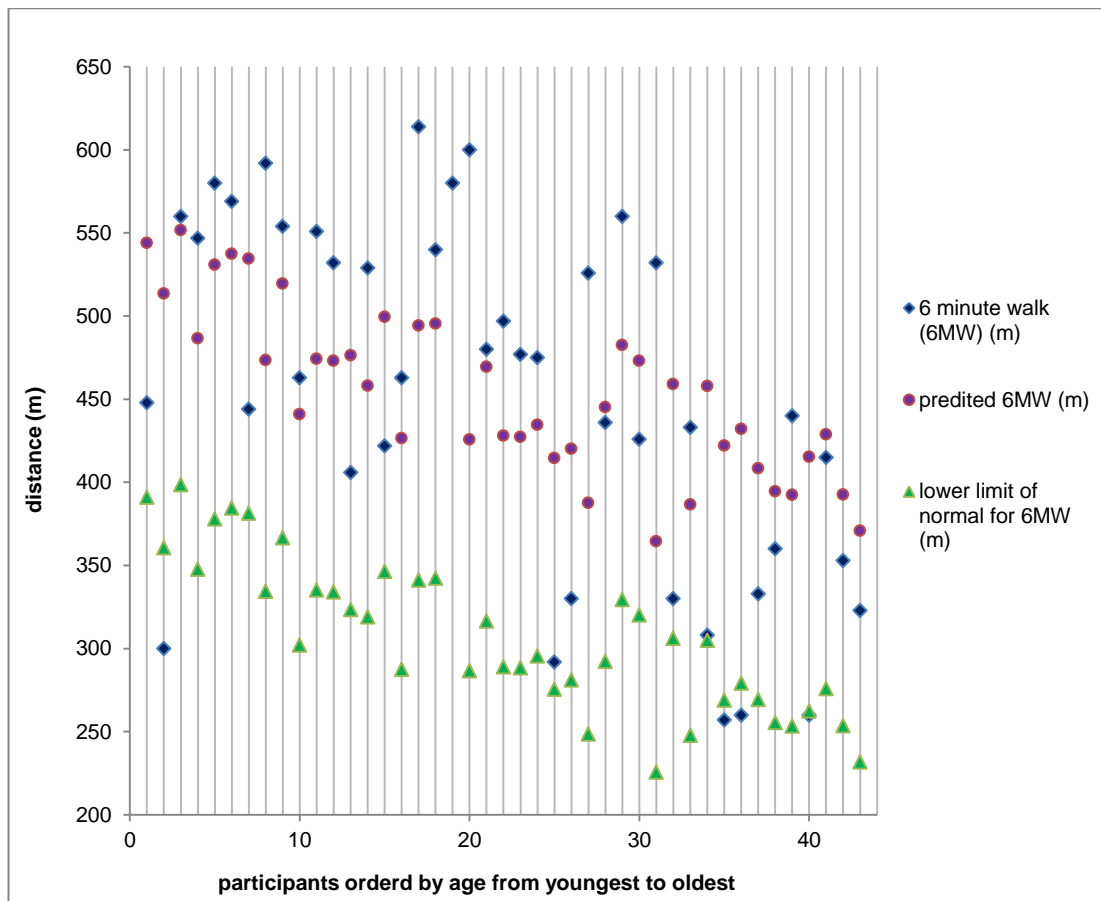
The 60 - 69 year old male participants walked a statistically significantly shorter distance than would be expected based on normative values walking a mean±sd distance of 483±100 m vs 572 m (p=.039). However there was no statistically significant difference in the expected distance walked by the 70 - 79 year old men compared to normative values (p=.739). There was no statistically significant difference between the distance walked by either the 60 - 69 year old women or the 70 - 79 year old women and normative values (p=.739, p=.205 respectively).

Normative values for the 6MW test have been published (Steffen et al., 2002) but in addition to these values Enright & Sherrill (1998) have suggested that it is possible to predict the distance a person will walk within the 6MW test based on their age (y) and BMI (kg/m<sup>2</sup>). Based on this work they have published prediction equations which are shown in table 3.13. As part of these regression equations, lower limits of normal performance have also been published which provide information about the shortest distance a person would be expected to walk within the 6MW test. These lower limits of normal are also based on age (y) and BMI (kg/m<sup>2</sup>) and are also shown in table 3.13.

**Table 3.13 Reference equations for 6MW distance in healthy adults (Enright & Sherrill, 1998)**

<b>Gender</b>	<b>Prediction equation to estimate distance walked in 6MW test</b>
Male:	6MW = 1140 m - (5.61 x BMI) - (6.94 x age (y)) Subtract 153 m for the Lower Limit of Normal
Female	6MW = 1017 m - (6.24 x BMI) - (5.83 x age (y)) Subtract 139 m for the Lower Limit of Normal

The predicted distances walked within the 6MW test have been calculated for each participant along with the lower limit of normal for that individual and the results are shown in figure 3.1. As one female participant did not have their height measured and thus their BMI calculated these calculations have not been possible for that participant.



**Figure 3.1 Six minute walk performance, predicted 6 minute walk and the lower limit of normal for 6MW performance (Enright & Sherrill, 1998) (n=43)**

Nineteen participants (12 males, 7 females) walked a shorter distance than predicted using prediction equations and four male participants and no female participants walked a shorter distance than the lower limit of normal for people of their age, gender and BMI status (Enright & Sherril, 1998).

### 3.5.4 Gait speed

The 6MW test is a measure of functional ability however in terms of diagnosis of sarcopenia, gait speed is utilised as initial diagnostic criterion and so the mean±sd gait speed of the participants was also calculated. The study population had a mean±sd gait speed of 1.26±0.3 m/s. When analysed by gender the male participants had a mean±sd gait speed of 1.21±0.32 m/s and the female participants

had a mean $\pm$ sd gait speed of 1.31 $\pm$ 0.27 m/s. There was no statistically significant difference in gait speed between the male and female participants.

In terms of considering gait speed in the context of sarcopenia, a gait speed of <0.8 m/s is an initial indication of poor functional ability and the participants were compared to this. Of the male participants 3/21 (14%) had a gait speed of <0.8 m/s giving an initial indication of sarcopenia but none of the 23 female participants fell below this threshold.

In addition to measuring nutritional and functional status, dietary intake was measured as there is a clear relationship between dietary intake and nutritional status with a positive energy balance causing weight gain and a negative energy balance causing weight loss. In addition diet and in particular protein has a role to play in a person's functional status.

### **3.6 DIETARY INTAKES**

Dietary intake was measured for seven consecutive days using a seven day unweighed diet diary. As macronutrient intake has an impact on nutritional and functional status, mean $\pm$ sd daily macronutrient was calculated as absolute values and as a percentage of total energy intake using Windiets computer dietary analysis package (Univation Ltd 2005.). Furthermore as higher intakes of vitamin C have been shown to be associated with greater muscle strength in older adults (Cesari et al., 2004) and vitamin D intakes have been shown to influence functional status in older adults (Houston et al., 2007) the mean $\pm$ sd daily intakes of these nutrients were also calculated using Windiets. Due to the inextricable link between vitamin D and calcium (Van der Velde et al, 2014) and the fact that iron is frequently found to be deficient in older adults (Fairweather-Tait et al., 2014) the dietary intakes of these



nutrients have also been calculated. Differences in dietary intakes between the male and female participants were established using an Independent t-Test. The results of the dietary analysis are shown in table 3.14.

**Table 3.14 Mean±sd daily dietary intakes measured by 7 day unweighed diet diary with comparison between genders**

<b>diet</b>	<b>All n=44 Mean±sd</b>	<b>Males n=21 Mean±sd</b>	<b>Females n=23 Mean±sd</b>	<b>p</b>
energy intake (kJ)	7620± 529	8512±1499	6805±1037	<.001
energy intake (kcal)	1813±365	2026±357	1619±246	<.001
% energy from fat	34.7±4.1	35.3±3.7	34.2±4.5	.352
% energy from SFA	13.1±2.9	13.5±2.7	12.7±3.1	.348
% energy from PUFA	5.5±1.5	5.5±1.5	5.6±1.5	.654
% energy from MUFA	11±1.7	11.4±1.4	10.5±1.9	.083
% energy from protein	16.4±3.4	16.1±2.2	16.8±4.2	.533
protein intake (g)	73±16.7	79±12.1	67±18.6	.021
protein intake g/kgBW	0.98±0.28	0.95±0.16	1.0±0.36	.439
% energy from carbohydrate	46±5.3	45.5±4.7	46.5±5.8	.539
% energy from sugar	20.1±5.4	19.2±5.7	21±5.1	.267
% energy from NMES	13.4±4.8	13.5±5.0	13.2±4.7	.822
% energy from alcohol	2.6±2.8	2.9±3.3	2.3±2.3	.460
NSP (g)	14±4.7	15±4.4	14±4.8	.193
vitamin D (µg)	3±1.5	3±1.5	3±1.6	.675
vitamin C (mg)	103±42.5	102±44.1	104±42	.901
Calcium (mmol)	832 ± 256	856 ± 205	811 ± 331	.596
Iron	12.6 ± 4.6	13.3 ± 4	11.9 ± 5.1	.304

With the exception of energy and protein where men had statistically significantly higher mean±sd intakes than women (2026±357 vs 1619±246 kcal p<.001) and 79±12.1 vs 67±18.6 g protein (p=.021)) there were no statistically significant differences in dietary intakes when comparing the male participants to the females.

Dietary intakes of the participants were compared to Dietary Reference Values (DRV) for the UK population (DoH, 1991). The reference nutrient intake (RNI) was used for comparison for micronutrients (vitamin C, vitamin D, calcium and iron) as this is the level of intake required to prevent deficiencies in 97% of the population. The results of this analysis are shown in table 3.15.

**Table 3.15 Comparison of dietary intakes of study population to Dietary Reference Values for the UK population (DoH, 1991)**

Recommended intakes		All		Males		Females	
		n=44	p	n=21	p	n=23	p
		Mean±sd		Mean±sd		Mean±sd	
% energy from fat	35%	34.7±4.1	.674	35.3±3.7	.670	34.2±4.5	.388
% energy from SFA	11%	13.1±2.9	<.001	13.5±2.7	<.001	12.7±3.1	.17
% energy from PUFA	6.5%	5.5±1.5	<.001	5.4±1.5	.003	5.6±1.5	.011
% energy from MUFA	13%	11±1.7	<.001	11.4±1.4	<.001	10.5±1.9	<.001
% energy from CHO	50%	46±5.3	<.001	45.5±4.7	<.001	46.5±5.8	.008
% energy from NMES	11%	13.4±4.8	.002	13.6±5	.033	13.2±4.7	.036
NSP (g)	18	14.4±4.7	<.001	15.4±4.4	.014	13.5±4.8	<.001
% energy from alcohol	5%	2.6±2.8	<.001	2.9±3.3	<.001	2.3±2.3	<.001
Vitamin D (µg)	10	3±1.5	<.001	3±1.5	<.001	3±1.6	<.001
Vitamin C (mg)	40	103±43	<.001	102±44	<.001	104±42	<.001
Calcium (mmol)	700	832 ± 256	.003	856 ± 205	.002	811 ± 331	.012
Iron (mg)	8.7	12.6 ± 4.6	<.001	13.3 ± 4	<.001	11.9 ± 5.1	.007

Some positive results were found when comparing dietary intakes to current recommendations with the study population meeting current UK guidance for total fat intakes as there was no statistically significant difference found between the mean intake of fat as a percentage of energy and recommended intakes of no more than 35% energy from fat ( $p=.674$ ). This was also the case when the group was analysed by gender (men  $p=.670$ , women  $p=.388$ ). The study population as a whole and when analysed by gender also met current UK guidance for percentage energy from alcohol having statistically significantly lower mean±sd intakes compared to recommendations of not more than 5% of energy intake from alcohol (all  $p<.001$ , men  $p<.001$ , women  $p<.001$ ). Recommended vitamin C intakes were also met by the group as a whole and when analysed by gender with mean±sd vitamin C intakes being statistically significantly higher than the RNI of 40 mg/day for the population (all  $p<.001$ , men  $p<.001$ , women  $p<.001$ ). This was also the case for calcium intakes where the whole study population exceeded recommended calcium intakes of 700mmol/day ( $832 \pm 256$  mmol,  $p=.003$ ) as did the male participants ( $856 \pm 205$ ,  $p=.002$ ) and female participants ( $11.9 \pm 5.1$ ,  $p=.012$ ). In addition the whole study population consumed a mean ± sd iron intake of  $12.6 \pm 4.6$  mg/day which exceeded recommended intakes of 8.7 mg/day ( $p<.001$ ). This finding was consistent when the

study population was reviewed by gender with the male participants consuming  $13.3 \pm 4$  mg/day ( $p < .001$ ) and the female participants consuming  $11.9 \pm 5.1$  mg/day ( $p = .007$ ).

Although the overall fat intake of the study population was found to be within recommended levels the proportions of this from different types of fat showed poor diet quality in terms of CVD risk. The whole study population were found to have statistically significantly higher mean $\pm$ sd saturated fat (SFA) intake compared to the recommended intake of not more than 11% of energy from SFA (all  $13.1 \pm 2.9\%$  ( $p < .001$ )). This is attributable to the male participants who consumed significantly more SFA than recommended ( $13.51 \pm 2.7\%$  vs 11%, ( $p < .001$ )) whilst the SFA intake of the female participants although higher than recommendations was not statistically significantly different ( $12.7 \pm 3.1\%$  ( $p < .17$ )). In addition all participants consumed statistically significantly lower mean $\pm$ sd polyunsaturated fat (PUFA) intakes than the recommendation of at least 6.5% of energy from PUFA (all  $5.5 \pm 1.5\%$  ( $p < .001$ ), men  $5.4 \pm 1.5\%$  ( $p = .003$ ) all  $5.6 \pm 1.5\%$  ( $p = .011$ )). Furthermore they were found to have a statistically significant lower mean $\pm$ sd monounsaturated (MUFA) intake than recommendations of at least 13% of energy from MUFA (all  $11 \pm 1.7\%$  ( $p < .001$ ), men  $11.4 \pm 1.4\%$  ( $p < .001$ ), women  $10.5 \pm 1.9\%$  ( $p < .001$ )). This distribution of dietary fat intakes is indicative of a poor dietary fat profile and does not fall in line with current recommendations of following a more Mediterranean type diet which is rich in MUFA and low in saturated fat.

The profile of carbohydrate (CHO) intake was also found to be of concern as this too did not meet current guidance in terms of a healthy diet. Mean $\pm$ sd CHO intakes were found to be statistically significantly lower than current recommendations of at least 50% of energy from CHO (all  $46 \pm 5.3\%$  ( $p < .001$ ), men  $45.5 \pm 4.7\%$  ( $p < .001$ ),

women  $46.5 \pm 5.8\%$  ( $p=.008$ )). In addition to this intakes of refined CHO in the form of non-milk extrinsic sugar (NMES) was found to exceed current recommendations of not more than 11% of energy coming from this source of CHO with statistically significantly higher intakes found across the study population (all  $13.4 \pm 4.8\%$  ( $p=.002$ ), men  $13.6 \pm 6\%$  ( $p=.033$ ), women  $13.2 \pm 4.7\%$  ( $p=.035$ )). Conversely the mean  $\pm$ sd non-starch polysaccharide (NSP) intakes of the group were found to be statistically significantly lower than current recommendations of at least 18 g/day ( $14.4 \pm 4.7$  g ( $p<.001$ ), men  $15.4 \pm 4.4$  g ( $p=.014$ ), women  $13.5 \pm 4.8$  g ( $p<.001$ )). Again these results relating to CHO intake are reflective of a poor quality diet and are not in line with current guidance to follow a more Mediterranean style diet rich in NSP.

Perhaps not surprisingly due vitamin D requirements being met primarily through synthesis by sunlight, the mean  $\pm$ sd dietary intake of vitamin D was found to be statistically significantly lower than the current recommendation of 10  $\mu$ g/day (all  $3 \pm 1.5$   $\mu$ g ( $p<.001$ ), men  $3 \pm 1.5$   $\mu$ g ( $p<.001$ ) women  $3 \pm 1.6$   $\mu$ g ( $p<.001$ )). It is impossible to determine the potential for vitamin D synthesis through sunlight as this was not measured within this study however none of the participants within the study group reported taking a vitamin D supplement. This is out with current recommendations that all people aged 65 years and over should take a vitamin D supplement of 10  $\mu$ g/day to enable them to meet the DRV for vitamin D. Overall the results found in relation to dietary intake are indicative of a relatively poor quality dietary intake.

To provide an indication of accuracy of dietary reporting, resting energy expenditure was measured using a Fitmate Calorimeter (Cosmed Company, Rome). This alongside the measured PAL factor from the *activPAL*<sup>TM</sup> had the potential to determine total energy expenditure which when compared to estimated energy

intakes from the diet diaries could identify any under-reporting of dietary intakes which is known to be a common problem when using a with diet diary (Stubbs et al., 2014). Good practice guidance along with the required condition for measuring resting energy expenditure was followed (Compher et al., 2006; Levine 2005). Meeting the required conditions i.e. that subject should be completely rested (before and during measurements), lying down but fully awake, fasted for at least 10 – 12 hours, in a thermo-neutral environment (22 – 26°) and free from emotional stress proved difficult in this population. Despite giving participants explicit instructions about being fasted and rested, many participants had undertaken some form of early morning activity (walking or swimming) or had eaten breakfast. Both of these would have increased metabolic rates and thus influenced REE measurements and as such the measurements were deemed by the researcher to be inaccurate and could not be used with any degree of confidence. In view of that these results are not reported.

It is however possible to estimate energy expenditure using prediction equations and a measured PAL factor. The Scientific Advisory Committee for Nutrition (SACN) suggest that equations published by Henry (2005) are the most accurate for the UK population (SACN, 2011) and so these in combination with the measured PAL factor from the *activPAL*<sup>TM</sup> were used to estimate total energy expenditure in the study population. The predicted energy expenditure using this methodology was compared to dietary intakes assessed from the diet diaries using a paired t-Test. The results of this analysis are shown in table 3.16.

**Table 3.16 Comparison between energy intake from diet diaries and predicted energy expenditure using Oxford equations (Henry, 2005) and measured PAL by *activPAL*<sup>TM</sup>**

	Mean $\pm$ sd energy intake (kcal) from diet diaries	Mean $\pm$ sd predicted total energy expenditure (kcal)	p
all	1813 $\pm$ 365	2010 $\pm$ 288	p<.001
male	2026 $\pm$ 357	2310 $\pm$ 221	p=.002
female	1619 $\pm$ 246	1928 $\pm$ 212	p<.001

As discussed previously (chapter 1.10.4) there is an association between functional status and both antioxidant status and levels of inflammatory markers. These are influenced by dietary intakes with antioxidant status reflecting in part dietary intakes of antioxidants (vitamins A, C and E and selenium) and low grade inflammation being associated with both under and over nutrition. In view of this antioxidant status was measured using FRAP (ferric reducing ability plasma) and levels of inflammation by measuring high sensitivity C-reactive protein (hsCRP) levels.

### **3.7 ANTIOXIDANT STATUS AND INFLAMMATORY MARKERS**

Blood samples were taken from the participants to measure antioxidant status using FRAP and to measure hsCRP to determine levels of inflammation. Two blood samples were taken from each participant (one collected in a tube containing lithium heparin (for hsCRP) and one in a tube containing Ethylenediaminetetraacetic acid (EDTA) (for FRAP analysis). Blood could not be collected from three male and three female participants due to poor venous access and so 18 males and 20 females had blood samples collected. The samples were centrifuged and the plasma removed. The plasma for each sample was then divided into two separate samples (section 2.6) and the samples were frozen in a -80<sup>o</sup> freezer in line with QMU procedures. When the researcher went to defrost the samples for analysis several samples were missing despite being appropriately labelled and stored correctly.

As a result only 12 samples were analysed for antioxidant status using FRAP (4 males and 8 females) and 12 samples were measured for hsCRP (5 males and 7 females). Whilst some of the blood samples which were analysed using FRAP and for hsCRP were for the same participants this is not the case for all samples. Due to the small remaining number of blood samples and thus smaller again numbers when the population was analysed by gender, results were analysed using non-parametric analysis (i.e. median, IQR and Mann-Whitney *U* test for comparisons). The results of this analysis are shown in table 3.17.

**Table 3.17 Median (IQR) plasma inflammatory markers and antioxidant status with comparison between genders**

	All n=12		Males		Females	
	Median (IQR)	n	Median (IQR)	n	Median (IQR)	p
FRAP $\mu\text{mol/L}$	1351 (999,1510)	4	1392 (1273,1446)	8	1299 (598,1585)	.808
hsCRP mg/L	1.55 (0.62,3.26)	5	2.25(0.40,2.88)	7	0.859 (0.70,4.45)	.639

The results in table 3.17 show that there was no statistically significant differences found between antioxidant status or levels of inflammatory markers (hsCRP) when comparing male participants with female participants (FRAP  $p=.808$ , hsCRP  $p=.639$ ). There are no normative data available for comparison of plasma FRAP levels and so establishing this comparison is not possible. Only one female participant had an elevated hsCRP which could indicate an inflammatory response, all other participants had a lower than normal hsCRP level. The hsCRP results found are indicative of a healthy population as no low grade inflammation was present. As activity levels influence inflammatory markers along with nutritional status and functional status (section 1.11 and 1.13) the habitual activity levels of the participants was also measured and the data analysed.

### 3.8 LEVELS OF HABITUAL ACTIVITY

Participants were asked to wear an *activPAL*<sup>TM</sup> accelerometer (PAL Technologies Ltd, Glasgow) continuously for seven consecutive 24 hour periods to measure habitual activity over one full week. The *activPAL*<sup>TM</sup> monitor was placed on the mid-point of the anterior thigh as per the manufacturer's guidance and secured between two 10 x 12 cm waterproof dressings (Tegaderm Film 3M) (figure 2.2). This enabled the monitor to be worn continuously for the required seven day recording period. Participants were permitted to shower when wearing the *activPAL*<sup>TM</sup> and so the only time the *activPAL*<sup>TM</sup> monitor was removed was if a participant had a bath or participated in underwater activities such as swimming. On these occasions the *activPAL*<sup>TM</sup> was removed for the duration of that activity and then replaced immediately after the participant had dried themselves. The data collected by the activity monitors are therefore a robust and true reflection of the habitual activity of the participant. In addition to the *activPAL*<sup>TM</sup> the participants also completed an activity diary to provide additional information regarding types of activities they engaged in. The activity diary required participants to record activities in 30 minute blocks and was completed for the same time period as the *activPAL*<sup>TM</sup> monitoring. The researcher utilised the activity diary to confirm agreement with the *activPAL*<sup>TM</sup> output and to establish time awake to enable sedentary behaviour to be assessed. The recording in the activity diary was assessed against the output from the *activPAL*<sup>TM</sup> to ensure that the participant appeared to be asleep. Where a participant went to bed to read or listen to the radio this was considered sedentary time. In addition to determining sleep time any activity which could not be recorded by the *activPAL*<sup>TM</sup> monitors were noted (i.e. upper body movement e.g. ironing, decorating and swimming) to establish if any the participant was engaging in activities which would be considered moderate intensity (i.e. MET > 3) which were



not recorded by the *activPAL*<sup>TM</sup> monitor and thus provide an indication of any potential under-reporting of activities. The activity diaries were also reviewed to establish if participants met the recommendation of participating in muscle-strengthening activities on 2 or more days a week (DoH, 2011).

Time spent sitting and lying (min), standing (min) and stepping (min), along with number of steps and intensity of activity (MET) were measured. In three participants (2 male, 1 female) only five consecutive 24 hour periods of activity were recorded as a result of the *activPALs*<sup>TM</sup> running out of battery power. As habitual activity is reported as mean $\pm$ sd daily time and as five consecutive 24 hour periods is considered reflective of habitual activity (Kang et al., 2009) the data for these participants are included in the results for habitual activity. The mean $\pm$ sd daily time (min) for each component of habitual activity (i.e. time spent sitting or lying, time spent standing, time spent stepping and number of steps) was calculated for the whole study population and for the male and the female participants separately. As the time spent stepping (min) for the male participants was not normally distributed the median and (IQR) were also calculated for this parameter. In addition the mean $\pm$ sd daily MET for the participants was also calculated from the *activPAL*<sup>TM</sup> data to give a predicted physical activity level (PAL) factor. Data from the *activPAL*<sup>TM</sup> in combination with the information recorded within the activity diary gave an indication of sedentary time (min) (i.e. activities where a person is awake and seated or reclining and participating in activities which require low levels of energy expenditure (i.e. < 1.5 METs) (Owen et al., 2010a)). Time spent in sedentary behaviour was then calculated as both mean $\pm$ sd daily minutes and as a percentage of time awake. Differences in levels of activity between the male and female participants were established using an independent t-Test (and a Mann-Whitney *U* test for time stepping). Levels of habitual activity are shown and

comparison between genders is shown in table 3.18. Results of the non-parametric analysis for time spent stepping is shown in table 3.19.

**Table 3.18 Levels of habitual activity in the study population with comparison between genders**

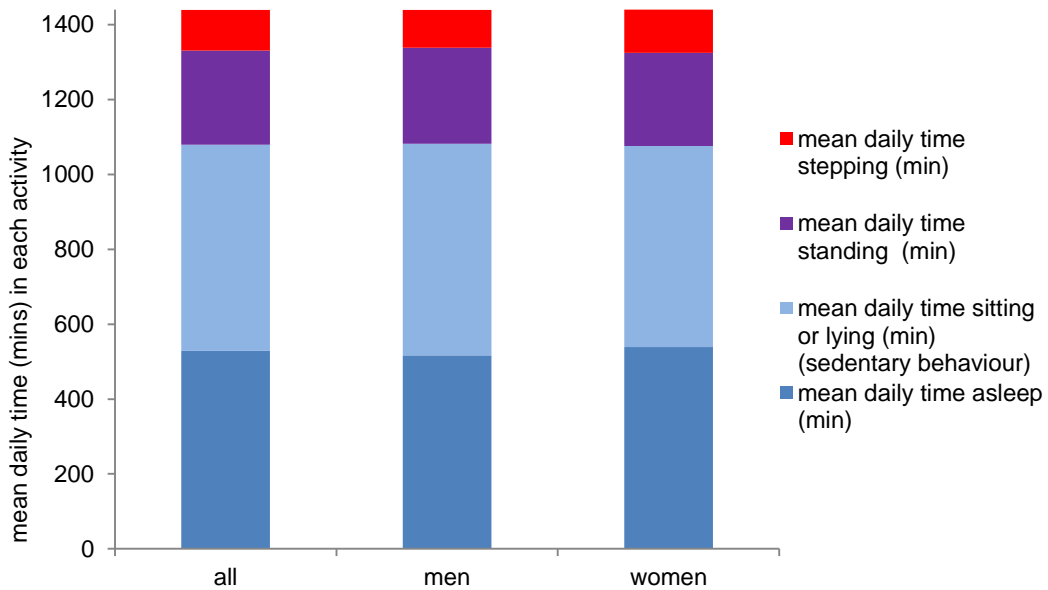
Activity	All n=44	Males n=21	Females n=23	p
	Mean ± sd	Mean ± sd	Mean ± sd	
Daily number of steps	8721 ± 3585	8039 ± 3908	9344 ± 3223	.232
Daily time stepping (min)	108 ± 38	101 ± 42	115 ± 33	.236
Daily time standing (min)	253 ± 78	258 ± 75	249 ± 82	.776
Daily time sitting or lying (min)	1080 ± 103	1088 ± 105	1074 ± 103	.836
Daily time MET >3 (min)	41 ± 21	41 ± 20	42 ± 23	.900
Mean daily MET	1.41 ± .06	1.41 ± .07	1.42 ± .06	.541
Daily sedentary time (min)	551 ± 88	565 ± 95	537 ± 81	.311
% awake time in sedentary	61 ± 10	61 ± 10	60 ± 10	.638
Mean daily sit to stand transitions	52.2 ± 11.9	50.7 ± 11.5	52.6 ± 12.3	.431
Mean daily sit to stand transitions during waking hours	51.2 ± 11.6	50 ± 11.3	52.4 ± 12.1	.501

**Table 3.19 Median (IQR) time spent stepping (min) and comparison between genders**

	All n=44	Males n=21	Females n=23	p
	Median (IQR)	Median (IQR)	Median (IQR)	
Daily Time stepping (min)	102 (76,131)	89 (70,124)	104 (88,146)	.148

There were no statistically significant differences found in any measure of habitual activity when comparing the male and female participants.

Figure 3.2 shows mean daily time spent asleep (min), mean daily time spent sitting and lying but awake i.e. sedentary (min), mean daily time spent standing (min) and mean daily time spent stepping (min) for the group as a whole and for male and female participants.



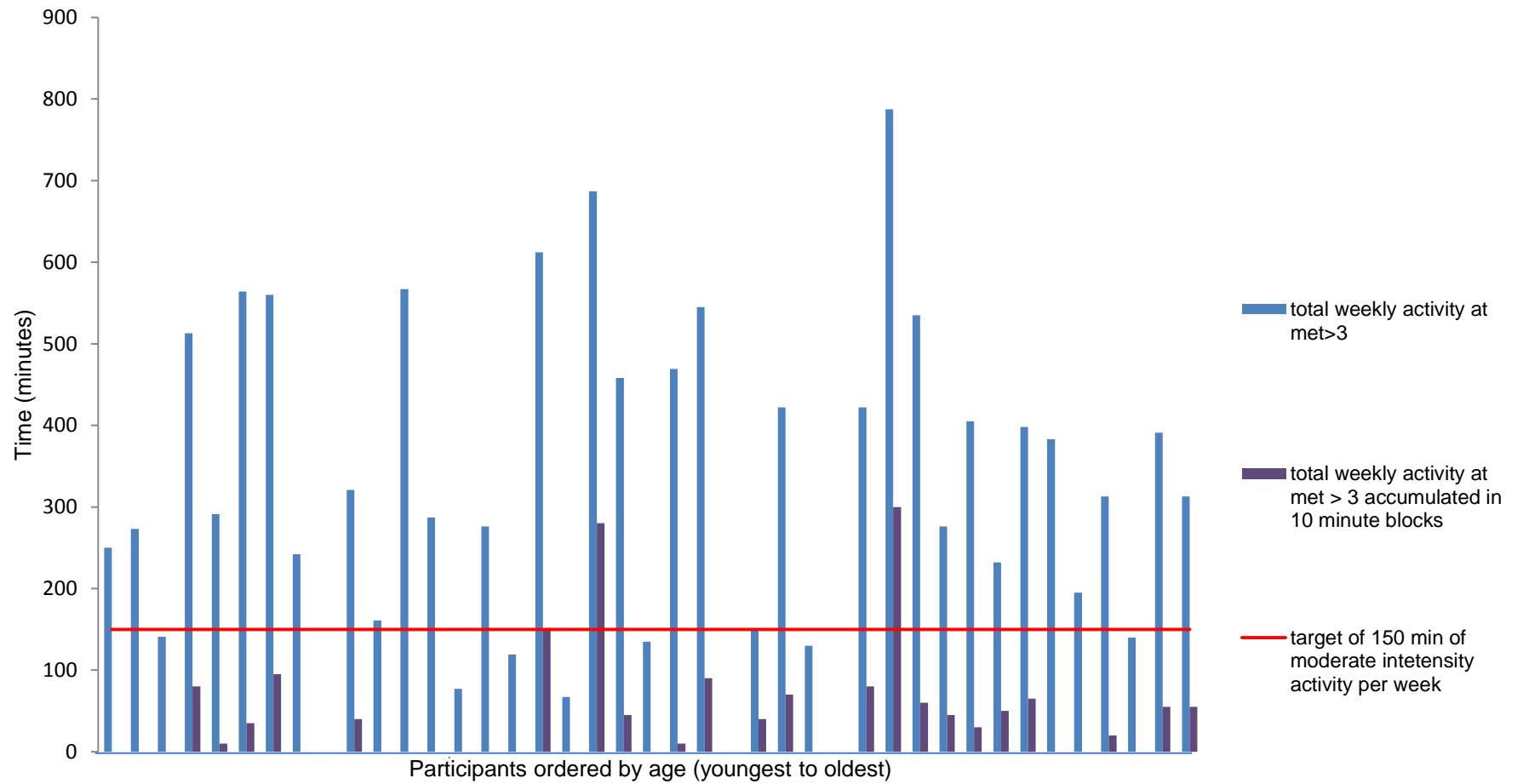
**Figure 3.2 mean daily time spent asleep, sitting and lying (sedentary behaviour), standing and stepping (min) (n=44)**

Current Scottish Government guidance is for all adults to participate in a minimum of 150 minutes of moderate intensity activity (i.e. MET > 3) each week (The Scottish Government, 2012). This activity can be accumulated in blocks of not less than 10 minutes of activity. Total weekly time spent in moderate intensity activity and time spent in moderate intensity activity when accumulated in blocks of at least 10 minutes was calculated for each participant. For the purposes of this study moderate intensity activity is all activity at MET > 3 (i.e. includes vigorous intensity activity) and this data are shown in figure 3.3. As activity data was measured for only five days for three participants (two males, one female) due to the *activPAL*<sup>TM</sup> monitors running out of battery power, total weekly moderate intensity activity and weekly moderate intensity activity when accumulated in 10 minute blocks has not been calculated for these participants.

When considering total weekly time spent in moderate intensity activity, 15/19 (79%) men and 19/22 (86%) women exceeded the recommendation of 150 minutes of

moderate intensity activity throughout the week. However when measuring this in blocks of not less than 10 minutes only 3/19 (16%) men and 1/22 (5%) women met the weekly target of 150 minutes of moderate intensity activity.

In addition to targets for moderate intensity activity specific recommendations related to sedentary behaviour for older people have also been devised. These indicate that older people should aim to minimise the amount of time spent being sedentary (sitting) for extended periods (DoH, 2011). This recommendation clearly lacks any quantifiable measure and so the number of sit to stand transitions which the participants completed was also calculated. This was measured as mean $\pm$ sd sit to stand transitions during each 24 hour period and during those hours which are considered waking hours. Where participants got up during the night to visit the bathroom and immediately returned to bed this not considered awake time. The waking hours reflects the measure of waking hours when measuring activity and sedentary behaviour. The mean $\pm$ sd sit to stand transitions completed during waking hours was 51.2 $\pm$ 11.6 with no significant difference between the male and female participants. This equates to a mean $\pm$ sd sit to stand transition every 18.1 $\pm$ 4.6 minutes. This figure can help inform a quantifiable recommendation for reducing sedentary time.



**Figure 3.3 Total weekly time in moderate intensity activity (MET > 3), weekly time in moderate intensity activity at MET > 3 when accumulated in 10 minute blocks in line with guidance recommendations (n=41)**

There was a high level of variation in daily activity levels throughout the week and so to establish whether mean daily activity levels were reflective of habitual activity the reliability of the data was established by calculating a two-way random model intraclass correlation coefficient ( $ICC_{(2,7)}$ ) (McGraw & Wong, 1996; Shrout & Fleiss, 1979). This assesses the reliability of mean daily habitual activity levels as a reflection of habitual activity when measured over a seven day period. An  $ICC_{(2,7)}$  and 95% CI were calculated for daily time spent sitting and lying (min), daily time spent standing (min), daily time spent stepping (min) and daily number of steps. The results of this analysis are shown in table 3.20.

**Table 3.20 Intraclass correlation coefficient ( $ICC_{(2,7)}$ ) assessing reliability of mean daily habitual activity measured during 7 days of activity (n=41) (n=41)**

parameter	ICC $_{(2,7)}$	95% CI	p value
Time spent sitting and lying	.898	.842,.939	p<.001
Time spent standing	.880	.815,.928	p<.001
Time spent stepping	.878	.812,.927	p<.001
Total number of steps	.855	.776,.913	p<.001

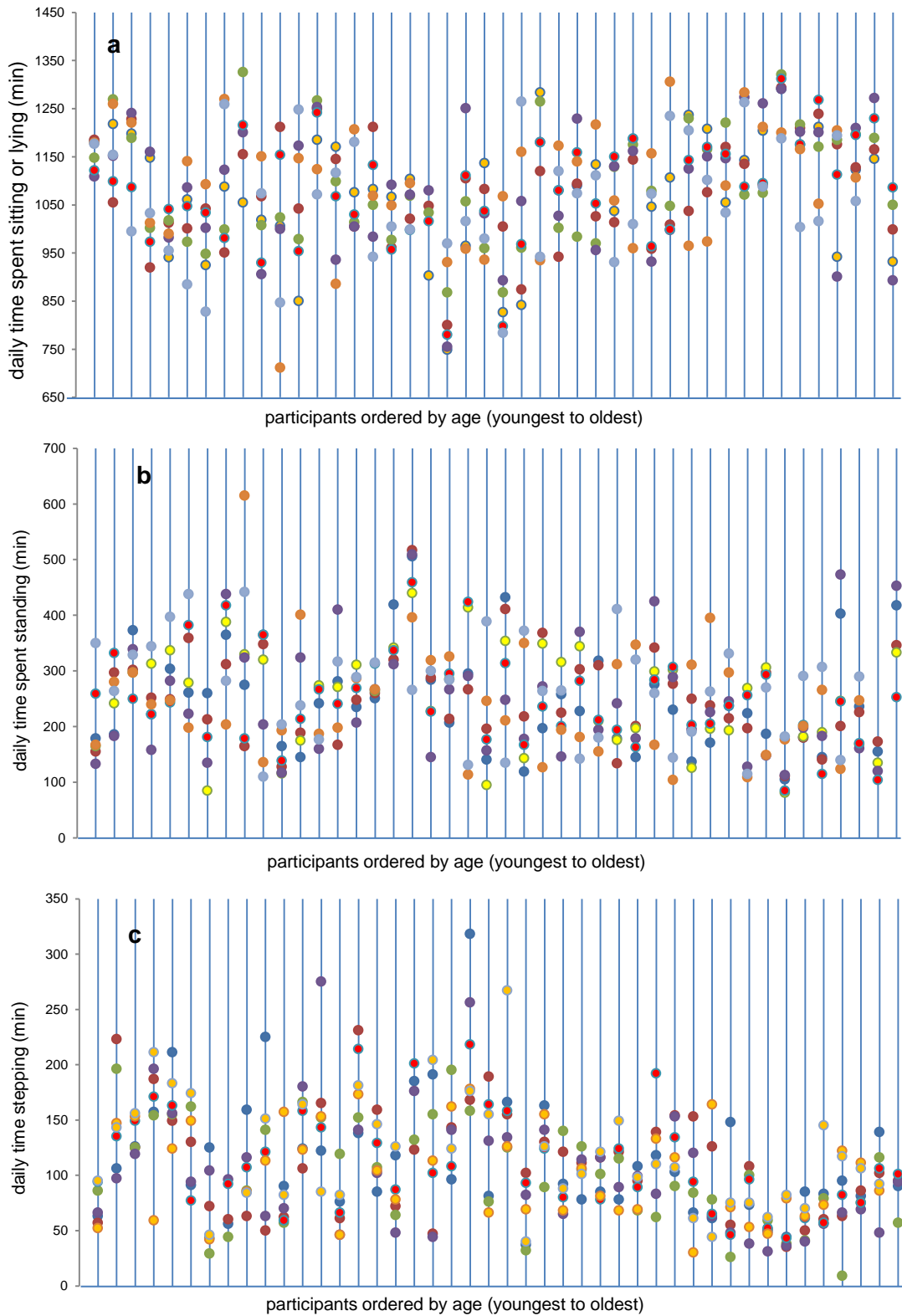
Statistically significant results along with high ICC values for the  $ICC_{(2,7)}$  show that habitual activity levels measured over seven consecutive 24 hour periods can provide a reliable reflection of mean habitual activity levels. Due to the variation in activity and nature of older people's lifestyles the reliability of using one individual 24 hour period from within this seven consecutive 24 hour period recording as a measure of habitual activity was also assessed. To establish this a two-way random single measures interclass correlation ( $ICC_{(2,1)}$ ) was calculated. These results are shown in table 3.21.

**Table 3.21 Intraclass correlation coefficient ( $ICC_{(2,1)}$ ) assessing reliability of an individual day as a measure of habitual activity (n=44)**

parameter	ICC $_{(2,1)}$	95% CI	p value
time sitting and lying	.556	.433,.686	p<.001
time standing	.511	.386,.648	p<.001
time stepping	.506	.381,.644	p<.001
total number of steps	.457	.331,.600	p<.001

The statistically significant results in table 3.21 show that one single 24 hour period can provide a reliable indication of habitual activity in older adults. However the  $ICC_{(2,7)}$ , which reflects mean daily habitual activity when measured across a week, shows better reliability than when habitual activity is assessed using a single day of monitoring as seen in the higher ICC values for the  $ICC_{(2,7)}$  compared to the  $ICC_{(2,1)}$ . This should be considered when providing guidance for activity levels as it appears activity targets based on weekly rather than daily activity levels may be more achievable as this takes into consideration the day to day variation seen when measuring habitual activity.

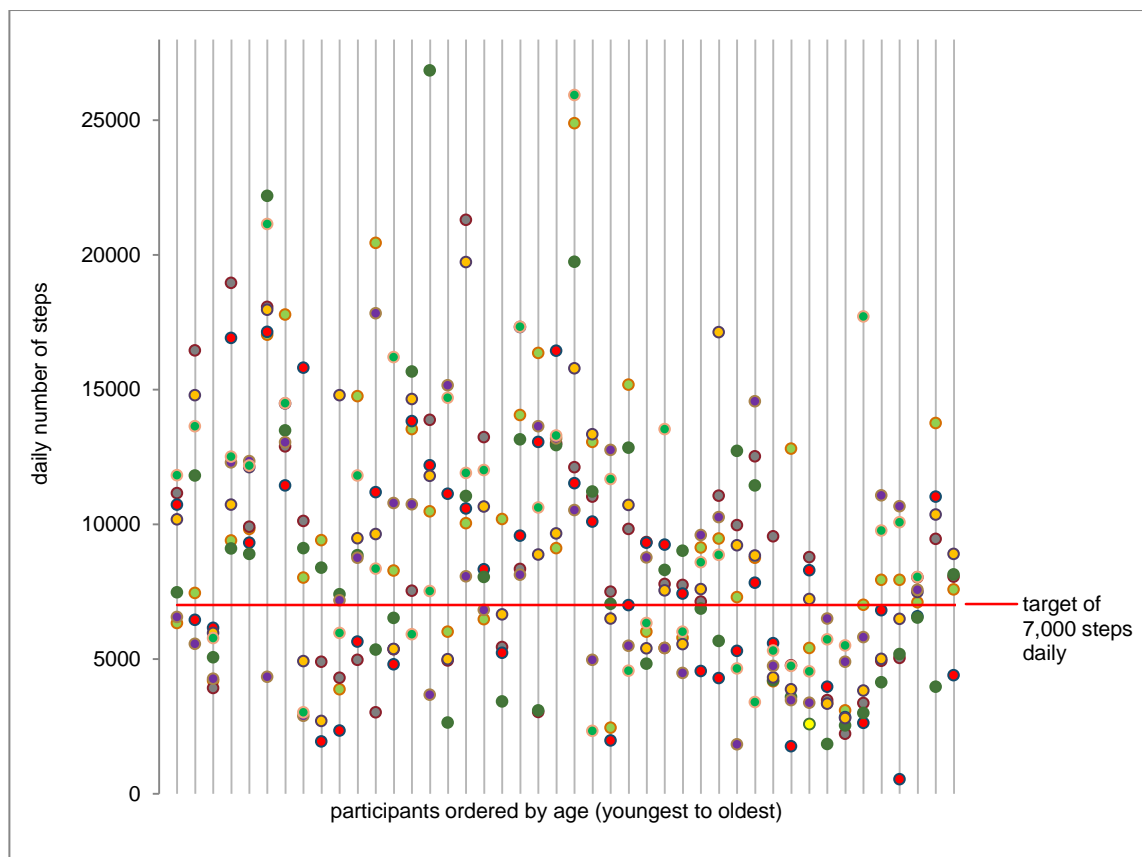
The variation in time spent sitting and lying, time spent standing and time spent stepping is shown in figure 3.4.



**Figure 3.4 Within and between subject variation of daily habitual levels of activity (n=44)**  
 a=variation in time spent sitting and lying, b=variation in time spent standing, c=variation in time spent stepping)



The variation in daily number of steps and comparison of this to the recommendation of 7,000 - 10,000 steps which should be taken each day by older adults per day (Tudor-Locke et al., 2011) is shown in figure 3.5.



**Figure 3.5 Within and between subject variations in meeting target of 7000 -10000 steps daily (n=44)**

In addition to recommendations for increasing physical activity levels and reducing sedentary behaviour older adults are advised to participate in muscle-strengthening activities on 2 or more days a week. The Scottish Health Survey (The Scottish Government 2012) identifies activities which are definitely muscle strengthening and potentially muscle strengthening. The relevant activities and number of participants who participated in these activities is shown in table 3.22.

When including activities which are considered potentially muscle strengthening alongside those which are definitely muscle strengthening activities 15 participants (34%) (9 (43%) men and 6 (26%) women) met the recommendation to participate in strength based activities on 2 or more days of the week. However 23 (53%) or participants (10 (48%) men and 13 (30%) women) did no muscle strengthening activities at all and the remaining six participants (2 men, 4 women) participated in one muscle strengthening activity during the recording period.

**Table 3.22 Number of participants who engaged in muscle strengthening activities during the recording period.**

	All	males	females
<b>Definitely muscle strengthening:</b>			
Swimming, Horse riding,		3	1
<b>Potentially muscle strengthening:</b>			
Cycling	1	1	
Workout at a gym	2	2	1
Any type of dancing	1	1	
Badminton	1	1	
Pilates	1		1
Aquaerobics/aquafit	1		1
Martial arts/tai chi	2		2
Lawn bowls	3	1	2
Golf	6	2	4
Hill walking/rambling	1	1	
Curling	1	1	

The role of fatigue in habitual activity has been established and has been previously discussed (section 1.19) and so levels of fatigue in the study population were also measured.

### **3.8 FATIGUE**

Levels of fatigue were measured in all participants using the MFI (multi-dimensional fatigue inventory). As discussed previously (section 1.19) this has been validated for use in a healthy older adult population. The questionnaire is a self-report of fatigue and measures five domains (general fatigue, physical fatigue, reduced activity, reduced motivation and mental fatigue) with each domain measured by four questions all of

which are 5-point Likert scales. Scores can range from 4 - 20 with higher scores being indicative of higher levels of fatigue. It is recommended by the developer that total scores of all domains should not be used but that the score for general fatigue is indicative of overall fatigue. Levels of fatigue along with comparisons between genders (using a Mann-Whitney *U* Test) are shown in table 3.23.

**Table 3.23 Median (IQR) scores for fatigue measured by MFI and comparison between genders**

<b>fatigue MFI</b>	<b>All n=44 Median (IQR)</b>	<b>Males n=21 Median (IQR)</b>	<b>Females n=23 Median (IQR)</b>	<b>p</b>
general	8 (6,10)	9 (6.5,10.5)	7 (6, 9)	.051
physical	8 (5.2,10)	8 (5.5,11.5)	7 (5,10)	.478
reduced activity	8 (5,10)	8 (6,11)	6 (4,9)	.064
reduced motivation	6 (5,8.8)	6 (5.5,9)	6 (4,8)	.348
mental	6 (4,8.8)	6 (4,9.5)	6 (4,8)	.840

There were no statistically significant differences found in any domain of fatigue when comparing male participants with female participants indicating similar levels of fatigue across the study population.

Normative values are available for levels of fatigue in older adults (Schwarz et al., 2003) although these are reported as mean±sd (despite Likert scales producing non-parametric data) and so the mean±sd fatigue levels of the study population were compared to the normative values using a one sample t-Test and the results are shown in table 3.24.

**Table 3.24 Comparison of levels of fatigue within the study population to normative values (Schwarz et al., 2003)**

	norm mean±sd	men fatigue score mean±sd	p	norm mean±sd	women fatigue score mean±sd	p
general fatigue	10.1±3.7	8.8±2.9	.053	10.8±3.7	7.2±2.4	<.001
physical fatigue	10.3±4.3	8.8±3.9	.084	11.1±4.2	8.0±3.7	<.001
reduced activity	10.3±4.0	8.4±2.7	.005	10.5±4.0	7.1±3.6	.002
reduced motivation	9.1±3.3	7.3±2.7	.006	9.9±3.5	6.7±2.9	<.001
mental fatigue	8.7±3.5	6.8±3.0	.009	9.2±3.4	6.7±2.7	<.001

When comparing levels of fatigue within the study population to normative data there were no statistically significant differences found in levels of general fatigue ( $p=0.053$ ) and physical fatigue ( $p=.084$ ) in the male participants compared to normative values. However in the other domains of fatigue the male participants had statistically significantly lower levels of fatigue compared to normative values (reduced activity  $8.4\pm2.7$  vs  $10.3\pm4.0$  ( $p=.005$ ), reduced motivation  $7.3\pm2.7$  vs  $9.1\pm3.3$  ( $p=.006$ ), mental fatigue  $6.8\pm3.0$  vs  $8.7\pm3.5$  ( $p=.009$ )). This suggests that out with physical considerations of fatigue the male study participants were less fatigued than would be expected perhaps reflecting the fact that they are healthy older adults.

In the female participants all domains of fatigue were statistically significantly lower than normative values (general fatigue  $7.2\pm2.4$  vs  $10.8\pm3.7$  ( $p<.001$ ), physical fatigue  $8.0\pm3.7$  vs  $11.1\pm4.2$  ( $p<.001$ ), reduced activity  $7.1\pm3.6$  vs  $10.5\pm4.0$  ( $p=.002$ ), reduced motivation  $6.7\pm2.9$  vs  $9.9\pm3.5$  ( $p<.001$ ), mental fatigue  $6.7\pm2.7$  vs  $9.2\pm3.4$  ( $p<.001$ )). This may again be reflective of the health status of the female participants in that they had a healthy nutritional status and would be considered healthy in terms of levels of low grade inflammation.

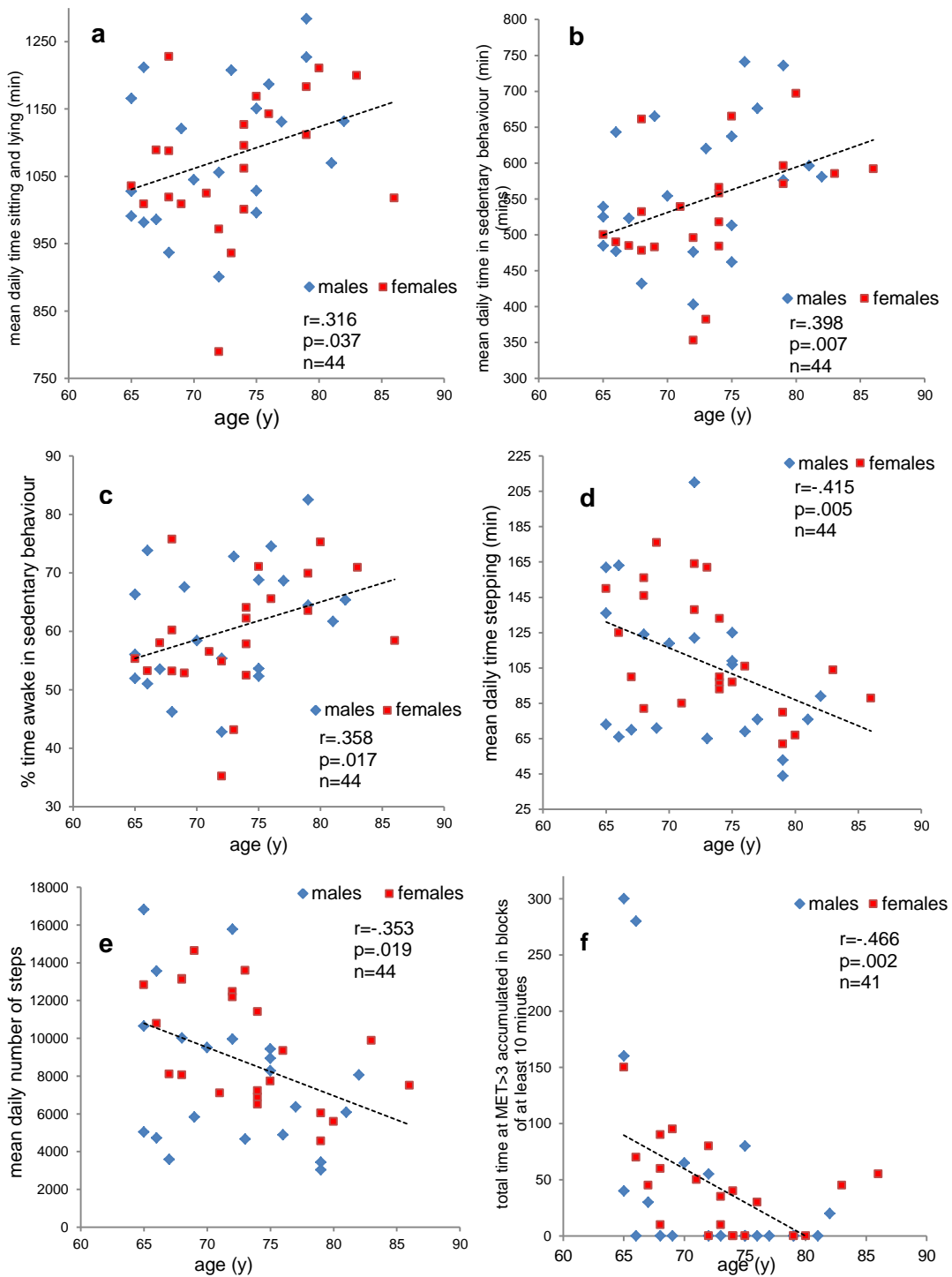
### **3.10 ASSOCIATIONS BETWEEN LEVELS OF HABITUAL ACTIVITY AND NUTRITIONAL STATUS, FUNCTIONAL STATUS, DIETARY INTAKE AND LEVELS OF FATIGUE**

Levels of habitual activity were correlated with markers of nutritional status, functional status and dietary intake using a Pearson's correlation co-efficient and with levels of fatigue using a Spearman's rho correlation co-efficient. When the data was analysed initially no statistically significant differences between genders were found for these

parameters and in view of this and the fact that the study recruited only relatively small numbers, associations have been measured based on data for the whole study population rather than by gender. There are known differences between genders for height, weight, WC, TSF, MAMC, HGD and dietary intakes (with men having greater heights, weight, WC, MAMC, HGD and energy and protein intakes and women having higher TSF). Within the study population these parameters (with the exception of HGD) were found to be normally distributed and so due to the normal distribution, the fact that the parameters lie on a continuum across a population and the relatively small numbers recruited it is still appropriate to calculate correlation coefficients for the whole group rather than by gender. The data however are shown as male and female participants for information.

#### **3.10.1 Relationship between levels of habitual activity and age**

Levels of habitual activity were correlated with age to establish where if any associations existed. Age had a statistically significant positive association with mean daily time sitting and lying (min) ( $r=.316$ ,  $p=.037$ ), mean daily time spent in sedentary behaviour (min) ( $r=.398$ ,  $p=.007$ ) and percentage time awake spent in sedentary behaviour ( $r=.358$ ,  $p=.017$ ). It also had a statistically significant negative association with mean daily time stepping (min) ( $r=-.415$ ,  $p=.005$ ), mean daily number of steps ( $r=-.353$ ,  $p=.019$ ) and total time in activity at MET > 3 accumulated in blocks of at least 10 minutes (min) ( $r=-.466$ ,  $p=.002$ ) (figure 3.6). There were no other statistically significant associations between age and other measures of habitual activity (mean daily time standing (min) ( $p=0.192$ ), total time in activity at MET > 3 (min) ( $p=-.466$ ) and mean daily sit to stand transitions when awake ( $p=.059$ ).



**Figure 3.6 Association between mean daily activity levels and age (y)**

a=association between age (y) and mean daily time spent sitting and lying (min)

b=association between age (y) and mean daily time in sedentary behaviour (min)

c=association between age (y) and mean % time in sedentary behaviour

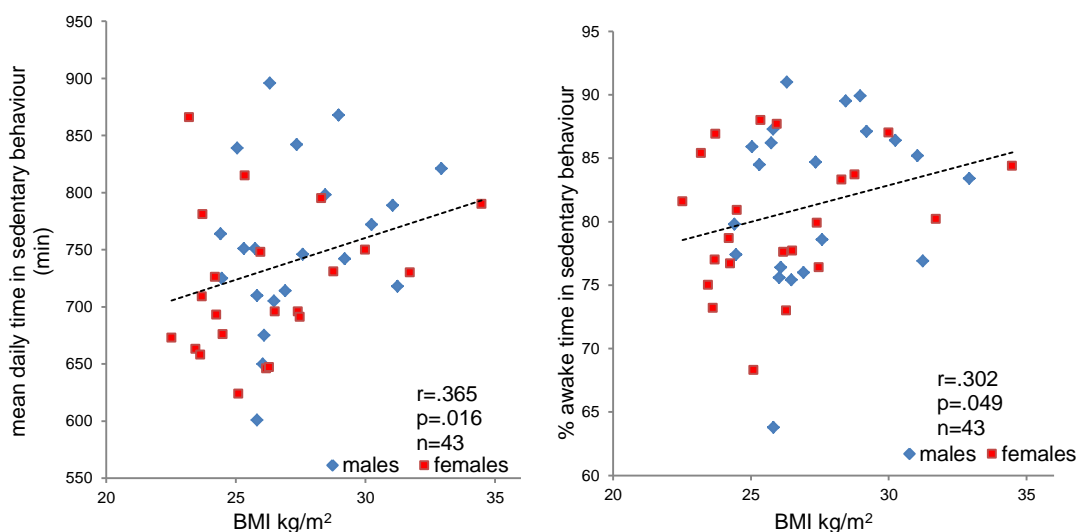
d=association between age (y) and mean daily time spent stepping (min)

e=association between age (y) and mean daily number of steps

f=association between age (y) and total weekly time at MET > 3 (min) accumulated in blocks of at least 10mins

### 3.10.2 Relationship between levels of habitual activity and nutritional status

Markers of nutritional status were correlated with levels of habitual activity to establish where if any associations existed. The only markers of nutritional status which were found to have a statistically significant association with levels of habitual activity were BMI ( $\text{kg}/\text{m}^2$ ) and WC (cm). BMI ( $\text{kg}/\text{m}^2$ ) was found to have a statistically significant positive association with mean daily time in sedentary behaviour ( $r=.365$ ,  $p=.016$ ) and with percentage awake time in sedentary behaviour ( $r=.302$ ,  $p=.049$ ) (figure 3.7).

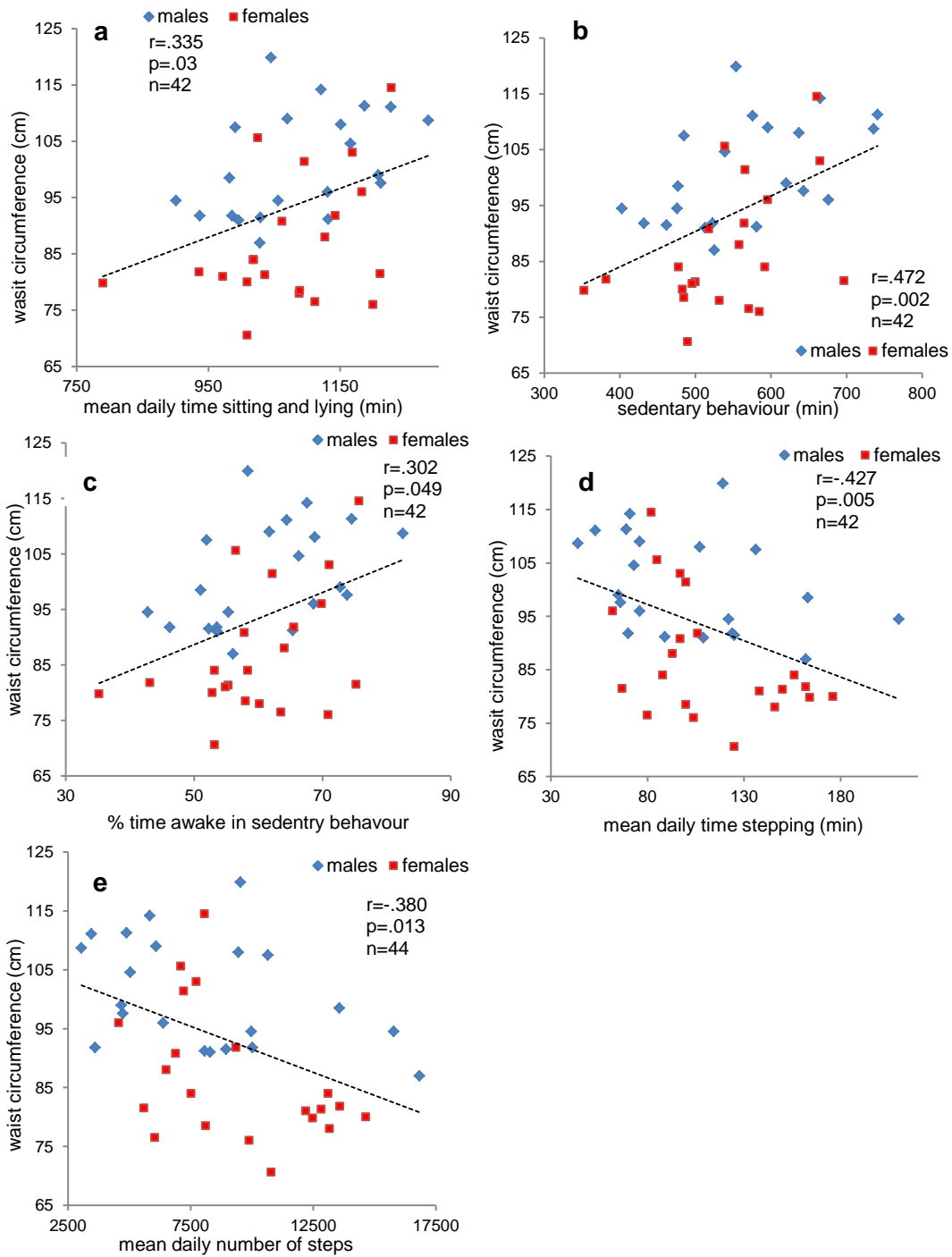


**Figure 3.7 Association between mean daily activity levels and BMI ( $\text{kg}/\text{m}^2$ )**

a=association between BMI ( $\text{kg}/\text{m}^2$ ) and mean daily time in sedentary behaviour (min)

b=association between BMI ( $\text{kg}/\text{m}^2$ ) percent awake time in sedentary behaviour

WC (cm) was found to have a statistically significant positive association with mean daily time sitting and lying (min) ( $r=.335$ ,  $p=.030$ ), mean daily time in sedentary behaviour (min) ( $r=.472$ ,  $p=.002$ ) and percentage time awake spent in sedentary behaviour ( $r=.302$ ,  $p=.049$ ). WC (cm) also had a statistically significant negative association with mean daily time stepping (min) ( $r=-.427$ ,  $p=.005$ ) and with mean daily number of steps ( $r=-.380$ ,  $p=.013$ ) (figure 3.8). No other statistically significant association were found between markers of nutritional status and levels of habitual activity.



**Figure 3.8 Association between mean daily activity levels and waist circumference (cm)**

a=association between waist circumference (cm) and mean daily time spent sitting and lying (min)

b=association between waist circumference (cm) and mean daily time in sedentary behaviour (min)

c=association between waist circumference (cm) and mean % time in sedentary behaviour

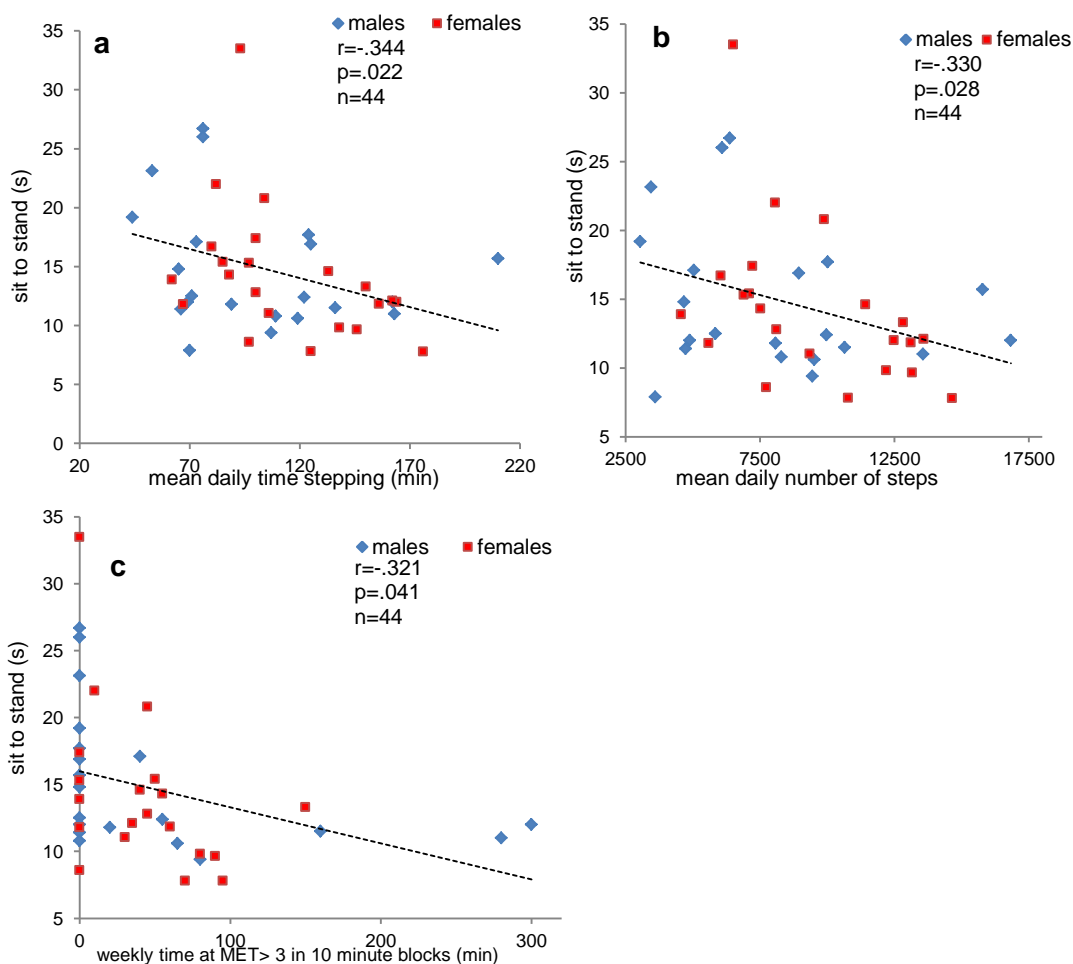
d=association between waist circumference (cm) and mean daily time spent stepping (min)

e=association between waist circumference (cm) and mean daily number of steps



### 3.10.3 Relationship between levels of habitual activity and functional status

Markers of functional status were correlated with levels of habitual activity to establish where if any statistically significant associations existed. The STS test (s) was found to have a statistically significant negative association with mean daily time stepping (min) ( $r=-.344$ ,  $p=.022$ ), mean daily number of steps ( $r=-.330$ ,  $p=.028$ ) and total weekly time spent in activity at MET > 3 when accumulated in blocks of at least 10 minutes (min) ( $r=-.321$ ,  $p=.041$ ) (figure 3.9). No other statistically significant associations were found between STS (s) and other measures of habitual activity.



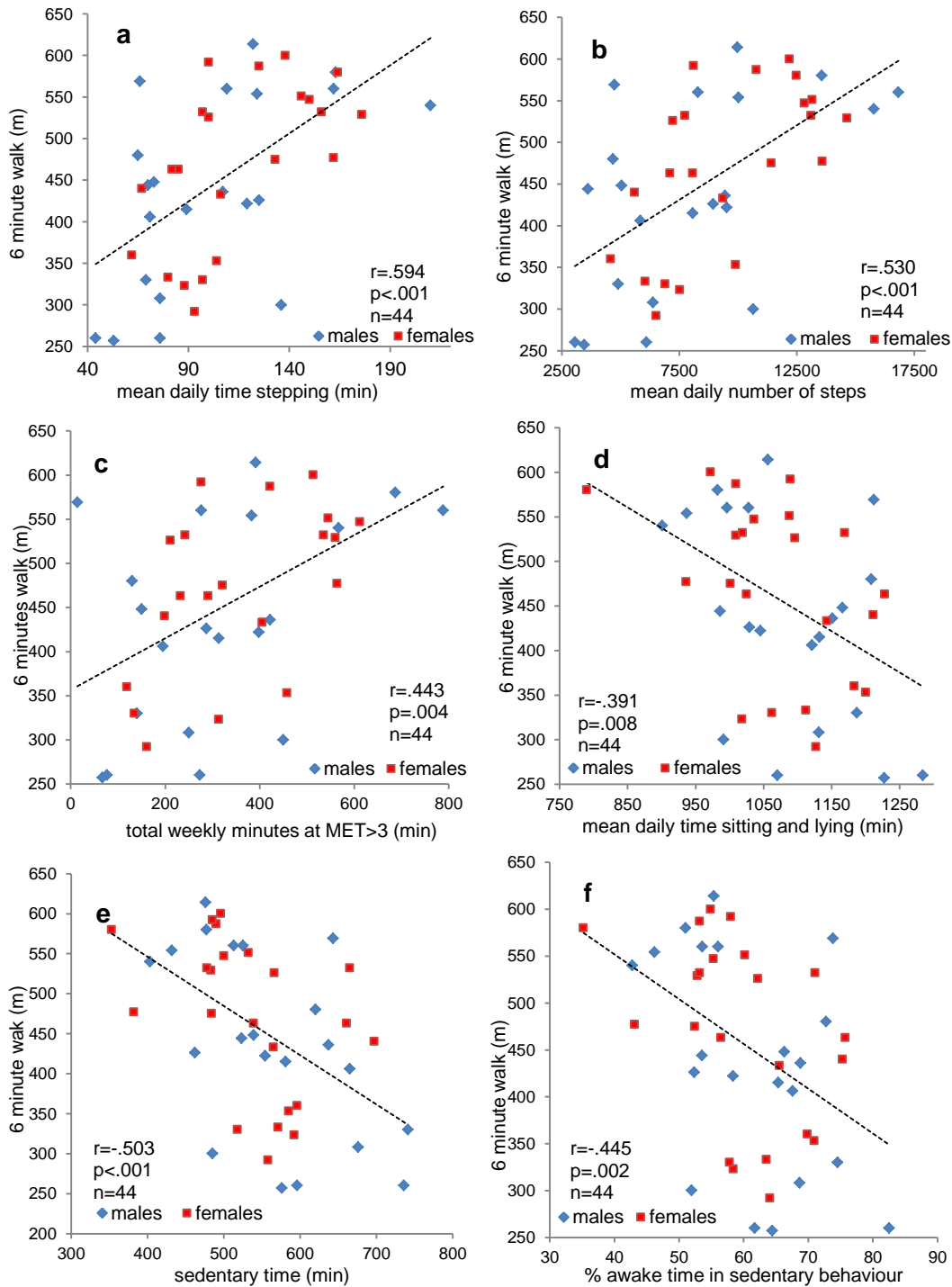
**Figure 3.9 Association between mean daily activity levels and STS (s)**

a=association between sit to stand time (s) and mean daily time stepping (min)

b=association between sit to stand time (s) and mean daily number of steps

c=association between sit to stand time (s) and weekly time in activity at MET>3 (min)

The 6MW test (m) was found to have a statistically significant positive association with mean daily time stepping (min) ( $r=.594$ ,  $p<.001$ ), mean daily number of steps ( $r=.530$ ,  $p<.001$ ) and total weekly time in activity at MET > 3 (min) ( $r=.443$ ,  $p=.004$ ). It was also found to have a statistically significant negative association with mean daily time sitting and lying (min) ( $r=-.391$ ,  $p=.008$ ), mean daily time in sedentary behaviour (min) ( $r=-.503$ ,  $p=.001$ ) and percentage time awake in sedentary behaviour ( $r=-.445$ ,  $p=.002$ ). In addition to the associations shown in figure 3.10 there was a statistically significant positive association found between 6MW and total weekly time in activity at MET > 3 accumulated in blocks of at least 10 minutes (min) ( $r=0.321$ ,  $p=.041$ ,  $n=44$ ) (not shown). No other statistically significant associations between 6MW (m) and other measures of habitual activity were found.



**Figure 3.10 Association between mean daily activity levels and six minute walk (m)**

a=association between distance in 6MW test (m) and mean daily time stepping (min)

b=association between distance in 6MW test (m) and mean daily number of steps

c=association between distance in 6MW test (m) and total weekly time in activity at MET>3 (min)

d=association between distance in 6MW test (m) and mean daily time spent sitting and lying (min)

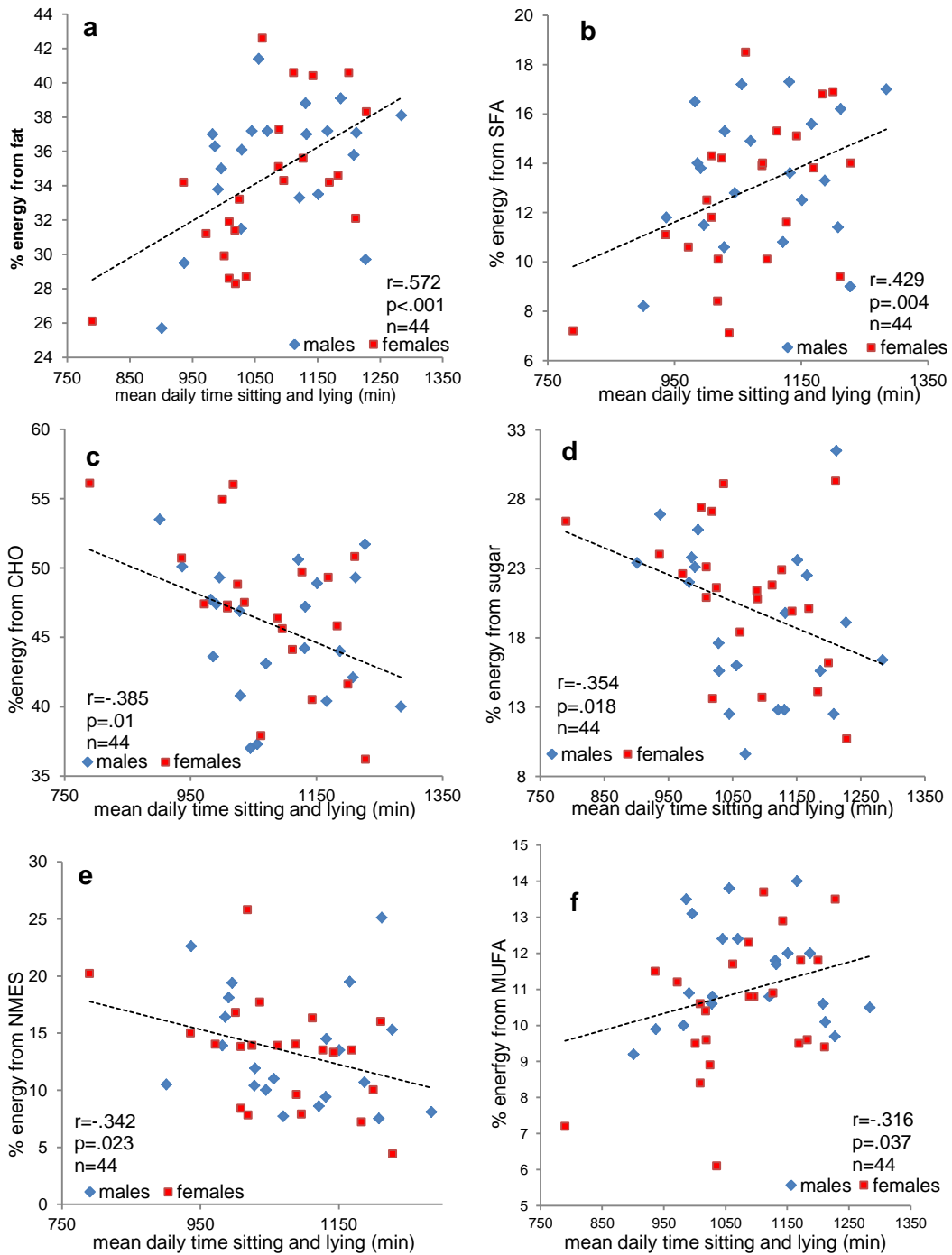
e=association between distance in 6MW test (m) and mean daily time in sedentary behaviour (min)

f=association between distance in 6/MW test (m) and % time awake spent in sedentary behaviour

#### **3.10.4 Relationship between levels of habitual activity and dietary intake**

Dietary intake was correlated with levels of habitual activity to establish where, if any associations existed. Mean daily time spent sitting and lying (min) was found to have a statistically significant positive association with percent energy intake from fat ( $r=.572$ ,  $p<.001$ ), percent energy intake from saturated fat (SFA) ( $r=.429$ ,  $p=.004$ ) and percent energy from monounsaturated fat (MUFA) ( $r=.316$ ,  $p=.037$ ). It was found to have a statistically significant negative association with percent energy intake from carbohydrate (CHO) ( $r=-.385$ ,  $p=.01$ ), percent energy intake from sugar ( $r=-.354$ ,  $p=.018$ ) and % energy intake from non-milk extrinsic sugar (NMES) ( $r=-.342$ ,  $p=.023$ ) (figure 3.11). Mean daily time spent sitting or lying (min) was not statistically significantly associated with any other measure of dietary intake including total energy intake.

Mean daily time standing (min) was found to have a statistically significant positive association with percent energy intake from CHO ( $r=.404$ ,  $p=.006$ ), percent energy intake from sugar ( $r=.334$ ,  $p=.027$ ) and percent energy intake from NMES ( $r=.408$ ,  $p=.006$ ). It was found to have a statistically significant negative association with percent energy intake from fat ( $r=-.50$ ,  $p=.001$ ) and percent energy intake from SFA fat ( $r=-.379$ ,  $p=.011$ ) (figure 3.12). Mean daily time spent standing (min) was not found to have a statistically significant association with any other measure of dietary intake including total energy intake.



**Figure 3.11 Association between mean daily time spent sitting and lying (min) and dietary intake**

a=association between mean daily time spent sitting and lying (min) and %energy intake from fat

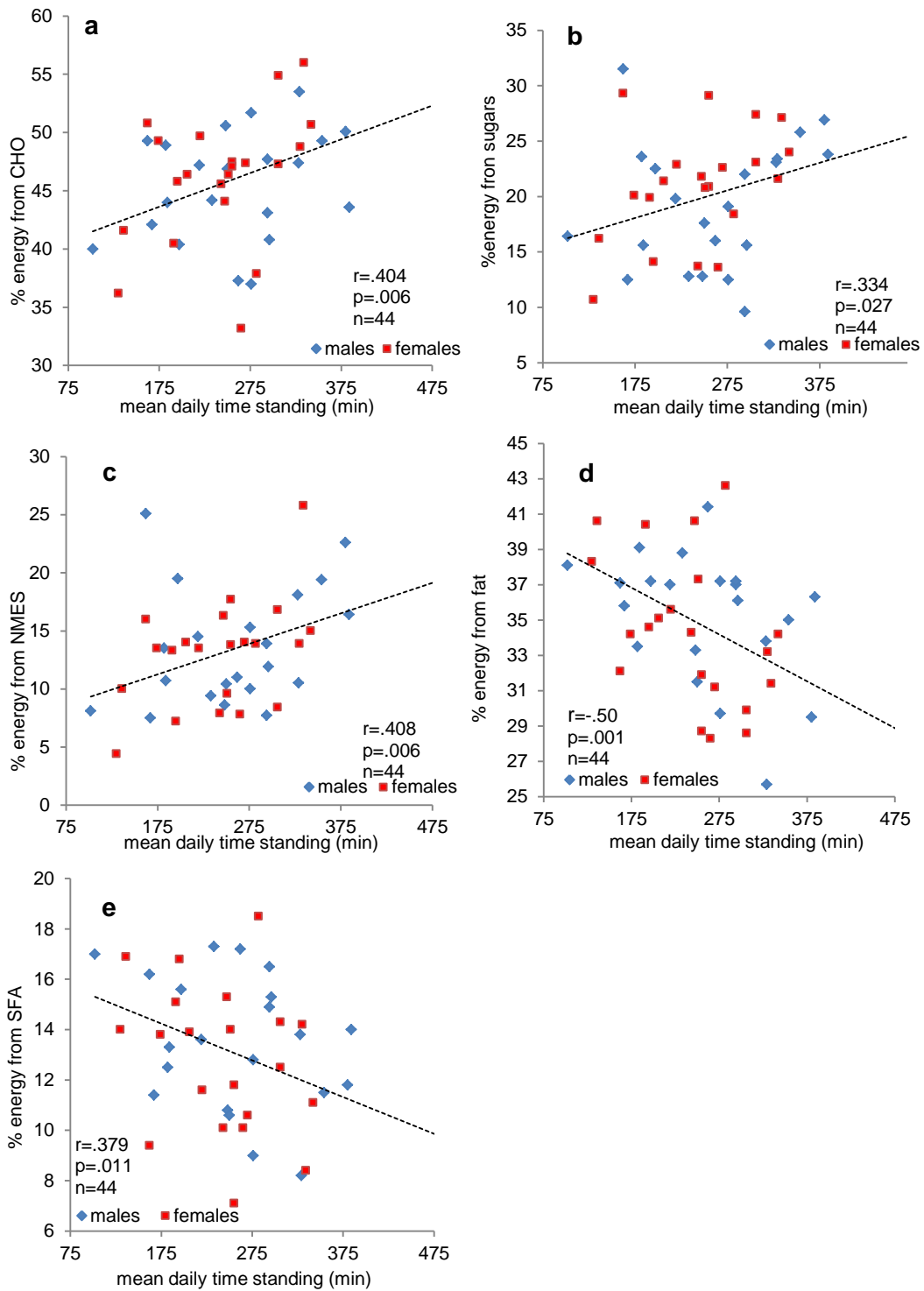
b= association between mean daily time spent sitting and lying (min) and %energy intake from SFA

c= association between mean daily time spent sitting and lying (min) and %energy intake from CHO

d= association between mean daily time spent sitting and lying (min) and %energy intake from sugar

e= association between mean daily time spent sitting and lying (min) and %energy intake from NMES

f= association between mean daily time spent sitting and lying (min) and %energy intake from MUFA



**Figure 3.12 Association between mean daily time spent standing (min) and dietary intake**

a= association between mean daily time spent standing (min) and %energy intake from CHO

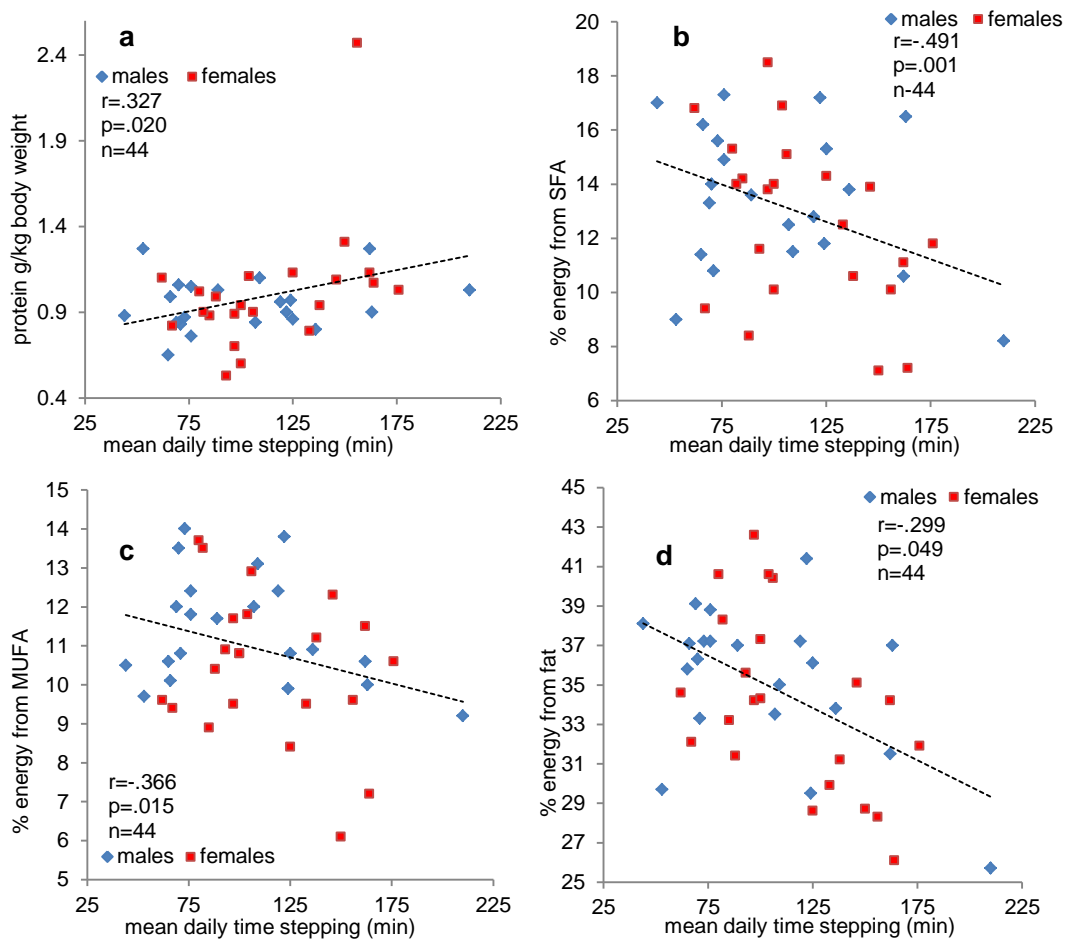
b= association between mean daily time spent standing (min) and %energy intake from sugar

c= association between mean daily time spent standing (min) and %energy intake from NMES

d=association between mean daily time spent standing (min) and %energy intake from fat

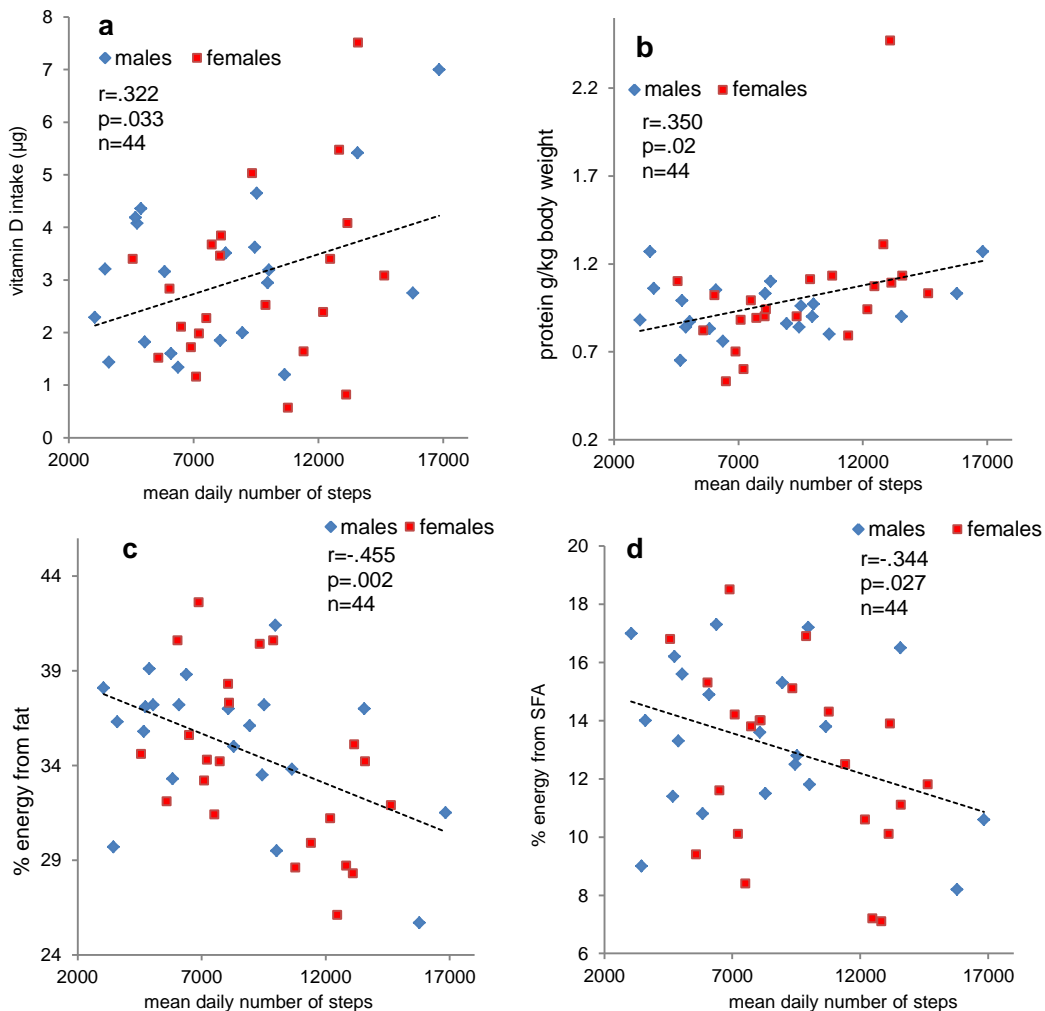
e= association between mean daily time spent standing (min) and %energy intake from SFA

Mean daily time stepping (min) was found to be statistically significantly positively associated with protein intake when measured as g/kgBW ( $r=.327$ ,  $p=.020$ ) but not when considered as absolute intakes (g). It was statistically significantly negatively associated with percent energy intake from fat ( $r=-.491$ ,  $p=.001$ ), percent energy intake from SFA ( $r=-.366$ ,  $p=.015$ ) and percent energy intake from MUFA ( $r=-.299$ ,  $p=.049$ ) (figure 3.13). Mean daily time spent stepping (min) was not found to have a statistically significant association with any other measure of dietary intake including total energy intake.



**Figure 3.13: Association between mean daily time spent stepping (min) and dietary intake**  
a=association between mean daily time spent stepping (min) and protein intake (g/kgBW)  
b=association between mean daily time spent stepping (min) and %energy intake from fat  
c=association between mean daily time spent stepping (min) and %energy intake from SFA  
d=association between mean daily time spent stepping (min) and %energy intake from MUFA

Mean daily number of steps was found to be statistically significantly positively associated with mean daily vitamin D intake ( $\mu\text{g}$ ) ( $r=.322$ ,  $p=.033$ ) and with protein intakes when measured as  $\text{g}/\text{kgBW}$  ( $r=.350$ ,  $p=.02$ ). It was found to be statistically significantly negatively associated with percent energy intake from fat ( $r=-.455$ ,  $p=.002$ ) and percent energy intake from SFA ( $r=-.344$ ,  $p=.027$ ) (figure 3.14). Mean daily number of steps was not found to be statistically significantly associated with any other measure of dietary intake including total energy intake.



**Figure 3.14 Association between mean daily number of steps and dietary intake**

a=association between mean daily number of steps and %energy from fat

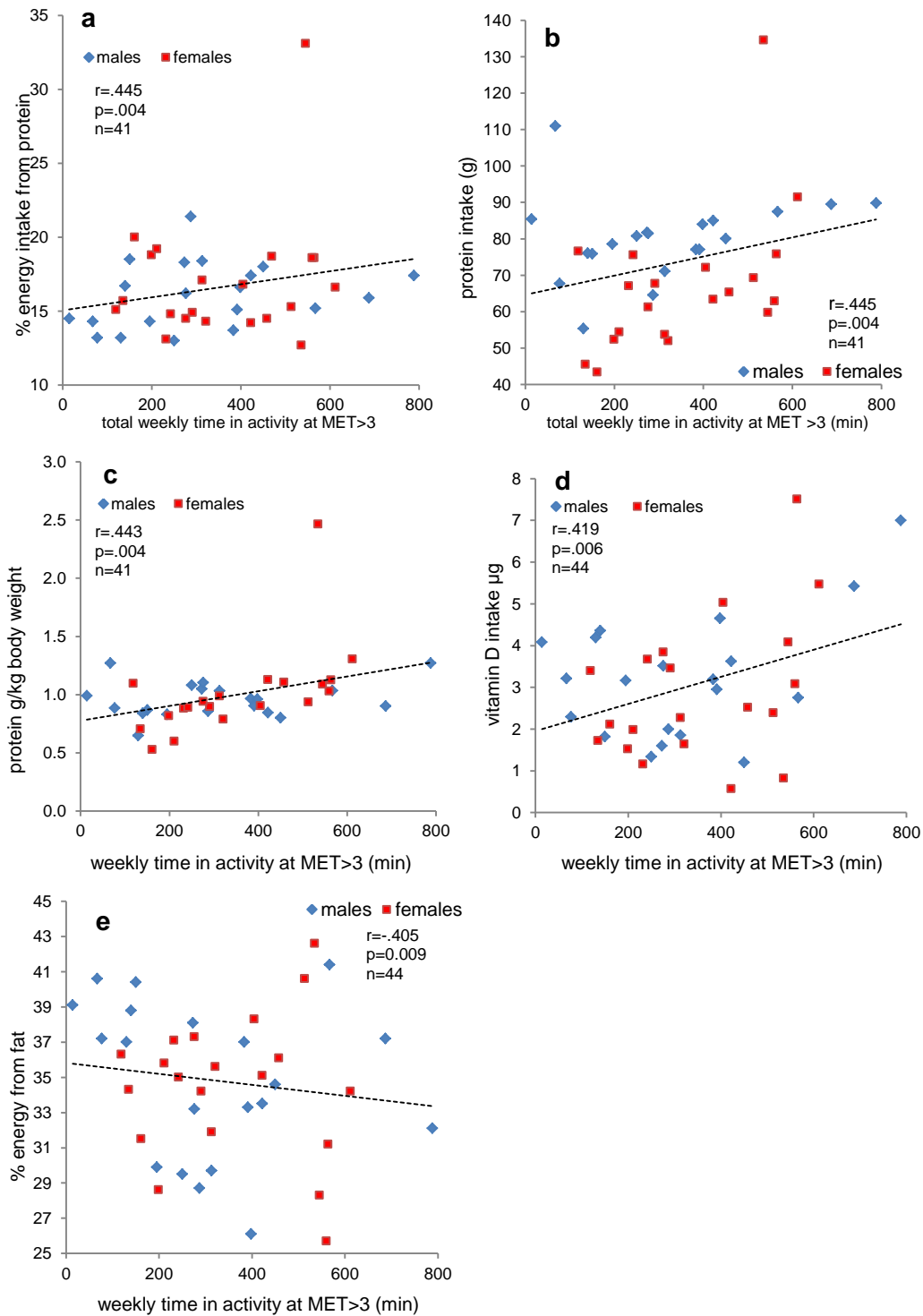
b=association between mean daily number of steps and %energy from SFA

c=association between mean daily number of steps and vitamin D intake ( $\mu\text{g}$ )

d=association between mean daily number of steps and mean daily protein intake ( $\text{g}/\text{kgBW}$ )

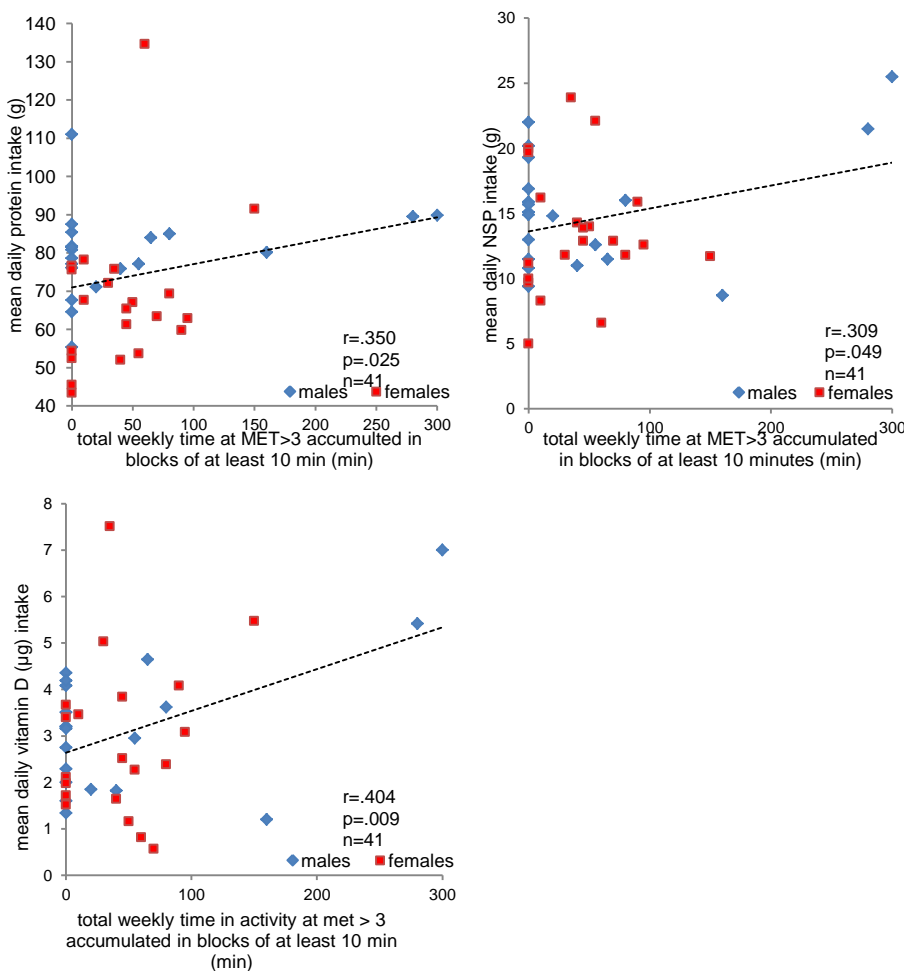


Total weekly time spent in moderate intensity activity (min) (i.e. activity at MET >3) was found to be statistically significantly positively associated with percent energy intake from protein ( $r=.341$ ,  $p=.029$ ), with total protein intake (g) ( $r=.445$ ,  $p=.004$ ), with protein intakes when measured as g/kgBW ( $r=.443$ ,  $p=.004$ ) and with mean daily vitamin D intake ( $\mu\text{g}$ ) ( $r=.419$ ,  $p=.006$ ). It was found to be statistically significantly negatively associated with percent energy intake from fat ( $r=-.405$ ,  $p=.009$ ) (figure 3.15). Total weekly time in moderate intensity activity (min) was not found to be statistically significantly associated with any other measure of dietary intake including total energy intake.



**Figure 3.15 Association between total weekly time in activity at MET > 3 and dietary intake**  
 a=association between total weekly time in activity at MET> 3 (min) and percent energy intake from protein  
 b=association between total weekly time in activity at MET > 3 (min) and mean daily protein intake (g)  
 c=association between total weekly time in activity at MET > 3 (min) and mean daily protein intake (g/kgBW)  
 d=association between total weekly time in activity at MET > 3 (min) and vitamin D intake ( $\mu\text{g}$ )  
 e=association between total weekly time in activity at MET > 3 (min) and percent energy from fat

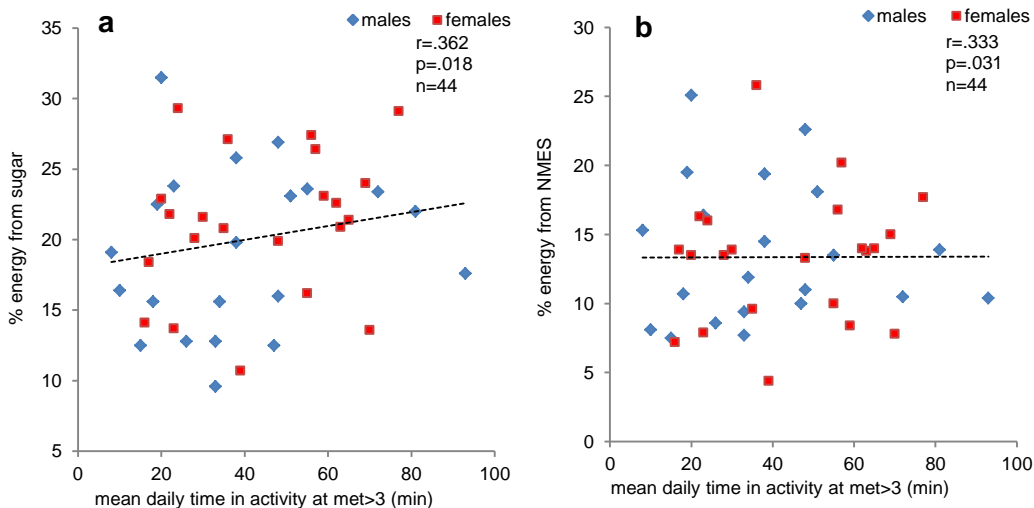
When measuring total weekly time spent in moderate intensity activity accumulated in blocks of at least 10 minutes (min) this was found to be statistically significantly positively associated with mean daily protein intake (g) ( $r=.350$ ,  $p=.025$ ), with mean daily non starch polysaccharide (NSP) intakes (g) ( $r=.309$ ,  $p=.049$ ) and with mean daily vitamin D intake ( $\mu\text{g}$ ) ( $r=.404$ ,  $p=.009$ ) (figure 3.16). It was not found to be statistically significantly associated with any other measure of dietary intake including total energy intake.



**Figure 3.16 Association between total weekly time (min) in moderate intensity activity (MET>3) when accumulated in blocks of at least 10 minute and dietary intake**

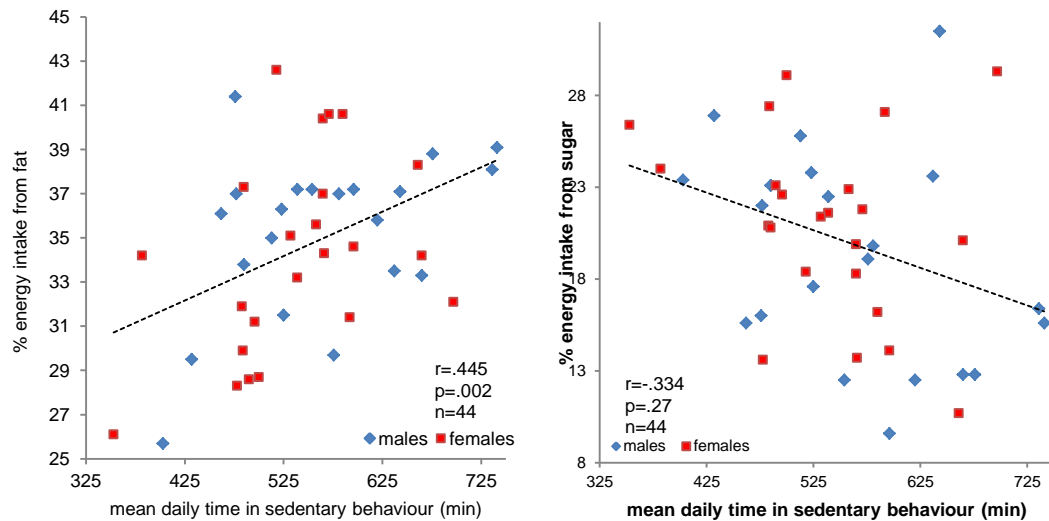
- a= association between total weekly time (min) in moderate intensity activity (MET>3) accumulated in blocks of at least 10 minute and mean daily protein intake (g)
- b= association between total weekly time (min) in moderate intensity activity (MET>3) accumulated in blocks of at least 10 minute and mean daily NSP intake (g)
- c= association between total weekly time (min) in moderate intensity activity (MET>3) accumulated in blocks of at least 10 minute and mean daily vitamin D intake ( $\mu\text{g}$ )

Mean daily time in moderate intensity activity (min) was found to be statistically significantly positively associated with percent energy intake from sugar ( $r=.362$ ,  $p=.018$ ) and percent energy intake from NMES ( $r=.333$ ,  $p=.031$ ) (figure 3.17). It was not found to be statistically significantly associated with any other measure of dietary intake.



**Figure 3.17 Association between mean daily time in activity at MET > 3 and dietary intake**  
a=association between mean daily time in activity at MET > 3 (min) and %energy intake from sugar  
b=association between mean daily time in activity at MET > 3 (min) and %energy intake from NMES

Mean daily time spent in sedentary behaviour (min) was found to be statistically significantly positively associated with percent energy intake from fat ( $r=.445$ ,  $p=.002$ ) and to be statistically significantly negatively associated with percent energy intake from sugar ( $r=-.334$ ,  $p=.027$ ) (figure 3.18). It was not found to be statistically significantly associated with any other measure of dietary intake including total energy intake.

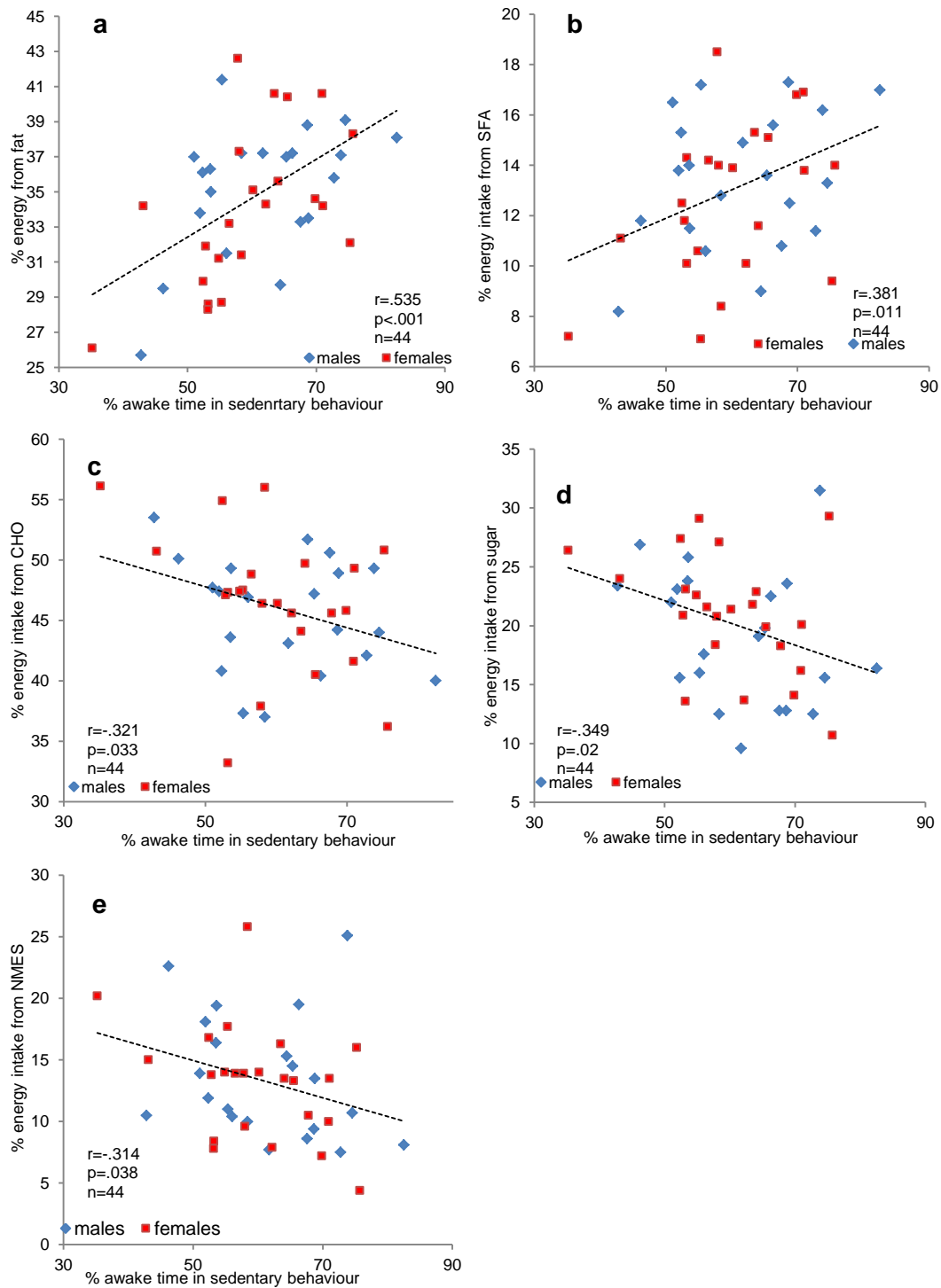


**Figure 3.18 Association between mean daily sedentary time (min) and dietary intake**

a=association between mean daily sedentary time (min) and percentage energy intake from fat

b=association between mean daily sedentary time (min) and percentage energy intake from sugar

When considering sedentary behaviour as a percentage of time awake it was found to be statistically significantly positively associated with percent energy intake from fat ( $r=.535$ ,  $p<.001$ ) and with percent energy intake from SFA ( $r=.381$ ,  $p=.011$ ). It was found to be statistically significantly negatively associated with percent energy from CHO ( $r=-.321$ ,  $p=.033$ ), with percent energy from sugar ( $r=-.349$ ,  $p=.02$ ) and with percent energy from NMES ( $r=-.314$ ,  $p=.038$ ) (figure 3.19) but no other statistically significant associations were found with measures of dietary intake including total energy intake.

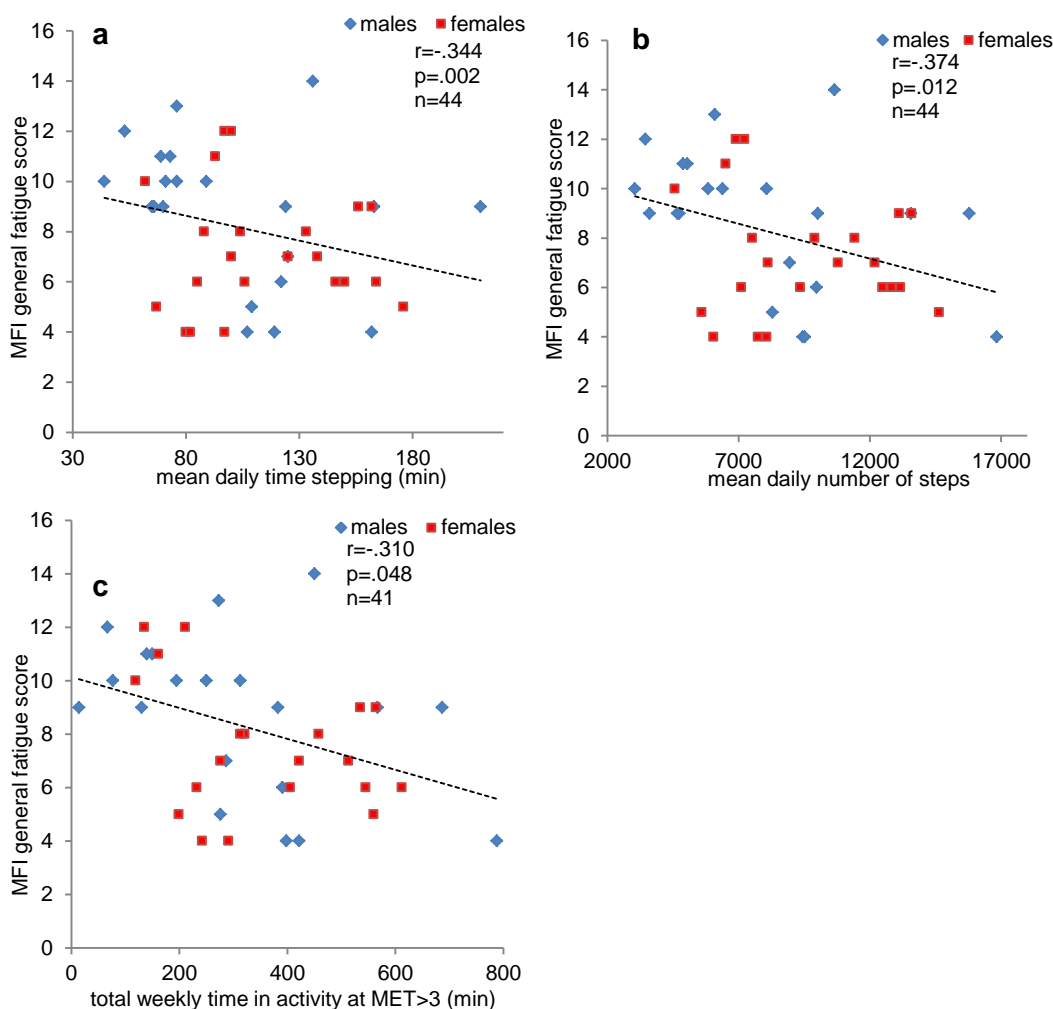


**Figure 3.19 Association between mean daily percent time awake in sedentary behaviour and dietary intakes**

a=association between percentage time awake in sedentary behaviour %energy intake from fat  
 b=association between percentage time awake in sedentary behaviour %energy intake from SFA  
 c=association between percentage time awake in sedentary behaviour %energy intake from CHO  
 b=association between percentage time awake in sedentary behaviour %energy intake from sugar  
 e=association between percentage time awake in sedentary behaviour %energy intake from NIMES

### 3.10.5 Relationship between habitual activity and levels of fatigue

Levels of fatigue were measured using the Multi-dimensional Fatigue Inventory (MFI) (Smets et al., 1995) and these scores were correlated with levels of habitual activity using spearman rho correlation analysis. The general fatigue score of the MFI was found to have a statistically significant negative association with mean daily time stepping (min) ( $r=-.344$ ,  $p=.022$ ), with mean daily number of steps ( $r=-.374$ ,  $p=.012$ ) and with total weekly time spent in activity at MET > 3 (min) ( $r=-.310$ ,  $p=.048$ ) (figure 3.20).



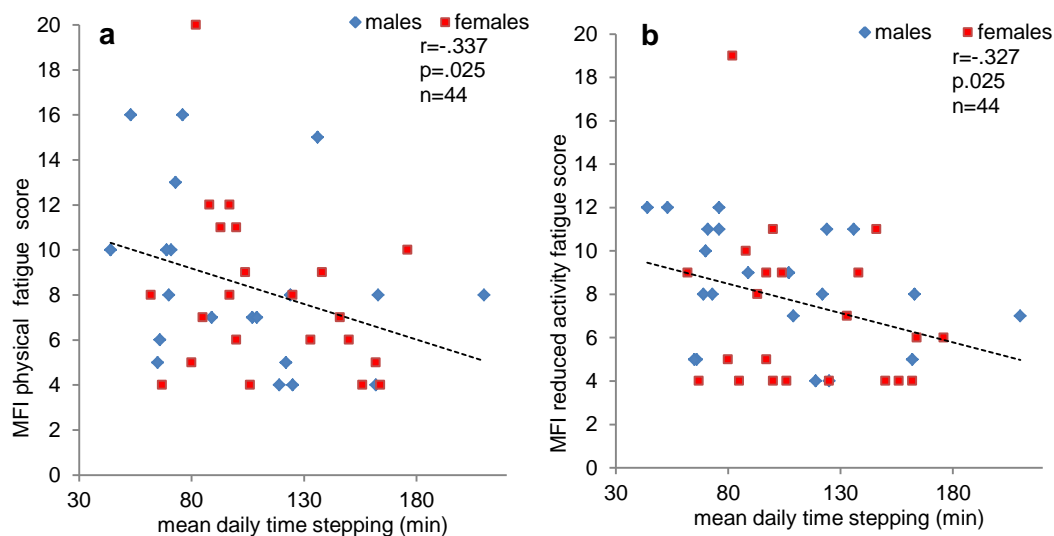
**Figure 3.20 Association levels of general fatigue and levels of habitual activity**

a=association between mean daily time stepping (min) and general fatigue score

b=association between mean daily number of steps and general fatigue score

c=association between total weekly time in activity at MET > 3 and general fatigue score

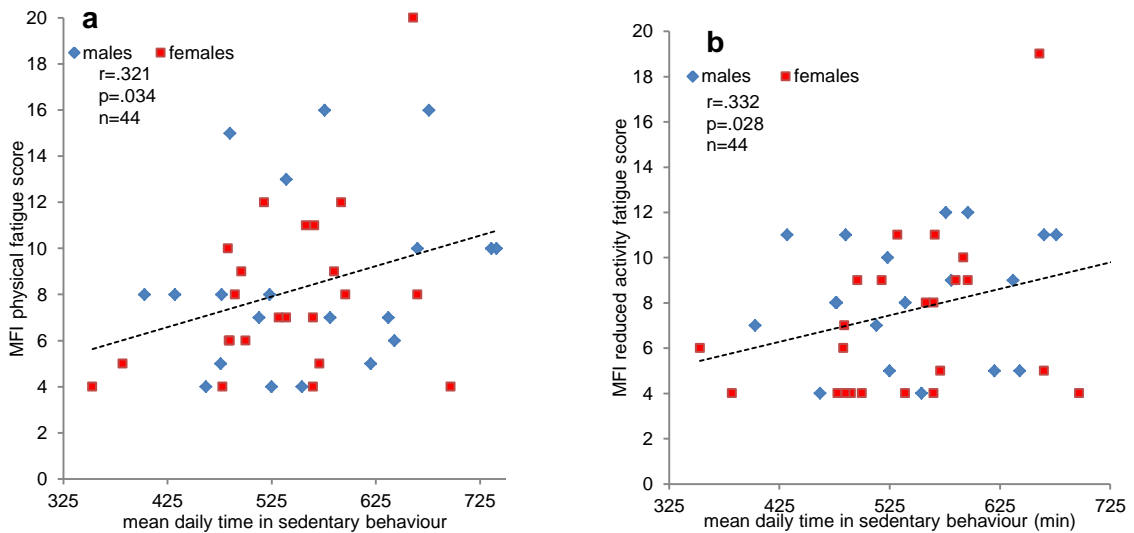
Mean daily time stepping (min) was also found to have a statistically significant negative association with physical fatigue score ( $r=-.337$ ,  $p=.025$ ) and the reduced activity fatigue score ( $r=-.327$ ,  $p=.025$ ) (figure 3.21).



**Figure 3.21 Association between mean daily time spent stepping (min) and levels of fatigue**  
a=association between mean daily time stepping (min) and physical fatigue score  
b=association between mean daily time stepping (min) and reduced activity fatigue score

Mean daily time spent in sedentary behaviour was found to be statistically significantly positively associated with physical fatigue scores ( $r=.321$ ,  $p=.034$ ) and with reduced activity fatigue scores ( $r=.332$ ,  $p=.028$ ) (figure 3.22).





**Figure 3.22 Association between mean daily time spent stepping (min) and levels of fatigue**

a=association between mean daily time sedentary behaviour (min) and MFI physical fatigue score

b=association between mean daily time stepping (min) and reduced activity fatigue score

No other statistically significant associations were found between levels of habitual activity and levels of fatigue.

### 3.10.6 Relationship of habitual activity BP, inflammation and antioxidant status

Correlation analysis was also performed using Spearman's rho correlation coefficient analysis between levels of habitual activity and blood pressure (mmHg), hsCRP (mg/L) and antioxidant status but no statistically significant associations were found .

### 3.11 PARTIAL CORRELATION ANALYSIS

The intention at the start of the study was to develop a regression model for habitual activity based on the parameters measured. However due to the smaller sample size than expected this analysis would no longer be meaningful. The general rule of thumb based on Harrell (2002) is that 10 - 20 observations are required per covariate to detect

an effect size at an appropriate level of power. It was however possible to undertake a partial correlation analysis controlling for age and gender.

### 3.11.1 Levels of habitual activity and nutritional status controlled for age and gender

The initial analysis determined that BMI ( $\text{kg/m}^2$ ) and WC (cm) but no other markers of nutritional status were associated with levels of habitual activity. A partial correlation analysis was performed with these parameters to control for age and gender both separately and together. The results from this partial correlation analysis between levels of habitual activity and nutritional status are shown in table 3.25 and table 3.26. The initial Pearson's correlation coefficient analysis is also shown for reference and comparison.

**Table 3.25 Association between BMI ( $\text{kg/m}^2$ ) and levels of habitual activity controlled for age and gender**

	BMI ( $\text{kg/m}^2$ )			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
mean daily time in sedentary behaviour (min)	$r=.365, p=.016$	$r=.396, p=.009$	$r=.351, p=.023$	$r=.373, p=.016$
% awake time in sedentary behaviour	$r=.302, p=.049$	$r=.322, p=.038$	$r=.306, p=.049$	$r=.317, p=.044$

When the relationship between BMI ( $\text{kg/m}^2$ ) and mean daily time spent in sedentary behaviour (min) was controlled for age, the relationship remained statistically significant and the strength of the relationship increased to a small degree ( $r=.396, p=.009$  vs  $r=.365, p=.016$ ). This increased strength of association is attributable to the relationship which exists between mean daily time in sedentary behaviour (min) and age ( $r=.416, p=.005$ ) as no statistically significant relationship exists between BMI ( $\text{kg/m}^2$ ) and age. When controlled for gender the relationship between mean daily time in sedentary

behaviour (min) and BMI ( $\text{kg/m}^2$ ) remained statistically significant although the strength of the relationship lessened ( $r=.351, p=.023$  vs  $r=.365, p=.016$ ). No statistically significant relationship existed between mean daily time in sedentary behaviour (min) and gender or between gender and BMI ( $\text{kg/m}^2$ ) thus explaining the change in the strength of the relationship. The relationship between mean daily time in sedentary behaviour (min) and BMI ( $\text{kg/m}^2$ ) is therefore influenced by age and not gender. Unsurprisingly then when a second order partial correlation analysis was performed controlling for age and gender together the relationship remained statistically significant and the strength of the relationship increased ( $r=.373, p=.016$  vs  $r=.365, p=.016$ ) as a result of the statistically significant relationship between mean daily sedentary time (min) and age.

Similar analysis was performed for WC and levels of habitual activity and this is shown in table 3.26.

**Table 3.26 Association between WC (cm) and levels of habitual activity controlled for age and gender**

	WC (cm)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
mean daily time sitting and lying (min)	$r=.335, p=.030$	$r=.356, p=.022$	$r=.389, p=.012$	$r=.391, p=.013$
mean daily time stepping (min)	$r=-.427, p=.005$	$r=-.473, p=.002$	$r=-.415, p=.007$	$r=-.433, p=.005$
mean daily number of steps	$r=-.380, p=.013$	$r=-.410, p=.008$	$r=-.359, p=.021$	$r=-.364, p=.021$
mean daily time in sedentary behaviour (min)	$r=.472, p=.002$	$r=.518, p=.001$	$r=.482, p=.001$	$r=.504, p=.001$
% time awake spent in sedentary behaviour	$r=.302, p=.049$	$r=.462, p=.005$	$r=.437, p=.004$	$r=.447, p=.004$

The relationships between WC (cm) and mean daily time sitting and lying (min), mean daily time in sedentary behavior (min) and percent awake time in sedentary behavior remained statistically significant and the strength of the relationships increased after

controlling for age only ( $r=.356$ ,  $p=.022$  vs  $r=.335$ ,  $p=.030$ ,  $r=.518$ ,  $p=.001$  vs  $r=.472$ ,  $p=.002$ ,  $r=.462$ ,  $p=.005$  vs  $r=.302$ ,  $p=.049$  respectively) and gender only ( $r=.389$ ,  $p=.012$  vs  $r=.335$ ,  $p=.030$ ,  $r=.482$ ,  $p=.001$  vs  $r=.472$ ,  $p=.002$ ,  $r=.462$ ,  $p=.005$  vs  $r=.302$ ,  $p=.049$  respectively). The relationship also remained statistically significant and the strength increased when controlling for these together ( $r=.391$ ,  $p=.013$  vs  $r=.335$ ,  $p=.030$ ,  $r=.504$ ,  $p=.001$  vs  $r=.472$ ,  $p=.002$ ,  $r=.447$ ,  $p=.004$  vs  $r=.302$ ,  $p=.049$  respectively). The relationship between WC (cm) and mean daily time stepping (min) and mean daily number of steps remained statistically significant when controlling for both age and gender together however when controlling for age only the relationship strengthened ( $r=-.473$ ,  $p=.002$  vs  $r=-.427$ ,  $p=.005$ ,  $r=-.410$ ,  $p=.008$  vs  $r=-.380$ ,  $p=.013$  respectively) and when controlling for gender the strength of the relationship weakened ( $r=-.415$ ,  $p=.007$  vs  $r=-.427$ ,  $p=.005$ ,  $r=-.359$ ,  $p=.021$  vs  $r=-.380$ ,  $p=.013$ ).

The changes in the strength of association are attributable to the relationships which exist between age and each measure of habitual activity (mean daily time spent sitting and lying  $r=.325$ ,  $p=.036$ ; mean daily time stepping  $r=-.422$ ,  $p=.005$ ; mean daily number of step  $r=-.362$ ,  $p=.018$ ; mean daily time in sedentary behaviour  $r=.405$ ,  $p=.008$ ; percentage awake time in sedentary behaviour  $r=.367$ ,  $p=.017$ ) and between gender and WC ( $r=-.591$ ,  $p<.001$ ). There were no statistically significant relationships between age and WC or between gender and levels of habitual activity. Age and gender appear to both influence the relationship between WC and measures of habitual activity but as a result of their influence on different parameters i.e. age with measures of habitual activity and gender with WC.

### 3.11.2 Levels of habitual activity and functional status controlled for age and gender

STS and 6MW tests were found to be statistically significantly associated with levels of habitual activity and so partial correlation analysis was performed to control for age and gender separately and together. The results for this analysis are shown in tables 3.27 and 3.28.

**Table 3.27 Association between STS (s) and levels of habitual activity controlled for age and gender**

	STS (s)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
mean daily time stepping (min)	$r=-.344, p=.022$	$r=-.234, p=.131$	$r=-.340, p=.025$	$r=-.218, p=.165$
mean daily number of steps	$r=-.330, p=.028$	$r=-.236, p=.127$	$r=-.326, p=.033$	$r=-.221, p=.159$
total weekly time spent in activity at MET>3 when accumulated in blocks of at least 10 minutes (min)	$r=-.321, p=.041$	$r=-.204, p=.206$	$r=-.325, p=.041$	$r=-.208, p=.204$

The partial correlation analysis between levels of habitual activity and STS (s) were no longer statistically significant after controlling for age only and age and gender together. The relationship remained statistically significant when controlling for gender only with the strength of the relationship lessening between STS and mean daily time stepping ( $r=-.340, p=.025$  vs  $r=-.344, p=.022$ ) and between STS and mean daily number of steps ( $r=-.326, p=.033$  vs  $r=-.330, p=.028$ ). The strength of the relationship between STS and total weekly time in activity at MET > 3 when accumulated in blocks of at least 10 minutes increased ( $r=-.325, p=.041$  vs  $r=-.321, p=.041$ ). These changes can be attributed to the statistically significant relationship between age and both STS (s) ( $r=.322, p=.04$ ) and measures of habitual activity (mean daily time stepping (min) ( $r=-.415, p=.005$ ), mean daily number of steps ( $r=-.353, p=.019$ ), total weekly time in activity at MET > 3 accumulated in blocks of at least 10 minutes (min) ( $r=-.466, p=.002$ )).

In terms of the relationship between 6MW (m) and mean daily time sitting and lying (min), this relationship was no longer statistically significant when controlled for age or for age and gender together, although the strength of the relationship remained constant when controlled for gender only (table 3.28).

**Table 3.28 Association between 6MW (m) and levels of habitual activity controlled for age and gender**

	6MW (m)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
mean daily time sitting and lying (min)	r=-.396, p=.008	r=-.272, p=.077	r=-.396, p=.009	r=-.265, p=.090
mean daily time stepping (min)	r=.594, p<.001	r=.475, p=.001	r=.582, p<.001	r=.437, p=.004
mean daily number of steps	r=.530, p<.001	r=.425, p=.004	r=.516, p<.001	r=.386, p=.012
mean daily time in sedentary behaviour (min)	r=-.503, p=.001	r=-.360, p=.018	r=-.490, p=.001	r=-.321, p=.038
percentage time awake in sedentary behaviour	r=-.445, p=.002	r=-.308, p=.044	r=-.440, p=.003	r=-.289, p=.063
total weekly time spent in activity at MET>3 (min)	r=.443, p=.004	r=.344, p=.03	r=.433, p=.005	r=.317, p=.049

However the strength of the relationships between 6MW (m) and mean daily time stepping (min), mean daily number of steps, mean daily time in sedentary behavior (min) and totally weekly time in activity at MET>3 (min) all lessened when controlling for age only (r=.475 p=.001 vs r=.594, p<.001; r=.425, p=.004 vs r=.530, p<.001; r=-.360, p=.018 vs r=-.503, p=.001; r=.344, p=.03 vs r=.443, p=.004 respectively) for gender only (r=.582, p<.001 vs r=.594, p<.001; r=.516, p<.001 vs r=.530, p<.001; r=-.440, p=.003 vs r=-.445, p=.002 respectively) and age and gender together (r=.437, p=.004 vs r=.594, p<.001; r=.386, p=.012 vs r=.530, p<.001; r=-.321, p=.038 vs r=-.503, p=.001; r=.317, p=.049 vs r=.443, p=.004 respectively). Finally the relationship between 6MW (m) and percentage time awake in sedentary behavior was no longer statistically

significant when controlled for age and gender together and the strength of the relationship lessened although remained statistically significant when controlled for age only ( $r=-.308$ ,  $p=.044$  vs  $r=-.445$ ,  $p=.002$ ) and gender only ( $r=-.440$ ,  $p=.003$  vs  $p=.044$  vs  $-.445$ ,  $p=.002$ ).

The changes in the relationships can be attributed to the statistically significant relationship between age and 6MW (m) ( $r=-.598$ ,  $p<.001$ ) and between age and measures of habitual activity (mean daily time sitting and lying (min) ( $r=.316$ ,  $p=.037$ ), mean daily time stepping (min) ( $r=-.415$ ,  $p=.005$ ), mean daily number of steps ( $r=-.353$ ,  $p=.019$ ), mean daily time in sedentary behavior (min) ( $r=.398$ ,  $p=.007$ ) and percentage awake time in sedentary behavior ( $r=.358$ ,  $p=.017$ )). There was no statistically significant relationship found between age and total weekly time in activity at MET > 3 (min). In addition there was no statistically significant relationship found between gender and 6MW (m) and between gender and any measure of habitual activity.

In view of the changes in the relationships between functional status and habitual activity following partial correlation analysis, it can be seen that age rather than gender influences these relationships. As both nutritional status and functional status are influenced by dietary intakes the relationship between diet and habitual activity may be important and a determination of whether statistically significant relationships remain after controlling for age and gender should also be considered.

### 3.11.3 Levels of habitual activity and dietary intakes controlled for age and gender

A partial correlation analysis was therefore performed on the statistically significant relationships between dietary intakes and habitual activity. The relationship between mean daily time spent sitting and lying (min) and dietary intakes were controlled for age and gender and are shown in table 3.29. The initial Pearson's correlation analysis is also shown for reference and comparison.

**Table 3.29 Association between mean daily time sitting and lying and dietary intake controlled for age and gender**

	mean daily time sitting and lying (min)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
% energy intake from fat	$r=.572, p<.001$	$r=.539, p<.001$	$r=.573, p<.001$	$r=.573, p<.001$
% energy intake from SFA	$r=.429, p=.004$	$r=.433, p=.004$	$r=.429, p=.004$	$r=.428, p=.005$
% energy from MUFA	$r=.316, p=.037$	$r=.292, p=.057$	$r=.319, p=.037$	$r=.285, p=.067$
% energy intake from CHO	$r=-.385, p=.01$	$r=-.445, p=.003$	$r=-.384, p=.011$	$r=-.442, p=.003$
% energy intake from sugar	$r=-.354, p=.018$	$r=-.321, p=.036$	$r=-.354, p=.02$	$r=-.315, p=.042$
% energy intake from NMES	$r=-.342, p=.023$	$r=-.348, p=.022$	$r=-.354, p=.024$	$r=-.351, p=.022$

The relationships between mean daily time sitting and lying (min) and percent energy intake from fat and percent energy intake from sugar remained statistically significant after controlling for both age and gender separately. When controlling for age only the strength of the relationships lessened ( $r=.539, p<.001$  vs  $r=.572, p<.001$ ;  $r=-.321, p=.036$  vs  $r=-.354, p=.018$  respectively) and for gender only the relationship with percent energy from fat increased to a very small degree ( $r=.573, p<.001$  vs  $r=.572, p<.001$ ) and with percent energy intake from sugar the relationship remained constant ( $r=-.354, p=.02$  vs  $r=-.354, p=.018$ ). When controlling for age and gender together the relationship between mean daily time sitting and lying (min) and percent energy intake from fat remained statistically significant and increased by a very small degree ( $r=.573,$



$p < .001$  vs  $r = .572$ ,  $p < .001$ ) whilst the relationship with percent energy intake from sugar lessened ( $r = -.315$ ,  $p = .042$  vs  $r = -.354$ ,  $p = .018$ ) although it too remained statistically significant.

The relationship between mean daily time sitting and lying (min) and percent energy intake from SFA remained statistically significant and strengthened when controlling for age only ( $r = .433$ ,  $p = .004$  vs  $r = .429$ ,  $p = .004$ ) and remained constant and statistically significant when controlling for gender only ( $r = .429$ ,  $p = .004$  vs  $r = .429$ ,  $p = .004$ ). When considering the combined effects of age and gender the relationship remained statistically significant but lessened to a very small degree ( $r = .428$ ,  $p = .005$  vs  $r = .429$ ,  $p = .004$ ). The same is true for the relationship between mean daily time sitting and lying (min) and percent energy from CHO where the relationship remained statistically significant and strengthened when controlling for age only ( $r = -.445$ ,  $p = .003$  vs  $r = -.385$ ,  $p = .01$ ) but not when controlling for gender only where the relationship lessened albeit to a very small degree ( $r = -.384$ ,  $p = .011$  vs  $r = -.385$ ,  $p = .01$ ). When controlling for age and gender together the relationship strengthened and remained statistically significant ( $r = -.442$ ,  $p = .003$  vs  $r = -.385$ ,  $p = .01$ ).

The relationship between mean daily time sitting and lying (min) and percent energy intake from MUFA remained statistically significant when controlling for age and gender separately with the relationship strengthening when controlling for gender only ( $r = .319$ ,  $p = .037$  vs  $r = .316$ ,  $p = .037$ ) and weakening when controlling for age only ( $r = .292$ ,  $p = .057$  vs  $r = .316$ ,  $p = .037$ ). When controlling for age and gender in combination the relationship was no longer statistically significant. The relationship between mean daily time sitting and lying (min) and percent energy intake from NMES remained statistically

significant when controlling for age and gender separately and combined. The relationship strengthened when controlling for age only ( $r=-.348$ ,  $p=.022$  vs  $r=-.342$ ,  $p=.023$ ), gender only ( $r=-.343$ ,  $p=.024$  vs  $r=-.342$ ,  $p=.023$ ) and age and gender combined ( $r=-.351$ ,  $p=.022$  vs  $r=-.342$ ,  $p=.023$ ).

The changes in the relationships between mean daily time sitting or lying (min) and dietary intake were attributable to the statistically significant relationship between age and mean daily time sitting or lying (min) ( $r=.316$ ,  $p=.037$ ). There was no statistically significant relationship between gender and time spent sitting or lying (min) or between age or gender and any measure of dietary intake.

The relationship between mean daily time spent standing (min) and dietary intake was assessed further in that it was controlled for age and gender separately and in combination. The results of the partial correlation analysis are shown in table 3.30.

**Table 3.30 Association between mean daily time standing (min) and dietary intake controlled for age and gender**

	mean daily time standing (min)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
% energy intake from fat	$r=-.50$ , $p=.001$	$r=-.475$ , $p=.001$	$r=-.512$ , $p<.001$	$r=-.487$ , $p=.001$
% energy intake from SFA	$r=-.379$ , $p=.011$	$r=-.375$ , $p=.013$	$r=-.390$ , $p=.01$	$r=-.384$ , $p=.012$
% energy intake from CHO	$r=.404$ , $p=.006$	$r=.438$ , $p=.003$	$r=.411$ , $p=.006$	$r=.442$ , $p=.003$
% energy intake from sugar	$r=.334$ , $p=.027$	$r=.311$ , $p=.042$	$r=.347$ , $p=.023$	$r=.322$ , $p=.038$
% energy intake from NMES	$r=-.408$ , $p=.006$	$r=-.409$ , $p=.006$	$r=-.407$ , $p=.007$	$r=.409$ , $p=.007$

After controlling for age and gender separately the relationships between mean daily time standing (min) and percent energy intake from fat, percent energy from SFA and percent energy from sugar remained statistically significant. The relationships weakened when controlling for age only ( $r=-.475$ ,  $p=.001$  vs  $r=-.50$ ,  $p=.001$ ;  $r=-.375$ ,

$p=.013$  vs  $r=-.379$ ,  $p=.011$ ;  $r=.311$ ,  $p=.042$  vs  $r=.334$ ,  $p=.027$  respectively) and strengthened when controlling for gender only ( $r=-.512$ ,  $p<.001$  vs  $r=-.50$ ,  $p=.001$ ;  $r=-.390$ ,  $p=.01$  vs  $r=-.379$ ,  $p=.011$ ;  $r=.347$ ,  $p=.023$  vs  $r=.334$ ,  $p=.027$  respectively). When controlling for age and gender in combination the relationships between mean daily time standing (min) and percent energy from fat and percent energy from sugar remained statistically significant but the strength of the relationship lessened ( $r=-.487$ ,  $p=.001$  vs  $r=-.50$ ,  $p=.001$ ;  $r=.322$ ,  $p=.038$  vs  $r=.334$ ,  $p=.027$  respectively) whereas the relationship with percent energy intake from SFA strengthened when controlling for age and gender combined ( $r=-.384$ ,  $p=.012$  vs  $r=-.379$ ,  $p=.011$ ).

The relationship between mean daily time standing (min) and percent energy from CHO remained statistically significant and strengthened when controlling for age ( $r=.438$ ,  $p=.003$  vs  $r=.404$ ,  $p=.006$ ) and gender separately ( $r=.411$ ,  $p=.006$  vs  $r=.404$ ,  $p=.006$ ) and together ( $r=.442$ ,  $p=.003$  vs  $r=.404$ ,  $p=.006$ ). In contrast the relationship between mean daily time standing (min) and percent energy from NMES increased when controlling for age only ( $r=-.409$ ,  $p=.006$  vs  $r=-.408$ ,  $p=.006$ ) and age and gender in combination ( $r=-.409$ ,  $p=.006$  vs  $r=-.408$ ,  $p=.007$ ) and lessened when controlling for gender only ( $r=-.407$ ,  $p=.007$  vs  $r=-.408$ ,  $p=.006$ ).

The changes in the relationships between mean daily time standing (mins) and dietary intake could not be attributed to either age or gender as there were no statistically significant relationships between age and mean daily time spent standing (min) or age and dietary intakes and no statistically significant relationship between gender and mean daily time spent standing (min) or gender and measures of dietary intake.

A partial correlation was performed on the relationship between mean daily time stepping (min) and dietary intake to control for age and gender to ascertain whether these relationships are influenced by these parameters independently and/or in combination with each other. The results for this analysis are shown in table 3.31.

**Table 3.31 Association between mean daily time stepping (min) and dietary intake controlled for age and gender**

	mean daily time stepping (min)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
% energy intake from fat	r=-.491, p=.001	r=-.444, p=.003	r=-.477, p=.001	r=-.420, p=.006
% energy intake from SFA	r=-.366, p=.015	r=-.374, p=.013	r=-.349, p=.022	r=-.352, p=.022
% energy intake from MUFA	r=-.299, p=.049	r=-.272, p=.078	r=-.265, p=.086	r=-.218, p=.166
protein intake (g/kgBW)	r=.327, p=.020	r=.294, p=.056	r=.313, p=.041	r=.271, p=.083

The relationship between mean daily time stepping (min) and percent energy from fat remained statistically significant although this relationship lessened when controlling for both age only (r=-.444, p=.003 vs r=-.491, p=.001) and gender only (r=-.477, p=.001 vs r=-.491, p=.001) and age and gender in combination (r=-.420, p=.006 vs r=-.491, p=.001). When considering the relationship between mean daily time stepping (min) and percent energy intake from SFA this relationship remained statistically significant and strengthened when controlling for age only (r=-.374, p=.013 vs r=-.366, p=.015) and lessened when controlling for both gender only (r=-.349, p=.022 vs r=-.366, p=.015) and age and gender in combination (r=-.352, p=.022 vs r=-.366, p=.015).

The relationship between mean daily time stepping (min) and percent energy intake from MUFA was no longer statistically significant when controlling for age and gender separately and together. The relationship between mean daily time stepping (min) and protein intakes (g/kgBW) were no longer statistically significant when controlling for age only and when controlling for age and gender together. However when controlling for

gender only the relationship remained statistically significant although the strength of the relationship lessened ( $r=.313$ ,  $p=.041$  vs  $r=.327$ ,  $p=.020$ ).

The changes in the relationship between mean daily time stepping (min) and dietary intake are attributable to the statistically significant relationship between age and mean daily time stepping (min) ( $r=-.415$ ,  $p=.005$ ). There was no statistically significant relationship between age and any measure of dietary intake or between gender and mean daily time stepping (min) or between gender and any measure of dietary intake.

The relationships between mean daily number of steps and dietary intakes were further explored using partial correlation analysis and the results from this analysis are shown in table 3.32.

**Table 3.32 Association between mean daily number of steps and dietary intake controlled for age and gender**

	mean daily number of steps			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
% energy intake from fat	$r=-.455$ , $p=.002$	$r=-.408$ , $p=.007$	$r=-.441$ , $p=.003$	$r=-.384$ , $p=.012$
% energy intake from SFA	$r=-.344$ , $p=.027$	$r=-.334$ , $p=.028$	$r=-.316$ , $p=.039$	$r=-.311$ , $p=.045$
protein intake (g/kgBW)	$r=.350$ , $p=.02$	$r=.320$ , $p=.036$	$r=.336$ , $p=.028$	$r=.299$ , $p=.054$
mean daily vitamin D intake ( $\mu\text{g}$ )	$r=.322$ , $p=.033$	$r=.269$ , $p=.081$	$r=.340$ , $p=.026$	$r=.288$ , $p=.065$

The relationships between mean daily number of steps and percent energy intake from fat and SFA remained statistically significant when controlling for age only although the strength of the relationships lessened ( $r=-.408$ ,  $p=.007$  vs  $r=-.455$ ,  $p=.002$ ;  $r=-.334$ ,  $p=.028$  vs  $r=-.344$ ,  $p=.027$  respectively) and this was also true when controlling for gender only ( $r=-.441$ ,  $p=.003$  vs  $r=-.455$ ,  $p=.002$ ;  $r=-.311$ ,  $p=.045$  vs  $r=-.344$ ,  $p=.027$  respectively). When controlling for age and gender in combination it is therefore not

surprising that strength of the relationship lessened with the relationships remaining statistically significant ( $r=-.384$ ,  $p=.012$  vs  $r=-.455$ ,  $p=.002$ ;  $r=-.311$ ,  $p=.045$  vs  $r=-.344$ ,  $p=.027$ ).

The relationship between mean daily number of steps and protein intake (g/kgBW) remained statistically significant when controlling for age ( $r=.320$ ,  $p=.036$  vs  $r=.350$ ,  $p=.02$ ) and gender ( $r=.336$ ,  $p=.028$  vs  $r=.350$ ,  $p=.02$ ) however the strength of the relationship lessened. However, when controlling for age and gender in combination, the relationship was no longer statistically significant. The relationship between mean daily number of steps and vitamin D ( $\mu\text{g}$ ) intake remained statistically significant when controlling for gender although the strength of the relationship lessened ( $r=.340$ ,  $p=.026$  vs  $r=.322$ ,  $p=.033$ ) and when controlling for age only and age and gender combined the relationship was no longer statistically.

The changes in the relationship between mean daily number of steps and dietary intake are attributable to the statistically significant relationship between age and mean daily number of steps ( $r=-.353$ ,  $p=.019$ ) as there was no statistically significant relationship between age and measures of dietary intake, between gender and mean daily number of steps or between gender and measures of dietary intake.

The relationships between total weekly time spent in moderate intensity activity (i.e. activity at MET > 3) (min) and dietary intake was further explored using partial correlation analysis and the results of this analysis are shown in table 3.33.

**Table 3.33 Association between total weekly time spent in moderate intensity activity (MET>3) and dietary intake controlled for age and gender**

	total weekly time activity MET>3 (min)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
% energy intake from fat	r=-.403, p=.009	r=-.334, p=.03	r=-.390, p=.013	r=-.321, p=.047
% energy intake from protein	r=.341, p=.029	r=.311, p=.05	r=.332, p=.036	r=.298, p=.066
mean daily total protein intake (g)	r=.445, p=.004	r=.373, p=.018	r=.517, p=.001	r=.451, p=.004
protein intake (g/kgBW)	r=.443, p=.004	r=.409, p=.009	r=.433, p=.005	r=.392, p=.014
mean daily vitamin D intake (µg)	r=.419, p=.006	r=.378, p=.016	r=.429, p=.006	r=.387, p=.015

The relationship between total weekly time spent in moderate intensity activity (min) and percent energy intake from fat and percent energy from protein remained statistically significant when controlling for age and gender separately. The strength of the relationships lessened when controlling for age alone ( $r=-.334, p=.03$  vs  $r=-.403, p=.009$ ;  $r=.311, p=.05$  vs  $r=.341, p=.029$  respectively) and for gender alone ( $r=-.390, p=.013$  vs  $r=-.403, p=.009$ ;  $r=.332, p=.036$  vs  $r=.341, p=.029$  respectively). When controlling for age and gender together the relationship between total weekly time in activity at MET > 3 (min) and percent energy from fat also lessened but remained statistically significant ( $r=-.321, p=.047$  vs  $r=-.403, p=.009$ ). The relationship between total weekly time in activity at MET > 3 (min) and percent energy from protein was no longer statistically significant when controlling for age and gender combined.

The relationship between total weekly time in activity at MET > 3 (min) and protein intake measured as g/kgBW, remained statistically significant after partial correlation analysis however the relationships lessened when controlling for age only ( $r=.409, p=.009$  vs  $r=.443, p=.004$ ) gender only ( $r=.433, p=.005$  vs  $r=.443, p=.004$ ) and age and gender combined ( $r=.392, p=.014$  vs  $r=.443, p=.004$ ).

The relationship between total weekly time spent in moderate intensity activity (min) and mean daily protein intake (g) and vitamin D intake ( $\mu\text{g}$ ) remained statistically significant when controlling for age and gender separately. However the relationships lessened when controlling for age only ( $r=.373$ ,  $p=.018$  vs  $r=.445$ ,  $p=.004$ ;  $r=.378$ ,  $p=.016$  vs  $r=.419$ ,  $p=.006$  respectively) and age and gender combined ( $r=.451$ ,  $p=.004$  vs  $r=.445$ ,  $p=.004$ ;  $r=.387$ ,  $p=.015$  vs  $r=.419$ ,  $p=.006$  respectively) and strengthened when controlling for gender only ( $r=.517$ ,  $p=.001$  vs  $r=.445$ ,  $p=.004$ ;  $r=.429$ ,  $p=.006$  vs  $r=.419$ ,  $p=.006$  respectively).

The changes in the relationship between total weekly time in activity at MET > 3 i.e. moderate intensity activity and percent energy intake from fat, percent energy intake from protein, protein intake measured as g/kgBW and vitamin D intakes ( $\mu\text{g}$ ) cannot be attributed to either age or gender as no statistically significant relationship existed between age and these measures of dietary intake or age and total weekly time spent in activity at MET > 3 (min). This is also true for gender as no statistically significant relationship was found between gender and these measures of dietary intake or between gender and total weekly time in activity at MET > 3 (min). The changes in the relationship between total weekly time at MET > 3 and total protein intakes (g) can however be attributed to gender as a statistically significant relationship was found between gender and total protein intake (g) ( $r=-.313$ ,  $p=.046$ ).

A partial correlation analysis was performed on the relationship between total weekly time in moderate intensity activity when accumulated in blocks of at least 10 minutes (min) and dietary intake. The results of this analysis are shown in table 3.34.



**Table 3.34 Association between total weekly time spent in moderate intensity activity (MET>3) accumulated in blocks of at least 10 minutes and dietary intake controlled for age and gender**

	activity MET>3 accumulated in blocks of t least 10 minutes (min)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
mean daily protein intake (g)	r=.350, p=.025	r=.208, p=.197	r=.342, p=.031	r=.205, p=.211
mean daily NSP intake (g)	r=.309, p=.049	r=.332, p=.043	r=.299, p=.061	r=.321, p=.046
mean daily vitamin D intake (µg)	r=.404, p=.009	r=.347, p=.028	r=.403, p=.01	r=.347, p=.031

The relationship between total weekly time in moderate intensity activity accumulated in blocks of at least 10 minutes (min) and mean daily protein intake (g) were no longer statistically significant when controlling for age only (r=.208, p=.197 vs r=.350, p=.025) and age and gender in combination (r=.205, p=.211 vs r=.305, p=.025). When controlling for gender only the relationship remained statistically significant but the strength of the relationship lessened (r=.342, p=.031 vs r=.350, p=.025). The relationship between time in activity at MET > 3 when accumulated in blocks of at least 10 minutes (min) and mean daily NSP intake (g) remained statistically significant after controlling for age only and age and gender in combination with the strength of the relationship increasing (r=.332, p=.043 vs r=.309, p=.049; r=.321, p=.046 vs r=.309, p=.049). However when controlling for gender only the relationship was no longer statistically significant (r=.299, p=.061 vs r=.309, p=.049). This marker of habitual activity (i.e. time in activity at MET > 3 accumulated in blocks of at least 10 minutes (min)) and vitamin D intake (µg) remained statistically significant but lessened when controlling for age only (r=.347, p=.028 vs r=.404, p=.009), when controlling for gender only (r=.403, p=.01 vs r=.404, p=.009) and thus unsurprisingly when controlling for age and gender combined the strength of the relationship also lessened (r=.347, p=.031 vs r=.404, p=.009) whilst remaining statistically significant.

The changes in the relationships between age and gender and total weekly time in activity at MET > 3 when accumulated in blocks of at least 10 minutes (min) are attributable to the statistically significant relationship between age and this measure of habitual activity ( $r=-.466$ ,  $p=.002$ ). There was no statistically significant relationship between age and any measure of dietary intake, between gender and total weekly time in activity in MET > 3 when accumulated in blocks of at least 10 minutes (min) or between gender and measures of dietary intake and so these relationships do not appear to influence the overall relationship.

The statistically significant relationships between mean daily time in moderate intensity activity (min) and dietary intakes were also further examined using partial correlation analysis to control for age and gender separately and together. The results from this analysis are shown in table 3.35.

**Table 3.35 Association between mean daily time in moderate intensity activity (min) and dietary intake controlled for age and gender**

	mean daily time in activity MET>3 (min)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
% energy intake from sugar	$r=.362$ , $p=.018$	$r=.362$ , $p=.02$	$r=.363$ , $p=.02$	$r=.363$ , $p=.021$
% energy intake from NMES	$r=.333$ , $p=.031$	$r=.331$ , $p=.034$	$r=.334$ , $p=.033$	$r=.333$ , $p=.036$

The relationships between mean daily time in moderate intensity activity (min) and percent energy intake from sugar remained constant after controlling for age only ( $r=.362$ ,  $p=.02$  vs  $r=.362$ ,  $p=.018$ ) and increased when controlling for gender only ( $r=.363$ ,  $p=.02$  vs  $r=.362$ ,  $p=.018$ ) which also happened when controlling for age and gender in combination ( $r=.363$ ,  $p=.021$  vs  $r=.362$ ,  $p=.018$ ). The relationship between mean daily time in moderate intensity activity (min) and percent energy intake from NMES remained statistically significant although the strength of the relationship

lessened when controlling for age only ( $r=.331$ ,  $p=.034$  vs  $r=.333$ ,  $p=.031$ ) and strengthened when controlling for gender only ( $r=.334$ ,  $p=.033$  vs  $r=.333$ ,  $p=.031$ ). When controlling for age and gender in combination the relationship remained statistically significant and the strength of the relationship remained constant ( $r=.333$ ,  $p=.036$  vs  $r=.333$ ,  $p=.031$ ).

A similar analysis was also performed on the statistically significant relationships found between mean daily time in sedentary behaviour (min) and dietary intakes to control for age and gender independently and in combination and these results are shown in table 3.36.

**Table 3.36 Association between mean daily time in sedentary behaviour (min) and dietary intake controlled for age and gender**

	mean daily time in sedentary behaviour (min)			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
% energy intake from fat	$r=.445$ , $p=.002$	$r=.393$ , $p=.009$	$r=.432$ , $p=.004$	$r=.370$ , $p=.016$
% energy intake from sugar	$r=-.334$ , $p=.027$	$r=-.295$ , $p=.055$	$r=-.316$ , $p=.039$	$r=-.265$ , $p=.09$

The relationship between mean daily time in sedentary behaviour (min) and percent energy intake from fat and percent energy from sugar remained statistically significant after the partial correlation analysis. However the relationship lessened when controlling for age only ( $r=.393$ ,  $p=.009$  vs  $r=.445$ ,  $p=.002$ ;  $r=-.295$ ,  $p=.055$  vs  $r=-.334$ ,  $p=.027$  respectively) and when controlling for gender only ( $r=.432$ ,  $p=.004$  vs  $r=.445$ ,  $p=.002$ ;  $r=-.316$ ,  $p=.039$  vs  $r=-.334$ ,  $p=.027$  respectively). When controlling the relationship between mean daily time in sedentary behaviour (min) and percent energy from fat for age and gender in combination, the relationship also lessened although it remained statistically significant ( $r=.370$ ,  $p=.016$  vs  $r=.445$ ,  $p=.002$ ). However when

controlling the relationship between mean daily time in sedentary behaviour (min) and percent energy intake from sugar for age and gender in combination this relationship was no longer statistically significant ( $r=.333$ ,  $p=.036$  vs  $r=-.334$ ,  $p=.027$ ).

The changes in the relationships between mean daily time in sedentary behaviour (min) and dietary intake can be attributed to the statistically significant relationship between age and mean daily time in sedentary behaviour (min) ( $r=.398$ ,  $p=.007$ ). There was no statistically significant relationship between age and measures of dietary intake, between gender and mean daily time in sedentary behaviour (min) or between gender and measures of dietary intake.

Finally in terms of dietary intake, the relationships between percent time spent awake in sedentary behaviour and dietary intakes were also further analysed using partial correlation analysis to control for age and gender. These results are shown in table 3.37.

**Table 3.37 Association between percent time awake in sedentary behaviour and dietary intake controlled for age and gender**

	percent awake time in sedentary behaviour			
	Pearson's correlation coefficient	partial correlation controlled for age	partial correlation controlled for gender	partial correlation controlled for age and gender
% energy intake from fat	$r=.535$ , $p<.001$	$r=.496$ , $p=.001$	$r=.531$ , $p<.001$	$r=.487$ , $p=.001$
% energy intake from SFA	$r=.381$ , $p=.011$	$r=.385$ , $p=.011$	$r=.375$ , $p=.013$	$r=.374$ , $p=.015$
% energy intake from CHO	$r=-.321$ , $p=.033$	$r=-.389$ , $p=.01$	$r=-.317$ , $p=.038$	$r=-.383$ , $p=.012$
% energy intake from sugar	$r=-.349$ , $p=.02$	$r=-.314$ , $p=.014$	$r=-.343$ , $p=.025$	$r=-.299$ , $p=.055$
% energy intake from NMES	$r=-.314$ , $p=.038$	$r=-.322$ , $p=.035$	$r=-.317$ , $p=.038$	$r=-.328$ , $p=.034$

The relationships between percent awake time in sedentary behaviour and percent energy intake from fat and percent energy intake from sugar remained statistically significant when controlling for age and gender separately. The strength of the relationships did however lessen when controlling for age only ( $r=.496$ ,  $p=.001$  vs

$r=.535, p<.001$ ;  $r=-.314, p=.014$  vs  $r=-.349, p=.02$  respectively) and gender only ( $r=.531, p<.001$  vs  $r=.535, p<.001$ ;  $r=-.343, p=.025$  vs  $r=-.349, p=.02$  respectively). When controlling for age and gender in combination the strength of the relationship between percent awake time in sedentary behaviour and percent energy intake from fat remained statistically significant but unsurprisingly lessened ( $r=.487, p=.001$  vs  $r=.535, p<.001$ ). However the relationship with percent energy intake from sugar was no longer statistically significant.

When controlling the relationships between percent awake time in sedentary behaviour and percent intake from SFA and percent energy intake from CHO, the strength of the relationships increased when controlling for age only ( $r=.385, p=.011$  vs  $r=.381, p=.011$ ;  $r=-.389, p=.01$  vs  $r=-.321, p=.033$  respectively) and weakened when controlling for gender only ( $r=.375, p=.013$  vs  $r=.381, p=.011$ ;  $r=-.317, p=.038$  vs  $r=-.321, p=.033$  respectively). All these relationships remained statistically significant. When controlling for the combined effects of age and gender the relationship between percent awake time in sedentary behaviour and percent energy intake from SFA remained statistically significant albeit weakened ( $r=.374, p=.015$  vs  $r=.381, p=.011$ ). However the relationship between percent time awake in sedentary behaviour and percent energy intake from CHO was no longer statistically significant after controlling for the combined effects of age and gender.

The relationship between percent awake time in sedentary behaviour and percent energy intake from NMES remained statistically significant and strengthened when controlling for age only ( $r=-.322, p=.035$  vs  $r=-.314, p=.038$ ) and when controlling for

gender only ( $r=-.317$ ,  $p=.038$  vs  $r=-.314$ ,  $p=.038$ ) and when controlling for age and gender combined ( $r=-.328$ ,  $p=.034$  vs  $r=-.314$ ,  $p=.038$ ).

The changes in the relationships between percent awake time in sedentary behaviour and dietary intake were attributable to the statistically significant relationship between age and percent awake time in sedentary behaviour ( $r=.358$ ,  $p=.017$ ). There was no statistically significant relationship between age and measures of dietary intake, between gender and percent time awake in sedentary behaviour and between gender and measures of dietary intake.

The partial correlation analysis demonstrated that when controlling for age and gender, where these influenced the relationships, this was primarily due to the statistically significant relationship between age and measures of habitual activity. There was no measure of habitual activity which was statistically significantly associated with gender suggesting gender does not influence these relationships. With the exception of the statistically significant relationship between age and protein intakes (g) and gender and protein intakes (g) there were no statistically significant relationships between age and measures of dietary intake or between gender and dietary intakes. Between these two controlling variables, age had the greater influence and this was as a result of its statistically significant relationship with measures of habitual activity. This should therefore be acknowledged and taken into consideration when setting recommendations for activity in older people as it can be seen that sedentary behaviour increases with age and conversely levels of activity therefore decrease with age.

#### **3.11.4 Relationship between age and levels of fatigue**

As previously stated assessing fatigue generates non-parametric data and so partial correlation analysis was not possible meaning the influence of age and gender could not be established for the relationship between fatigue and levels of activity. However Spearman's rho correlation analysis was performed between age and measures of fatigue and between gender and measures of fatigue to provide some insight into any potential influence these parameters would have on the statistically significant relationships found. A statistically significant positive relationship between age and the reduced motivation score of the MFI was found ( $r=.314$ ,  $p=.038$ ) and a statistically significant negative association between gender and the general fatigue score of the MFI ( $r=-.298$ ,  $p=.049$ ) was found. No other statistically significant relationships existed. As measures of habitual activity were not associated with the reduced motivation score in this current study age did not appear to influence levels of fatigue in this study population. However gender influences the relationship between general fatigue and measures of habitual activity (mean daily time stepping (min), mean daily number of steps and totally weekly time in activity at MET > 3 (min)).

#### **3.12 SARCOPENIA**

Although this study did not focus on sarcopenia the relationship between nutritional status, functional status, dietary intake and habitual activity all influence the diagnosis of sarcopenia. The study population was, like all older adult populations, at risk of developing sarcopenia and so the diagnostic criteria for sarcopenia (Cruz-Jentoft et al., 2010) were applied to the population to establish the prevalence of sarcopenia in this population. Only 3/44 (7%) of the participants, all of whom were men, had a gait speed of <0.8 m/s indicating potential for sarcopenia. Following measurement of gait speed

muscle strength should then be considered and of the three participants who had a slow gait speed only one had a HGD strength of <30 kg. This participant also had a low muscle mass when comparing MAMC to normative data. In view of this within this healthy older adult population 1/44 (2%) participants could be classified as sarcopenic.

It may be that the levels of habitual activity in this population are resulting in low prevalence of sarcopenia however as this was not an intervention study it is not possible to confirm this.



## **CHAPTER 4: DISCUSSION**

This study measured levels of habitual activity in older adults, i.e. those aged 65 years and over, and established the relationship between levels of habitual activity and nutritional status, functional status, dietary intake, antioxidant status, inflammatory markers and levels of fatigue. This chapter will discuss the finding, study limitations and implications for practice.

### **4.1 PARTICIPANT CHARACTERISTICS**

The participants recruited to this study had a mean $\pm$ sd age of 72.8 $\pm$ 5.5 years and a mean $\pm$ sd BMI of 26.8 $\pm$ 2.8 kg/m<sup>2</sup>. There were similar numbers of male and female participants (21m, 23f) and although not fully reflective of proportions of older adults in Scotland with 62% of the older adults in Scotland being female (The Scottish Government, 2013) this does not influence the interpretation and extrapolation of the results. Due to the nature of the study and the fact that the data collected was in the main normally distributed, with the exception of only a few parameters (see section 3.2), the difference in proportions of male and female participants does not prevent conclusions being drawn.

### **4.2 HABITUAL ACTIVITY LEVELS**

Levels of habitual activity were measured in this study using an *activPAL*<sup>TM</sup> accelerometer and the data was categorised into mean daily time spent sitting and lying (min), mean daily time spent standing (min) and mean daily time spent stepping (min) along with mean daily number of steps. Further analysis determined the total weekly time spent in moderate intensity activity i.e. at MET > 3 (min), total weekly time spent in

moderate intensity activity when accumulated in blocks of at least 10 minutes (min) in line with guidance for physical activity (DoH, 2011), mean daily time spent in sedentary behaviour (min) and percent awake time in sedentary behaviour. To establish levels of habitual activity this was continuously measured for seven consecutive days.

Participants were found to spend a mean $\pm$ sd 1080 $\pm$ 103 minutes sitting and lying, 253 $\pm$ 78 minutes standing, 108 $\pm$ 38 minutes stepping each day and they took a mean $\pm$ sd 8,721 $\pm$ 3,585 steps each day. As the impact of activity on health is generally considered in the context of moderate intensity activity and time spent in sedentary behaviour, it is this premise which is utilised for determining recommendations for levels of activity and so habitual activity levels in this study were also categorised in this way. The study participants spent a mean $\pm$ sd 41 $\pm$ 21 minutes in moderate intensity activity and 551 $\pm$ 88 minutes in sedentary behaviour each day. The time spent in sedentary behaviour was equivalent to a mean $\pm$ sd 61 $\pm$ 10% time awake.

This study is the first to report objectively measured levels of habitual activity measured using an *activPAL*<sup>TM</sup> accelerometer and supported by an activity and sleep diary and where activity was measured continuously over a seven day period. Such an approach has enabled an accurate measure of habitual activity to be made and the use of the activity and sleep diary enables reporting of sedentary behaviour during waking hours only. This is essential as the definition of sedentary activities is “those activities where a person is awake and seated or reclining and participating in activities which require low levels of energy expenditure (i.e. < 1.5 METs)” (Owen et al., 2010a).

Previous studies have reported levels of sedentary behaviour in Scottish older adults using the *activPAL*<sup>TM</sup> accelerometer (Fitzsimons et al., 2013; Grant et al., 2010a). However the study by Fitzsimons et al. (2013) measured sedentary behaviour using the sedentary behaviour questionnaire (SBQ) (Rosenburg et al., 2010) and the study by Grant et al. (2010a) included sleeping time within the reported sedentary time. This current study therefore adds to the evidence base regarding sedentary behaviour in Scottish older adults as it is the first study to report objectively measured sedentary time based on the definition of sedentary behaviour (Owen et al., 2010a).

Understanding levels of sedentary behaviour in older adults is of great importance as it is well documented that a reduction in sedentary behaviour brings with it improvements in health (Wilmot et al. 2012). The participants in this current study spent  $9.18 \pm 1.47$  h/day sedentary, which equates to being sedentary for  $61 \pm 10$  percent of awake time. As previous studies have measured sedentary using different methodologies any comparison to previous results should be interpreted with caution.

One previous study found that older adults aged 60 - 69 years spent a mean $\pm$ se  $8.41 \pm 0.09$  h/day sedentary and those aged 70 – 85 years spent a mean $\pm$ se  $9.28 \pm 0.06$  h/day sedentary (Matthews et al., 2008). In addition a recent systematic review of levels of activity in older adults found that the daily percentage of sedentary time ranged between 62% and 86% (Gorman et al. 2014). It therefore appears that the participants of this current study had higher levels of sedentary behaviour than previous studies would suggest when considering sedentary behaviour as an absolute value with participants in this current study spending a mean $\pm$ sd  $9.18 \pm 1.47$  h/day sedentary. If however sedentary time is considered as a percentage of time awake then it would

appear that the population in this current study were less sedentary than previous studies have reported (i.e.  $61 \pm 10\%$  vs 62 - 86%). As sedentary behaviour is associated with poorer health status (Proper et al., 2011; Thorp et al., 2011) the apparent low levels of sedentary behaviour seen in this study population may partly explain the good health status of the participants in that participants presented with few comorbidities. However as different methodologies have been utilised in the studies by Matthews et al. (2008) and Gorman et al. (2014) compared to this current study the results must be interpreted taking this into consideration.

The study by Matthews et al. (2008) objectively measured physical activity levels and sedentary behaviour using an actigraph accelerometer and habitual activity levels were not measured continuously over 24 hour periods. The studies included in the systematic review by Gorman et al. (2014) also used an actigraph accelerometer making direct comparisons with the results of this current study difficult. Determining sedentary time using an actigraph requires the determination of a suitable cut-point below which the person is believed to be sedentary. There is a lack of consensus as to the most appropriate cut-point to determine sedentary behaviour in older adults and as a result there is considerable variation in the cut-points used within the studies which are included in the systematic review by Gorman et al. (2014) with cut-points ranging from ranging from 574 to 3,250 counts/min for moderate to vigorous intensity activity.

In addition previous studies have excluded non-wear time data meaning that activity levels have not been recorded continuously over 24 hour periods. Where studies have not asked participants to wear the accelerometers for full 24 hour periods there is no consistency in how non-wear time is determined. Typically it is calculated by selecting

a period of consecutive zero counts from the accelerometer output above which it is deemed that the device must have been removed. As continuous zero readings can occur when a person is sitting or lying i.e. sedentary this is not included in the analysis and thus true levels of sedentary behaviour are not calculated. Generally a minimum of 10 hours of recording has been considered a reflection of habitual activity (Matthews et al., 2008; Gorman et al., 2014) and it has been acknowledged that measuring habitual activity in this way is likely to underestimate sedentary time (Gorman et al., 2014).

A particular strength and uniqueness of this current study over and above other published data is that habitual activity was measured continuously throughout the recording period and this along with the use of an activity and sleep diary means that an accurate measure of sedentary behaviour was made. Recording habitual activity in this way is a clear improvement on previous studies which have quantified habitual activity using accelerometers although measuring habitual activity and sedentary behaviour in this way is not without its challenges.

To determine accurate levels of sedentary behaviour an activity and sleep diary identified the time each participant was asleep and this was then excluded from calculations for sedentary behaviour. The activity levels of each participant during waking hours could then be analysed to determine a true measure of habitual activity and sedentary behaviour. To do this data from the *activPAL*<sup>TM</sup> in 15 second epochs was sorted in the excel spreadsheet and any activity where the participant was awake, sitting or lying and at MET < 1.5 was considered sedentary. All 15 second epochs of sedentary behaviour were then totalled to provide both a daily time in sedentary behaviour reported to the nearest whole minute and a percentage of awake time in

sedentary behaviour to enable meaningful comparisons. Although this was a time consuming activity it does provide an accurate measure of sedentary behaviour which is in contrast to previous studies which have reported sedentary behaviour as a percentage of the day.

The objective measure of sedentary behaviour in this current study has the potential to influence relevant recommendations. Current UK guidance states that all older adults should minimise the amount of time spent being sedentary (sitting) for extended periods (DoH, 2011). Whilst valuable in terms of reducing health risk this recommendation lacks meaningful quantification and providing a quantified recommendation in terms of maximum lengths of sitting time without a break to stand or move would be helpful and potentially more achievable for older people as it provides a specific target to aim for.

To this end the number of sit to stand transitions which the participants completed during waking hours in this current study could be used. Participants completed a mean $\pm$ sd 51.2 $\pm$ 11.6 sit to stand transitions during waking hours with no significant difference between the male and female participants. This is fewer sit to stand transitions than reported in previous studies which have measured sit to stand patterns in older adults. Grant et al., (2010b) reported a mean $\pm$ sd 71 $\pm$ 25 sit to stand movements per day in a small sample of community dwelling older adults (n=20) and Egerton & Bauer (2009) reported a mean $\pm$ sd 65.5 $\pm$ 17.3 sit to stand transitions per day in a group of `older adults living in their own homes (n=15). The reason for the differences in results between these studies and this current study is not clear. Each study measured sit to stand transitions using an *activPAL*<sup>TM</sup> accelerometer and each study recruited older adults of similar ages. The study by Egerton & Bauer (2009) measured activity

over only 72 hours and this may explain the difference in results with that study compared to this current study. As has been shown in this current study there is significant day to day variation in activity levels in older people and so recording over a shorter period of time does have the potential to influence the results found. However both this current study and the study by Grant et al. (2010b) measured habitual activity over a seven day period and so the reason for these differences is not clear although could be partially explained by the relatively small sample sizes i.e.  $n=20$  in the Grant et al (2010b) study and  $n=44$  in this current study.

Further research to determine patterns of sit to stand transitions across a larger older adult population would be useful as this movement may influence subsequent activity levels. In this current study there was a statistically significant positive association found between the number of sit to stand transitions and both the mean daily time stepping ( $r=.339$ ,  $p=.024$ ) and the mean daily number of steps ( $r=.421$ ,  $p=.004$ ) this could suggest that when a person stands from a seated position they are likely to follow this by walking with some sort of stepping activity. This information could be utilised to inform recommendations for levels of activity. In this current study the mean $\pm$ sd sit to stand transitions equate to study participants currently standing from a seated position every  $18.1\pm 4.6$  minutes during waking hours. Encouraging people then to stand at least every 15 minutes (or four times every hour) whilst awake and to make sure they move during these standing breaks may have the potential to increase activity levels and reduce sedentary behaviour. Whether this is actually the case or not does however require further research as the role of the sit to stand transition in sustainably reducing sedentary behaviour is not entirely clear.

An intervention study aimed at reducing sedentary behaviour in older Scottish adults measured activity levels including sit to stand transitions using an *activPAL*<sup>TM</sup> accelerometer (Fitzsimons et al., 2013). Participants of that study were given an individualised consultation to reduce sedentary behaviour and following this a statistically significant reduction in sitting and lying time and an increase in stepping time was seen. Despite this no change in the number of sit to stand transition was seen. It should of course be noted that this study did not set out to increase sit to stand transitions but to reduce sedentary behaviour which may explain why no difference was found. It would appear that the participants of the study by Fitzsimons et al. (2013) completed more sit to stand transitions than the participants of this current study ( $55 \pm 20$  vs  $51.2 \pm 11.6$ ) however this may not actually be the case. The Fitzsimons et al (2013) study reports mean sit to stand transitions in each 24 hour period whilst this current study reports sit to stand transitions during waking hours only (i.e. where participants got up during the night to visit the bathroom and immediately returned to bed this was not considered awake time and those sit to stand transitions were excluded from the analysis). Further research is therefore warranted to establish whether a quantified recommendation around maximum sitting times would be beneficial in reducing sedentary behaviour.

Even if people do not significantly increase stepping time or number of steps through increasing sit to stand transitions encouraging people to stand up more often and to stay standing for a period of time may also have some health benefits. Initial research in this area is promising as benefits in reducing sedentary behaviour through an increased amount of standing time have been seen in middle age. A study by Stewart et al. (2014) showed an improvement in levels of function (as measured by STS) and a



reduction in BMI (and therefore improvement in nutritional status) over a 12 week period where the study participants reduced levels of sedentary behaviour by standing more. A reduction in sitting and lying time (min) and an increase in standing time (min) was also seen but there was no change in stepping time (min) over the intervention period. Whilst that study was undertaken in middle aged adults it does demonstrate that it is possible to reduce sedentary behaviour through an increase in standing time and this may be a more achievable target for older people than increasing moderate intensity activity.

This argument is supported by a recent systematic review by Prince et al. (2014) which compared the effectiveness of interventions with a focus on physical activity and/or sedentary behaviour for reducing sedentary time in adults. Although this systematic review did not focus solely on older adults the results are still of value as it established that interventions which focused on physical activity alone or physical activity including a component of sedentary behaviour produced less consistent findings and generally resulted in only modest reductions in sedentary time. However those studies which specifically targeted sedentary behaviour found that large and clinically meaningful reductions in sedentary time were achieved.

It is therefore unquestionable that specific recommendations focusing on reducing sedentary behaviour would be beneficial and to enable people to achieve this providing some quantification would not only be helpful but potentially easier to achieve. However targeting only sedentary behaviour is not appropriate when considering habitual activity levels and recommendations should have a dual focus as physical

activity and in particular moderate intensity activity also confers health benefits (WHO, 2014).

Recommendations for levels of activity for adults (including older adults) indicate that at least 30 minutes of moderate intensity activity should be accumulated on most days of the week totalling not less than 150 minutes each week (WHO, 2010b). In the UK this has been modified with the recommendation being that these 150 minutes of moderate intensity activity can be accumulated in bouts of at least 10 minutes (DoH, 2011). The mean $\pm$ sd daily time spent in moderate intensity activity of the study population (41 $\pm$ 21 min) is therefore initially encouraging and suggests that targets for levels of activity were being met. Indeed when calculated as total time spent in moderate intensity activity 79% (n=15) of the male participants and 86% (n=19) of the female participants met the target of at least 150 minutes of moderate intensity activity each week. However when the data were explored further and moderate intensity activity was measured when accumulated in blocks of at least 10 minutes only 16% of men (n=3) and 5% of women (n=1) met this recommendation. This is therefore worrying as the benefits of accumulating at least 150 minutes of moderate intensity activity each week are well established and these benefits include lower body weight and BMI, reduced visceral adiposity and reduced CVD risk (WHO, 2010b).

The concept of accumulating short bouts of activity to determine physical activity recommendations is important. As guidance endorses the accumulation of moderate intensity activity in bouts of not less than 10 minutes this implies that bouts of moderate intensity activity shorter than 10 minutes do not contribute towards meeting the recommendations. However this premise may well be flawed. Taking children as an

example the majority of moderate intensity activity in this group is accumulated in sporadic bursts of activity lasting less than 10 minutes and therefore these would not count towards meeting the guidelines (Esliger & Tremblay 2007). Although there is no published literature to confirm whether this is true in older adults it is not unreasonable to assume that by the nature of ageing this population may also be more likely to undertake episodes of moderate intensity activity in shorter bursts. Indeed the results from this current study would indicate this is the case with 83% of all participants meeting targets for activity when all moderate intensity activity is counted in contrast to only 10% when accumulated in blocks of at least 10 minutes.

The premise of accumulating activity in bouts of at least 10 minutes has been determined as a result of health benefits and in particular a reduction in CVD risk seen when accumulating activity in this fashion. It is however acknowledged that the basis of this was determined from self-reported activity and Esliger & Tremblay (2007) suggest that bouts of activity of shorter than 10 minutes are more likely to be overlooked during self-report. The true value of these short bursts of activity is therefore not known although there is emerging evidence that there are beneficial CVD effects associated with short bursts of moderate intensity activity in adults (Glazer et al., 2013). What is clear however is that the manner in which moderate intensity activity is quantified makes a significant difference to the number of people who do or do not meet guidelines for levels of activity. Clearly it would not be appropriate to change recommendations just to enable more people to meet targets for activity however further research into the impact of shorter bursts of moderate intensity activity on health is required to determine whether health benefits are still seen. If this was found to be the case as emerging evidence suggests (Glazer et al., 2013; Fan et al., 2013)

recommendations should then change to better reflect this. This is of particular importance in relation to populations who are less likely to be able to maintain sustained episodes of moderate intensity activity such as older people.

The participants in this current study had differing levels of habitual activity than those reported in the Scottish Health Survey for Older People (The Scottish Government, 2012). The reported levels of physical activity in the Scottish Health Survey found that in 2012, 56% of men aged 65-74 and 31% aged 75 years and over met targets for moderate intensity activity whilst 52% of women aged 65-74 and 21% aged 75 years and over met targets for the recommendation of 150 minutes of moderate intensity or 75 minutes of vigorous intensity (or a combination) each week. The difference in results is likely to be due to differences in methodologies used for measuring activity levels. The Scottish Health Survey determined levels of activity through interview rather than as an objective measure and so ensuring bouts of activity were at least 10 minutes long will be subjective. However some consideration must be given to the way in which moderate intensity activity was measured in this current study.

The *activPAL*<sup>TM</sup> accelerometer was used to measure moderate intensity activity by the use of metabolic equivalents (METs). To do this the *activPAL*<sup>TM</sup> accelerometer measures METS using a standard inbuilt equation based on stepping cadence and duration (PAL Technologies, 2010))

$$\text{MET/h} = (1.4 \times d) + (4 - 1.4) \times (c / 120) \times d$$

where c = cadence (steps per min); d = activity duration (in hours).

There is limited data on the validation of this equation however one study has validated the MET measurement by the *activPAL*<sup>TM</sup> in young females (Harrington et al., 2011).

This study of 62 young females measured energy expenditure using indirect calorimetry and MET by *activPAL*<sup>TM</sup> when participants were moving on a treadmill at varying speeds. The study found an ICC of .57 between METs measured by *activPAL*<sup>TM</sup> and those measured by indirect calorimetry suggesting moderate agreement between measurements (Landis & Koch, 1977). It should however be noted that there was a statistically significant difference found between the two measurement methodologies when considered overall and at each individual speed. The *activPAL*<sup>TM</sup> MET was found to be lower at high speeds and higher at low speeds than those measured by indirect calorimetry. It cannot be determined conclusively whether similar results would be found in an older adult as there is evidence to suggest that older adults expend differing amounts of energy to younger adults when completing the same activities.

Generally the energy cost of walking depends on speed of walking (Rose & Gamble, 1993) and this is the basis of measured METs using an accelerometer including the *activPAL*<sup>TM</sup> accelerometer. However a number of studies have shown that older people expend greater amounts of energy than younger people when they participate in the same activities and so using a standard equation to calculate METs in both young and old people may not be appropriate. Fitzsimons et al., (2005) found that when older adults walked at their self-determined slow pace of walking they expended similar levels of energy as younger adults walking at their self-determined fast pace of walking. A more recent study by Hall et al. (2013) found similar results and showed that in older people walking speeds of 1.5 - 3.0 mph would be considered to be moderate intensity activity rather than the expected low intensity activity. When comparing these results to standard METs published in the compendium of metabolic equivalents (Ainsworth et al. 2000) METs measured by indirect calorimetry were found to be up to 1.7 times higher

than standard METs. These results have been confirmed by a study by Witcher and Papadopoulos (2014) which found that older adults had consistently higher energy expenditure than younger adults when completing four, 6 minute walking activities on a treadmill. Whilst these studies measured walking activities similar results have been found when measuring other activity types in older people.

Kozey et al., (2010) undertook a study in older adults measured energy expenditure during both treadmill activities and activities of daily of living (ADL). In this study measured METS were different for 17/21 activities with some being higher and some being lower than METs reported in the compendium of metabolic equivalents (Ainsworth et al. (2000)). This was consistent across ages and between genders. In addition a study by Knaggs et al., (2011) measured energy expenditure during ADL in a group of older adults and when measured energy expenditure was compared to suggested normative MET values (Ainsworth et al. 2000) significant differences were found. Walking briskly, bed making, laundry and leisure walking were found to have higher than expected MET values ( $p=.001$ ) and other activities e.g. gardening, playing cards, washing windows, ironing, working on the computer and washing dishes were found to have lower than predicted MET values ( $p=.001$ ). The results from all these studies suggest that the use of METs based on accelerometer data may result in inaccurate MET measurements and thus the results from this current study should be interpreted with caution.

It has been suggested that the reason for the differences between measured METs and predicted MET values (Ainsworth et al., 2000) could be due to changes in gait stability and stride time in older people as this has the potential to increase energy expended in

the walking movement itself (Malasesta et al., 2003). Gait speed, gait instability and energy expenditure has been measured at different walking speeds and it was established that energy expenditure was significantly higher in the oldest age group (80+ years) compared to the youngest age group (aged 25 years) at all walking speeds and that it was significantly higher in the 65 year old age group at walking speeds of 1.33 m/s ( $p=.03$ ) and 1.65 m/s ( $p=.02$ ) compared to the younger aged group (Malasesta et al. 2003). It seems therefore that activities which would be considered low intensity in younger people could well be moderate or even vigorous intensity in older people. This may therefore indicate that the proportion of participants in this current study who met recommendations for moderate intensity activity could well be underestimated. This notion is supported by evidence presented by SACN (2011) in relation to physical activity level (PAL) factors.

In this current study the PAL factor measured by accelerometer was  $1.3 \pm 0.06$  and this can be compared to population based PAL factors which have been published for the UK population. The dietary reference values (DRV) for energy were first published for the UK population in 1991 (DoH 1991) and these initially suggested a standard PAL factor of 1.5 to be used for older adults. These energy requirements have since been reviewed by SACN (2011) and the suggested PAL factor for older adults did not change significantly as a value of 1.49 has since been recommended. This factor is based on the assumption that this is the factor suitable for a sedentary population and SACN (2011). As this current study recruited healthy active older adults it is reasonable to assume that their energy expenditure and this PAL factor would be higher than that of a sedentary population i.e. greater than 1.49. As the measured PAL factor in the study population was on 1.3 it is likely that this is an underestimation of activity levels and this

provides further weight to the argument that it is possible that a greater number of study participants were meeting recommendations for moderate intensity activity than initially appears. In view of this it would be sensible to consider activity levels relative to other recommendations.

A further recommendation for levels of activity is based on a daily step count with a recommendation of accumulating 10,000 steps each day (National Obesity Forum, 2006). In this current study the mean $\pm$ sd daily step count of the participants was 8,721 $\pm$ 3,585 with no difference in step count between men and women. This would suggest that the study population are not meeting step-based recommendations for levels of activity. However, although not UK based, guidelines related to step count have been suggested for older adults based on the premise that it may be difficult for older people to accumulate 10,000 steps each day. A review of the published literature assessed the quantity of steps required for health benefits and it is proposed that between 7,000 - 10,000 steps/day should be encouraged in older adults (Tudor-Locke et al., 2011). This recommendation takes into consideration steps taken as part of normal day to day activity and attempts to quantify total number of steps required for health benefits and to meet targets of 30 minutes moderate intensity activity on most days. Based on these recommendations the population in this current study are meeting the suggested targets for older people. As previous studies have shown walking over 6,500 steps/day is associated with better functional ability in older adults (de Melo et al., 2013) and that those older adults who walk at least 7,000–8,000 steps/day are likely to have a muscle mass above the sarcopenia threshold (Park et al., 2010). The fact that the study population are taking this amount of steps daily is



therefore encouraging and this may well at least partly explain why the study population are of good nutritional and functional status.

There does however appear to be conflict between recommendations for objectively measured levels of physical activity based on moderate intensity activity and recommendations for step counts. The participants in this current study met the target for step count in relation to older adults despite apparently not meeting recommendations for moderate intensity activity. They will therefore be obtaining health benefits in terms of functional ability (Park et al., 2010; de Melo et al., 2013) and this was seen in the results of the measures of functional status. This is extremely important as maintaining functional status in older adults has the potential to influence a person's ability to live independently for longer. At face value, the fact that the study population did not meet targets for moderate intensity activity if accumulated in blocks of at least 10 minutes is of concern and based on current recommendations suggests that there is no benefit to them in terms of CVD health. There is however emerging evidence that short bursts of activity are beneficial in terms of CVD health and weight management (Glazer et al., 2013; Fan et al., 2013) and so the fact that 83% of participants accumulated a total of at least 150 minutes of moderate intensity activity is in fact a positive finding. Consideration should therefore be given to including shorter bouts of moderate intensity activity in recommendations of levels of physical activity.

In the context of recommendations the method of promoting activity is also important and there is an argument to suggest that measuring activity in terms of step count for older adults enables people to better self-monitor their activity levels and thus enable them to meet activity targets. Indeed a systematic review of pedometer use found that

providing a step goal resulted in increased activity levels (Bravata et al., 2007). It may be that the message and targets around activity for older people should focus on increasing activity levels across the board with an encouragement of moderate intensity activity to enable the target of 150 minutes to be met allowing this to be accumulated in bouts of less than 10 minutes alongside simple and practical methods to self-monitor activity such as a step count (Tudor-Locke et al. 2004) or an activity point system (Ehram et al., 2009). Clearly this current study cannot provide evidence to show the impact of this on health for older people but this concept certainly warrants further investigation.

There is clear evidence then that both increasing moderate intensity activity and reducing sedentary behaviour confer health benefits and it is suggested that a joint prescription to accumulate adequate moderate intensity activity and avoid prolonged periods of sitting is beneficial in older adults (Gennuso et al., 2013). Current recommendations in the UK provide this dual recommendation (DoH, 2011) however in view of the results of this current study it could be argued that these recommendations require further development to include accumulating shorter bouts of moderate intensity activity to meet the 150 minutes recommended each week along with a quantified recommendation for sedentary behaviour.

In addition to recommendations for reducing sedentary behaviour and increasing physical activity levels to meet targets of 150 minutes of moderate intensity activity each week the Scottish Government recommend that older adults participate in strength based activities on 2 or more days of the week (The Scottish Government, 2012). Only 34% (n=15) participants of this study met this target and this is cause for concern as

muscle strengthening activities are important in older people to maintain muscle function (Montero-Fernández & Serra-Rexach 2013) and thus potentially the ability to live independently. Although it appears as if only a small proportion of participants met the recommendation for muscle strengthening activity the proportions in this study was considerably higher than that reported in the Scottish Health Survey where only 10% of adults aged 65 - 74 and 5% of adults aged 75 and over in Scotland met the recommendation (The Scottish Government, 2012).

To determine the number of people who were participating in muscle strengthening activities in both this current study and the Scottish Health Survey activity levels are compared those activities identified in the Scottish Health Survey (The Scottish Government 2012). The Scottish Health Survey identifies activities to be either definitely muscle strengthening or potentially muscle strengthening. This list was compiled from expert opinion and is not considered an exhaustive list of activities. Indeed the list comprises of only sporting activities and does not include muscle strengthening activities which are performed as a result of activities of daily living e.g. carrying shopping bags. It is therefore possible that a greater proportion of participants in this current study met the recommendation for muscle strengthening activities than has been reported. Indeed the functional status of the participants may support this suggestion as in this current study only 1 male and 5 female participants had a HGD measurement below the 95<sup>th</sup> confidence interval suggesting as a group the study population were of good functional status. In addition when the population were categorised for sarcopenia using the European Consensus statement criteria (Cruz-Jentoft et al. 2010) only one male participant would be considered sarcopenic (based on gait speed, muscle mass and muscle strength).

It therefore appears that the study population were of good functional status and this may indicate that they were participating in more muscle strengthening activities as a result of daily activities which have not been accounted for. This is a limitation of using only exercise within the list of muscle strengthening activities within the Scottish Health Survey. The impact of muscle strengthening activities as part of ADL cannot be determined from the results discussed here however this warrants further research. In addition some consideration should be given to broadening the list of muscle strengthening activities included in the Scottish Health Survey to include ADL activities and hobbies which would not be considered exercises but would results in improved muscle strength.

This current study provides an objective measure of habitual activity levels in older Scottish adults and provides an indication as to whether current recommendations for levels of activity are being met. In this context it is important to consider how activity is accumulated. Participants in this current study were asked to wear an accelerometer continuously for seven consecutive days to measure habitual activity levels and to complete an activity diary to measure strengthening activities. In 93% (n=41) of the study population accelerometer data were gathered for the required seven consecutive days and the remaining 7% (n=3) had habitual activity data recorded for five consecutive days. The difference is accounted for due to loss of battery power in the accelerometers. Despite a shorter recording period for three participants, the measured activity remains reflective of habitual activity as it has been established that the number of days to reliably predict habitual activity in adults is between three (Tudor-Locke et al., 2005) to five consecutive days (Kang et al., 2009) and to measure sedentary behaviour in older adults five days is adequate (Hart et al., 2011). The studies measuring habitual

activity (Tudor-Locke et al. 2005; Kang et al. 2009) found that measuring activity for 3 - 5 days produced an intraclass correlation (ICC) of .80 which is considered to be a substantial level of agreement (Landis & Koch, 1977). In view of this the measurement of habitual activity in this study was reflective of habitual activity and the results support the findings from the previously described studies regarding recording times.

The calculated intraclass correlation for levels of activity in this current study were  $ICC_{(2,7)}$  of .898,  $p < .001$  for time spent sitting and lying, .88,  $p < .001$  for time spent standing, .878,  $p < .001$  for time spent stepping and .855,  $p < .001$  for total number of steps. These are considered to be almost perfect levels of agreement (Landis & Koch, 1977) and demonstrate that habitual activity measured over five to seven consecutive days is a reliable reflection of overall activity levels. There was however obvious day to day variation in activity levels and when any one individual 24 hour period was considered as a measure of habitual activity although the results remained statistically significant the  $ICC_{(2,1)}$  reduced to .556,  $p < .001$  for time spent sitting and lying, .511,  $p < .001$  for time spent standing, .506,  $p < .001$  for time spent stepping and .457,  $p < .001$  for total number of steps. These levels of agreement are considered only moderate (Landis & Koch, 1977). The intraclass correlation analysis therefore confirms that not only are the measures of habitual activity reliable it is also evident there is significant day to day variation in activity levels in older people.

The reason for this day to day variation in activity levels is not known but it is not unreasonable to assume that if high levels of activity exist one day a person may be fatigued and have a period of rest the following day. Other studies have seen variation in day to day activity based on levels of rainfall and changes in temperature in particular

in cold, icy weather where there is an increased fear of falling (Aoyagi & Shepard, 2009). The recruitment for this current study was across the seasons with participants being recruited in summer, autumn, winter and spring. The issue of the cold, icy weather does not then fully explain the variation found as this would have only affected some participants. However rainfall is abundant across the year in Scotland and so this could certainly have had an impact on all participants particularly in terms of outdoor activity and resulted in reduced levels of activity on some days. The weather conditions were not noted in this current study and so it is not possible to state this with absolute certainty. What is apparent is that even without knowing the reason for this variation it was seen in all participants and so it is likely to reflect activity patterns in older people. The accumulation of physical activity across the week is therefore a sensible way to encourage older people to accumulate physical activity. This will then take into consideration normal day to day variation in activity levels and also mitigate for any other potential confounders such as the weather which can then further influence participation in activity.

As with all research, some consideration as to the reliability and validity of methodology used within this study should also be given. The measurements of habitual activity in this current study are considered both valid and reliable as the *activPAL*<sup>TM</sup> accelerometer has also been shown to be a valid and reliable measure of habitual activity (Grant et al., 2006; Grant et al., 2008). In addition compared to other accelerometers the *activPAL*<sup>TM</sup> has been found to be accurate at all gait speeds and has been found to measure 97% of all steps taken (Feito et al., 2012). Importantly the *activPAL*<sup>TM</sup> is accurate when measuring slow gait speeds (often the speed when accelerometers are least accurate) and sedentary behaviour (Feito et al., 2012). The

measure of habitual activity in this current study is therefore a good reflection of habitual activity a reliable and accurate measurement and has many advantages over other studies where habitual activity has been quantified. The conclusions drawn from the measures of habitual activity therefore significantly add to the body of evidence around physical activity.

In summary recommendations should continue to focus on both moderate intensity activity and sedentary behaviour in combination whilst encouraging muscle strengthening activities in older people. However there is the potential for these recommendations to be developed further by considering shorter bouts of moderate intensity activity, providing a quantified recommendation for reducing sedentary behaviour and extending muscle strengthening exercise to include appropriate ADL and hobbies. In addition further data sets of reliably and objectively measured levels of habitual activity in the older adult population are required to provide a more accurate measure of PAL factors.

### **4.3 NUTRITIONAL STATUS AND BODY COMPOSITION**

BMI is commonly used as a marker of nutritional status and the mean $\pm$ sd BMI of the study participants was (26.8 $\pm$ 2.8 kg/m<sup>2</sup>). When considered by gender the male participants had a mean $\pm$ sd BMI of 27.4 $\pm$ 2.4 kg/m<sup>2</sup> and the female participants had a mean $\pm$ sd BMI of 26.2 $\pm$ 3.0 kg/m<sup>2</sup>. This mean BMI measurement is lower than that of the older adult population across Scotland which is reported to be 28.1 kg/m<sup>2</sup> (The Scottish Government, 2011). The mean BMI of both the population in this current study and the Scottish older adult population would however be considered normal for their age when

referring to cut-offs for older adults (Beck & Ovesen, 1998). In terms of overweight and obesity 19% of the participants in this current study (24% of men and 14% of women) would be considered overweight or obese using criteria from Beck and Ovesen (1998). It is difficult to make a direct comparison between the study population and the general Scottish population as the Scottish Health Survey reports prevalence of overweight and obesity based on traditional BMI cut-offs WHO (2002) i.e. a BMI  $\geq 25$  kg/m<sup>2</sup>. However comparisons can be made based on a BMI  $\geq 30$  kg/m<sup>2</sup> (i.e. indicative of overweight using cut-offs for older adults (Beck & Ovesen, 1998)). Using this level of BMI and data from the Scottish Health Survey (The Scottish Government, 2011) a greater proportion of the Scottish older adult population would be considered overweight or obese compared to the population in this current study (31% vs 19%). This indicates that when considering BMI the population in this current study are of better nutritional status than the general older adult population in Scotland. However it is well established that BMI is only a crude marker of nutritional status and there is evidence to suggest that it should be interpreted alongside WC to better determine nutritional status and in particular CVD risk (NICE, 2006).

In the context of WC the results of this current study indicate that the study population had high levels of visceral adiposity despite being of normal weight (as measured by BMI). Of the male participants 71% (n=15) were found to have a high WC measurement and of the female participants 66% (n=14) were found to have a high WC. This is in contrast to the general older adult population in Scotland where 44% of older men and 56% of older women have a high WC measurement (The Scottish Government, 2011). These results are surprising as the study population have a lower BMI than the general population and so it seems reasonable to assume that lower WC



levels would be found. The results are also worrying as the WC measurements found in the study population are indicative of increased CVD risk despite what would be considered a normal BMI status. In addition there is strong evidence that WC may be as, or even more important than BMI in the older adult population as it has the ability to determine health risk associated with obesity in older ages which may be lacking from BMI measurements (Wannamethee et al 2007; Price et al 2006). It should however be noted that the study population reported few if any co-morbidities and none of the participants reported suffering from either CVD or T2DM (risk factors associated with an increased WC).

However WC, as a marker of nutritional status and CVD risk in older adults, has been questioned previously due to changes seen in both height (Fernihough & McGovern, 2014) and body composition in older adults (Kyle et al., 2001, Baumgartner, 1993). As a result concerns have been expressed about the misclassification of the health risks related to obesity in older people when using standard WC cut-off values (Visscher et al., 2001; Molarius et al., 2000). In view of this Heim et al. (2010) have suggested that alternative cut-offs should be developed for people aged 70 years and over and have suggested cut-offs of 100 – 106 cm for men and 99 cm in women. If these cut-offs were used in this current study 43% (n=9) of the male participants and 14% (n=3) of the female participants would be considered to have an elevated WC. In view of the lack of comorbidities and the lower BMI relative to the Scottish population these levels of increased WC are perhaps more reflective of a population which is considered healthy indicating that the suggested cut-offs for WC by Heim et al. (2010) are more appropriate for older people. Although the sample size for this study is small there is adequate

evidence to suggest that further research is needed to definitively establish cut-offs for WC in an older adult population.

The interpretation of WC should however be considered in the context of comorbidities as this will give a clearer picture of health status. There are differences reported in prevalence of co-morbidities between the study population and the Scottish population. Currently in Scotland 14% of men and 10% of women have T2DM and 41% of men and 31% of women have some form of CVD (The Scottish Government, 2011). This is clearly not reflected in the population of this current study despite higher WC levels. WHO recommend that an individual's relative risk of T2DM and CVD can be accurately classified using both BMI and WC in combination and this is supported by SIGN (2010). The general principle is that the higher both the BMI and WC, the greater the risk of CVD and T2DM developing. Utilising these criteria within the population of this current study, 59% of the participants had no increased risk, 23% had an increased risk, 11% had a high risk and 7% had a very high risk. In contrast within the general older adult population within Scotland, 28% of older adults have no increased risk of disease, 20% have an increased risk of disease, 24% have a high risk and 28% a very high risk (The Scottish Government, 2011). These levels of risk should however be interpreted appropriately as the risk is categorised based on traditional cut-offs for both BMI and WC and the appropriateness of both have been questioned (Beck & Ovesen, 1998; Heim et al., 2010). The comparison does however stand as the same methodology has been applied to both populations enabling comparisons to be made. The BMI measurements, absence of NCD and lower risk of CVD and T2DM developing therefore confirm that the older adults in this current are healthier than the general Scottish older adult population.

Upper arm anthropometry measurements were taken in this study to give an indication of both fat mass (FM) and fat free mass (FFM) in the study participants. These measures of upper arm anthropometry (mid upper arm circumference (MUAC), tricep skinfold thickness (TSF) and mid arm muscle circumference (MAMC)) can be compared to normative data and as discussed previously (section 1.5) the most appropriate normative data to use for comparison in this study is that published by Corish & Kennedy (2003). As comparison is made at an individual level and against centiles, it is not appropriate to compare the population using statistical analysis. However individual comparisons have been made and no female participants and only one (5%) of the male participants had a MUAC, TSF and MAMC below the 5<sup>th</sup> centile. Upper arm anthropometry measurements below the 5<sup>th</sup> centile may be indicative of undernutrition (Corish & Kennedy, 2003). Conversely in terms of overnutrition, no female participants and again only one male (5%) participant had a TSF above the 95<sup>th</sup> centile which along with a MAMC measurement below the 10<sup>th</sup> centile indicates high levels of fat mass (FM) and low levels of fat free mass (FFM). The remainder of the participants would all be considered normally nourished with MUAC, TSF and MAMC all within the 10<sup>th</sup> - 90<sup>th</sup> centiles (Corish & Kennedy (2003).

It has previously been suggested that measuring upper arm anthropometry as a marker of nutritional status is unreliable (Ellis, 2001) and there have long been concerns expressed about inter and intra observer variability in results obtained when using upper arm anthropometry (Kispert & Merrifield, 1987). These issues can however be overcome by the use of a single trained observer, appropriate calibrated equipment and standardised protocols (Jebb & Elia, 1993; Norton & Olds, 1999) as occurred in this

current study. In addition to strategies being in place to minimise error it is also possible to quantify the error of measurement through the calculation of the technical error of measurement (TEM). This was performed in this study and the TEM for MUAC and TSF was well within acceptable ranges (Norton & Olds, 1999) with the TEM calculated to be 0.1 cm (0.36%) for MUAC and 0.17 mm (1.1%) for TSF. The  $ICC_{(3,2)}$  for the MUAC was 0.999 and for the TSF was 1.0. The TEM for MAMC is not measured as both MUAC and TSF are used to calculate MAMC and so if error is low in these measurements this is reflected in the measurement for MAMC. In view of the low TEM and high  $ICC_{(2,1)}$  there is no doubt that the measures of body composition in this current study are a true reflection of the body composition of the participants and so the conclusions drawn from these measurements are valid.

Due to increasing levels of overweight and obesity within the Scottish population there would be an expectation of higher levels of FM within the study population however this was not found. It should be noted that whilst TSF measurements, an indirect measure of total body fat, are within normal ranges, this is in contrast to the high WC measurements which is an indirect measure of visceral adiposity. The BMI and body composition measurements of the study population indicate a healthy nutritional status and so this adds additional weight to the previously discussed argument that the WC cut-offs currently used may not be appropriate for an older adult population and further research in this area is required.

#### **4.4 RELATIONSHIP BETWEEN LEVELS OF HABITUAL ACTIVITY AND MEASURES OF NUTRITIONAL STATUS AND BODY COMPOSITION**

This study set out to determine the relationship between habitual activity and measures of nutritional status and body composition in older adults. Although not the aim of the study the associations between habitual activity and age were also determined to establish changes in levels of habitual activity with ageing.

As expected age was positively associated with mean daily time spent sitting and lying (min) ( $r=.316$ ,  $p=.037$ ) and mean daily time in sedentary behaviour (min) ( $r=.398$ ,  $p=.007$ ) and it was negatively associated with mean daily time spent stepping (min) ( $r=-.415$ ,  $p=.005$ ), mean daily number of steps ( $r=-.353$ ,  $p=.019$ ) and total time in activity at MET > 3 when accumulated in blocks of at least 10 minutes (min) ( $r=-.466$ ,  $p=.002$ ). These results indicate an increase in sedentary behaviour and a reduction in stepping and moderate intensity activity with ageing. This is in line with evidence from other studies (Phillips, 2003; Troiano et al., 2008; The Scottish Government, 2011). It is vital that this is taken into consideration when developing recommendations for activity levels in older people. As older people do not sustain activity levels with ageing it may be that specific recommendations for activity levels for older people should be devised rather than having recommendations for the entire adult population. More targeted specific recommendations for older adults should therefore be considered.

As there was no association between age and mean daily time spent standing (min) this information has the potential to be utilised in these recommendations. As people reduce levels of physical activity and increase sedentary behaviour with ageing (Troiano et al., 2008; The Scottish Government, 2011) there may be the potential to

replace at least part of this reduction in physical activity with low intensity activity including standing activities. These activities could be home based activities such as standing when speaking on the telephone, light housework, light gardening etc. and could also include walking which has been shown to be a successful intervention in older people (Baker et al., 2008; Mutrie et al., 2013; Kassavou et al., 2013). Clearly increasing walking has greater potential in enabling a person to meet activity targets however this may not always be possible but as the amount of time spent standing is not associated with age, encouraging activities where people stand should be possible in an older population. This can be done without increasing moderate intensity activity which may be off-putting or not possible for some older people whilst still reducing levels of sedentary behaviour. This may result in similar health benefits as those seen in middle age (Stewart et al., 2014) and may be more achievable for older people. Whether health benefits would be seen in older people cannot be determined from the results of this current study however the notion that sedentary time could be replaced by standing time certainly seems feasible. Further research to establish whether this is the case alongside determination of health benefits should therefore be considered.

In this current study measures of habitual activity were found to be associated with BMI ( $\text{kg/m}^2$ ) and WC (cm) but with no other marker of nutritional status. BMI ( $\text{kg/m}^2$ ) was positively associated with mean daily time in sedentary behaviour (min) ( $r=.365$ ,  $p=.016$ ) and when measured as a percentage of awake time ( $r=.302$ ,  $p=.049$ ). WC (cm) was positively associated with mean daily time spent sitting and lying (min) ( $r=.335$ ,  $p=.03$ ), mean daily time in sedentary behaviour (min) ( $r=.472$ ,  $p=.002$ ) and percentage time awake in sedentary behaviour ( $r=.302$ ,  $p=.049$ ) and was negatively associated with mean daily time stepping (min) ( $r=-.427$ ,  $p=.05$ ) and mean daily number of steps ( $r=-$

.380,  $p=.0013$ ). Other studies have shown that a reduction in sedentary behaviour results in a reduction in BMI ( $\text{kg}/\text{m}^2$ ) and a reduction in WC (cm) (Gennuso et al., 2013) and this is supported by results from this current study. Indeed it is sedentary behaviour rather than intensity of activity which was associated with both BMI ( $\text{kg}/\text{m}^2$ ) and WC (cm) which may suggest that this is more important in terms of nutritional status than other measures of habitual activity e.g. moderate intensity activity. This adds weight to the argument that quantifiable information within the recommendation to reduce sedentary behaviour would be helpful to enable older people to confer the health benefits associated with reducing sedentary behaviour (Proper et al., 2011; Thorp et al., 2011). In addition as BMI ( $\text{kg}/\text{m}^2$ ) was not associated with increased levels of activity and WC (cm) was negatively associated with mean daily time stepping and mean daily number of steps it appears that in this population at least an increase in movement irrespective of the intensity of activity may have health benefits when considering nutritional status.

Whilst it is unsurprising that BMI ( $\text{kg}/\text{m}^2$ ) and visceral adiposity as measured by WC (cm) are positively associated with sedentary behaviour and negatively associated with activity it is surprising that body composition in terms of FFM (as measured by MAMC) and FM (as measured by TSF) were not found to be associated with any measure of habitual activity. Previous studies have shown that higher levels of physical activity increase FFM and reduce FM (Kuh et al. 2005; Hughes, 2004; Park et al., 2010). The fact that these associations were not found in this current study may be attributable to the fact that it is muscle function and strength which is more important in terms of functional ability than muscle mass (Janssen et al., 2004a; Visser et al., 2005). Although no associations were found in this current study between habitual activity and

FFM measuring this remains important for a number of reasons. It is a key determinant in diagnosing sarcopenia (Cruz-Jentoft et al., 2010) and it plays a role in determining functional ability of a person (Broadwin et al., 2001; Landers et al., 2001).

Nutritional status alone is not responsible for a person's health and well-being and their ability to live independently. An understanding of functional status and its relationship with habitual activity is also required.

#### **4.5 FUNCTIONAL STATUS**

In this study functional status was measured using a combination of handgrip dynamometry (HGD), the sit to stand test (STS) and the six minute walk test (6MW). In addition gait speed was calculated from the 6MW test as gait speed is one of the diagnostic indicators for sarcopenia (Cruz-Jentoft et al., 2010). As discussed previously (section 1.9) each measure has a particular role in determining a person's functional ability and together these measurements provide an overall indication of a person's functional ability. This is the first study which has assessed functional status using this combination of functional measures. These tests provide a measure of upper body strength and function, lower body strength and function in addition to a measure of endurance. Together they provide a comprehensive overview of functional ability which in turn gives an indication of ability to complete ADL and potentially to live independently. It is therefore suggested that this combination of quick and easy to perform tests could be utilised in combination in older adults to determine functional status.



Each measure must be considered individually initially and when comparing HGD with normative data (Bohannon et al., 2006) a HGD measurement of lower than the 95<sup>th</sup> confidence interval (CI) is indicative of nutritional risk due to a loss of muscle strength which in turn indicates functional decline. As there are gender differences in HGD measurements with men being stronger than women comparisons with normative data are made by gender. In this current study 22% (n=5) of the female participants and 5% (n=1) of the male participants had a HGD measurement below the 95<sup>th</sup> CI indicating nutritional risk and functional decline. The normative data used for comparison is based on a US population as there is no equivalent data for the Scottish population and so comparisons between the participants of this study and the general older adult Scottish population is not possible. There is however no reason to believe the Scottish older adult population would have markedly different HGD measurements than other older adults in a Western Society i.e. USA. The results of this current study indicate that based on HGD the study population and in particular the male participants are of good functional status. It should of course be noted that the HGD measurements for the male participants were not normally distributed and results should be interpreted with caution.

Although sarcopenia was not the focus of this current study preventing the development of this in an older adult population has the potential to enable people to live independently for longer and it is inextricably linked to levels of activity. In view of this sarcopenia has also been considered and HGD can be used to provide an indication of sarcopenia (along with measurements of gait speed and muscle mass). To determine this, HGD using cut-off points suggested by Cruz-Jentoft et al. (2010) were interpreted alongside BMI and when using these criteria, 5% (n=1) of male participants and 18%

(n=4) females participants showed initial signs of sarcopenia. Interestingly one of the female participants identified as being at nutritional risk using HGD was not considered to be sarcopenic and one of the female participants considered sarcopenic was not considered to be at nutritional risk. These different criteria for establishing nutritional risk and sarcopenia clearly have implications when assessing older people. The differences in results obtained also provides strength to the argument that both nutritional status and functional status should be considered in combination in older adults as whilst there is clearly a relationship between nutritional status and function there can be a deterioration in one independently of a deterioration in the other.

To diagnose sarcopenia HGD is used in combination with gait speed. When applying the full diagnostic criteria for sarcopenia (Cruz-Jentoft et al., 2010) only 5% (=1) of the male participants would be considered sarcopenic (based on gait speed, muscle mass and muscle strength) and this participant was the same person who was identified as being at nutritional risk when using normative data for HGD and when considering HGD and BMI in combination. As this relates to only one participant it is difficult to make inferences from this but methodologies used to detect undernutrition, functional decline and sarcopenia warrants further study. Currently the methodology to identify undernutrition will not identify sarcopenia and vice versa and as each condition plays a role in the ageing process they have implications for a person's ability to live independently.

To provide a clearer indication of functional status other measures of function can be used in combination with HGD and in this current study a five repetition sit to stand test

(STS) and a six minute walk test (6MW) test were also measured. As with results from HGD, results from these tests can also be compared to normative data.

When compared to normative data (Bohannon, 2006) there was no significant difference in performance in the STS test and normative data in the 60 - 69 year old participants. However the older age group (70 - 79 year olds) were significantly slower in the STS test than would be expected relative to normative data ( $15.3 \pm 5.8$  vs  $12.6$  s,  $p=.033$ ). These results indicate that the younger participants were of at least normal functional status relative to normative data whereas the older age group (70 - 79) were of poorer than expected functional status. The reason for the differences between these results and normative data is not clear. The sample size is small in both groups (60 - 69 year olds  $n=15$ , 70 - 79 year olds  $n=24$ ) which may partially explain these differences. In addition the normative data has been produced from an American rather than a UK population and it may be that differences exist between populations although evidence to support this is lacking. Equally the normative data is now a little dated and there have been changes in the way people live in recent times in terms of the adult population becoming more sedentary (Owen et al., 2010b). This move towards a more sedentary lifestyle and a greater reliance on technology including cars, computers, television etc. may influence expected results when measuring functional ability. The results from the STS are in direct contrast to the results found in the 6MW test.

When compared to normative data for the 6MW (m) test (Steffen et al., 2002) the male 60 - 69 year old participants walked a shorter distance than expected ( $483 \pm 100$  vs  $572$  m,  $p=.039$ ). There was no difference between the female participants of this age group and normative data and this was also true of both male and female participants in the

70 - 79 year old age group. The reason that the 60 - 69 year old male participants as a group walked a shorter distance than expected is not clear as the other functional parameters measured i.e. HGD and STS do not indicate that the functional performance of this group is diminished. It should be noted that the sample size of this group is small (n=8) and so the performance of this small sample cannot be considered indicative of the population as a whole.

It has been suggested that it is possible to predict the distance a person can walk during the 6MW test based on their gender, age, BMI ( $\text{kg/m}^2$ ) and these estimates were made for the study population. Whilst 57% (n=12) of the male participants and 30% (n=7) of the female participants walked a shorter distance than expected only 10% (n=2) of the male participants and 9% (n=2) of the female participants walked a shorter distance than the distance considered to be the lower limit of normal (Enright & Sherrill, 1998). Only one of these participants, who was male, also had a low HGD indicating undernutrition and this is the same person who could be considered sarcopenic.

It could be argued then that, when considering the measures of functional status in combination, differences in results are obtained. These results could influence how a person was categorised in terms of nutritional and functional status and when considering a diagnosis of sarcopenia. It does however appear that despite some anomalies which are open to interpretation due to the small sample size, when the study population is stratified for age and gender, overall the study group are of a good nutritional and functional status. However, the differences seen in the ability of different methodologies to identify participants considered undernourished, sarcopenic or of poor functional status confirm that utilising only one functional assessment methodology is

inappropriate in an older adult population. A combination of tests is therefore warranted and a combination of both upper body function and lower body function should be considered.

Although not a primary outcome measure for this study gait speed was calculated as it informs the presence of sarcopenia. The mean $\pm$ sd gait speed (m/s) of the study population was measured to be 1.26 $\pm$ 0.3 m/s, with the male participants having a mean $\pm$ sd gait speed of 1.21 $\pm$ 0.32 m/s and the females having a gait speed of 1.31 $\pm$ 0.27 m/s. These speeds are within times reported to be comfortable gait speeds for older adults (which range from 0.6 to 1.45 m/s) and are also within gait speeds considered to be fast speeds for older adults which are reported to be 0.84 to 2.1 m/s (Bohannon (1997); Hageman & Blanke (1986); Murray et al. (1969); Oberg et al. (1993); Blanke & Hageman (1989); Ostrosky et al. (1994); Elble et al. (1991)). The methodology used for measuring gait speed across these studies differed with participants being asked to walk different distances (7.26 m walkway - Bohannon (1997), 14 m - Hageman & Blanke (1986); 14 m - Blanke & Hageman (1989); 6 m - Ostrosky et al., (1994); 10 m - Oberg et al. (1993)) whilst gait speed in this current study was calculated from the distance walked within the 6MW test. Comparisons between all these studies should therefore be undertaken with caution as a result of these different methodologies.

The gait speed measurements reported in these previous studies reflect gait speed over shorter distances where people would have been able to walk at a faster pace as they were walking for a much shorter time. In this current study as gait speed was not measured in this way the gait speeds obtained are likely to be slower than would be

expected over a much shorter course e.g. 10 m although they are likely to reflect a level of endurance. It could be argued that this is a much better reflection of comfortable walking speeds. Whilst it is not conventional to measure gait speed from the 6MW test it could also be argued that it is more appropriate when interpreting habitual activity and functional status for older adults. Measuring gait speed over a longer period better reflects normal activity whereas measuring gait speeds over shorter distances are likely to provide inappropriately high values which do not truly reflect a person's functional ability and thus their ability to live independently. Despite this, the participants in this current study would still be considered to have a normal gait speed and had they been asked to undertake a test to measure gait speed alone (rather than a test of function and endurance) it is not unreasonable to assume that the gait speeds recorded may in fact be quicker than those calculated from the 6MW test. As gait speed has been shown to be a valid and reliable indicator of physical performance and has been shown to predict falls, subsequent hospitalisation and incident disability in healthy older adults. (Guralnik et al., 2000; Studenski et al., 2003; Montero-Odasso et al., 2005) measuring this in older adults provides a good indication of their overall health status.

The differing results found across the various tests of functional ability used within this study provide evidence that a range of tests should be used to ensure a true reflection of functional status is established in an individual. The combination of tests utilised in this study provide a comprehensive overview of a person's functional ability. They provide an indication of upper body strength and function (HGD), lower body function (STS), lower body function in combination with endurance (6MW) and an early indicator of sarcopenia (gait speed). All these measures impact on a person's ability to live

independently and utilising only a single measure will not provide a clear indication of a person's functional status.

#### **4.6 RELATIONSHIP BETWEEN OF LEVELS OF HABITUAL ACTIVITY AND FUNCTIONAL STATUS**

A number of studies have confirmed that increasing levels of physical activity and decreasing levels of sedentary behaviour are important in maintaining physical function in older adults. These studies have shown relationships between low levels of habitual physical activity and the presence or the development of sarcopenia (Aubertin-Leheudre et al., 2006; Baumgartner et al. 1998; Rimbert et al., 2004; Szulc et al., 2004; Hughes et al., 2002; Rantanen et al., 1997). In view of this functional markers and levels of habitual activity were correlated for the study population to establish if any associations existed.

There were no associations found between HGD (kg) and any measure of habitual activity. Despite the fact that HGD is a cheap and reliable marker of functional status and that many published studies have established the role of HGD in predicting outcomes (Visser et al., 2005; Hairi et al., 2010; Bohannon, 1998; Rantanen et al., 2002; Newman et al., 2006), there are few published studies on the relationship between handgrip and habitual activity levels and the results of these studies are inconclusive (Kuh et al., 2005; Rantanen et al., 1999). One previous study found that grip strength was associated with levels of activity with mildly and moderately active men having stronger measured grip strengths than inactive men (Kuh et al., 2005). This same study did not find any relationship between HGD and activity in women. It should be noted that although this study was undertaken in the UK it reported data from

a much younger adult population in that the participants were aged 53 years. In addition activity in that study was based on self-reports rather than objectively measuring activity levels. It is well established that grip strength and function deteriorate with age (Bohannon et al., 2006) so this along with the different methodology used to measure habitual activity may well explain the differences in the results found between that study and this current study. A further study was undertaken in a group of older women (mean±sd age 78±8.1 years) and in this study women who were physically active had higher grip strengths than inactive women (Rantanen et al., 1999). This study was undertaken in a large US population and again activity was self-reported rather than objectively measured potentially explaining the differences in the results.

The measures of habitual activity in this current study all reflect lower body movements and whilst an activity diary completed by the participants supported the data from the accelerometer and could provide an indication of any upper body activity (including muscle strengthening exercises) which may influence upper body strength it is not possible to quantify that data objectively. Some consideration should be given to upper body activity to establish whether this along with other markers of habitual activity are better able to establish whether an association exists between habitual activity and HGD. Indeed it is reasonable to assume that increased upper body movement will influence upper body strength and thus may influence HGD measurements. There should therefore also be some consideration to upper body strength when establishing recommendations for activity levels for older adults as it is this upper body strength which will influence ability in some aspects of ADL e.g. cooking, opening packaging, carry shopping more so than lower body strength. Despite conflicting results in terms of



the relationship between grip strength as measured by HGD (kg) and habitual activity between this current study where no relationship was found and previous studies, HGD remains a useful measure in older adults. It has a clear role in terms of determining functional decline and thus an ability to perform ADL as well as being an established marker to predict subsequent disability and mortality (Newman et al., 2006; Hairi et al., 2010; Rantanen et al., 2000; Rantanen et al., 2003).

Although there were no associations found between HGD (kg) and measures of habitual activity this was not the case for other markers of functional status. A negative relationship was found between performance in STS (s) and mean daily time stepping (min) ( $r=-.344$ ,  $p=.022$ ), mean daily number of steps ( $r=-.330$ ,  $p=.028$ ) and total weekly time in activities at MET > 3 when accumulated in blocks of at least 10 minutes (min) ( $r=-.321$ ,  $p=.041$ ). These results support findings from a previous study which found better functional ability was associated with higher levels of walking (i.e. over 6,500 steps/day) (de Melo et al., 2013) and results from a systematic review which showed that higher levels of physical activity in older adults were associated with reduced risk of functional limitations and disability with age (Paterson & Warburton, 2010). These results therefore support the need for increased levels of activity in older adults as higher levels of activity are consistently associated with improved functional status and, in relation to STS, lower body strength and level of transfer function (Bohannon 2002; Janssen et al., 2002c; Ritchie et al., 2005; Nordin et al., 2008). Clearly only an association has been established in this current study and it is not possible to determine whether higher levels of activity improve function or whether greater function promotes more activity or indeed a combination of both. This along with activity types which influence function needs further investigation.

The study by de Melo et al (2013) suggests that even low intensity activity i.e. walking and lower than recommended amounts of activity are associated with better functional status in older adults. However in this current study a negative association was found between STS performance and not only stepping time (min) and number of steps but also total weekly time in activity at MET > 3 when accumulated in blocks of at least 10 minutes (min) suggesting that intensity of activity may also be important. When these associations were explored further however and controlled for age and gender it was found that the relationship was no longer statistically significant after controlling for age. This change in the relationship is due to the relationships between age and STS (s) ( $r=.322$ ,  $p=.04$ ) and between age and habitual activity as previously described. This suggests that there is an inevitable change not only in activity levels with ageing but also in function when measured by the STS test. This has been reported elsewhere (Steffen et al, 2002).

Associations were also found between the 6MW test and measures of habitual activity. The 6MW was positively associated with mean daily time stepping (min) ( $r=.594$ ,  $p<.001$ ), mean daily number of steps ( $r=.530$ ,  $p<.001$ ), total weekly time in activity at MET>3 (min) ( $r=.443$ ,  $p=.004$ ) and negatively associated with mean daily time sitting or lying (min) ( $r=-.391$ ,  $p=.008$ ), mean daily time in sedentary behaviour sedentary (min) ( $r=-.503$ ,  $p=<.001$ ) and percent awake time in sedentary behaviour ( $r=-.445$ ,  $p=.002$ ). The 6MW test is a reliable measure of function and, to some degree, endurance in that it is a prolonged episode of activity and it has been shown to be associated with maximal exercise capacity and subjective functional status questionnaires (Steele,

1996; Bittner 1997). It is a particularly useful measure in older adults as it reflects functional exercise level for activities of daily living (AST 2002).

Like the relationships between STS (s) and habitual activity, the relationships between the 6MW (m) test and measures of habitual activity were also controlled for age and gender. Age was found to be associated with the 6MW (m) test ( $r=-.598$ ,  $p<.001$ ) and with measures of habitual activity as previously described. This suggests that as people age there is a resultant reduction in distance walked in the 6MW (m) test and this is supported by normative data (Enright & Sherrill, 1998). In addition alongside ageing there is a resultant decrease in levels of physical activity which may be attributable to a reduced level of function although this cannot be determined by this current study. In view of these apparently inevitable declines in function and levels of activity with ageing it seems that it may not be possible for older people to meet current recommendations for levels of activity providing additional weight to the argument for the need for specific recommendations for activity targets for older adults.

The results from this current study clearly demonstrate that there is an association between function (as measured by 6MW and STS) and increased levels of activity and decreased levels of sedentary behaviour. These results are expected as increasing levels of physical activity have been shown to improve muscle strength and quality and functional ability in older adults (Liu & Latham, 2009). Although there is limited information available about patterns of activity in older adults and this has been acknowledged by other authors (Schrack et al., 2013) recent studies by Yorston et al. (2012) and Schrack et al. (2013) have found relationships between habitual activity and functional status although like this current study these relationships were influenced by

age. Whilst functional status and levels of activity decreased with age those people who maintained higher levels of activity remained functionally better. Yorston et al. (2012) measured function and activity by questionnaire in an Australian population and Schrack et al. (2013) measured functional status by gait speed and physical activity by accelerometer in a US population. Methodologies between these studies and this current study therefore differ however there is consistency in the results found and so it is clear that there is a relationship between functional status and levels of physical activity. Maintaining levels of activity in an ageing population is therefore key to maintaining function and so minimum targets for activity specific to the older adult population which are achievable but perhaps stretching and realistic should be set.

#### **4.7 DIETARY INTAKES**

Dietary intakes were recorded using an unweighed seven day diet diary which was subsequently analysed using Windiets research (Univation Ltd 2005). The mean±sd percentage energy intake from fat was not statistically different from healthy eating guidance ( $34.7\pm 4.1\%$  vs 35%,  $p=.388$ ). However participants consumed more SFA intakes ( $13.1\pm 2.9$  vs 11%,  $p<.001$ ), less PUFA ( $5.5\pm 1.5$  vs 6.5%,  $p=.011$ ) and less MUFA ( $11\pm 1.7$  vs 13%  $p<.001$ ) than is recommended within the context of a healthy diet (DoH, 1991). The total fat intakes suggest no increased risk of CVD as a result of consumption of this dietary component. However the proportions of both saturated fat and unsaturated fats are not reflective of a healthy diet and could result in increased CVD risk (DoH, 1991). This in combination with the raised WC measurements has the potential to increase CVD risk further (Wenger, 2014). Whilst the Scottish Health Survey for older people does measure some components of dietary intake, fat intake is not one and so comparisons cannot be made to that for the Scottish population.

However the National Diet and Nutrition Survey (NDNS) of the UK (DoH, 2012) does consider overall fat intakes and so it is possible to compare the intakes of the study population to this.

The NDNS (DoH, 2012) report that total fat intakes for people aged 65 years and over in the UK are in line with healthy eating guidance with  $34.8 \pm 6\%$  of energy coming from fat. This figure is similar to the mean  $\pm$  sd intakes for the population of this current study ( $34.7 \pm 4.1\%$ ). In terms of SFA intakes the NDNS found that mean intakes in older adults ( $13.7 \pm 3.6\%$ ) exceeded the recommended levels of no more than 11% food energy and the participants of this current study had similar intakes ( $13.1 \pm 2.9\%$ ). In terms of PUFA the study population have similar intakes as the UK population as a whole ( $5.5 \pm 1.5\%$  vs  $5.8 \pm 1.4\%$  respectively). Total MUFA intake is not reported within the NDNS and so cannot be discussed here. It should of course be noted that the NDNS includes data from the UK population and does therefore fully not fully reflect the only the Scottish older adult population. However it appears that in terms of fat intake the intakes of the study population are reflective of the UK adult population.

In the context of a healthy diet, whilst fat is a key determinant of this, other macronutrients should also be considered. Guidance suggests that 50% of overall energy intakes should come from CHO and no more than 11% of energy should come from NMES. The study population failed to meet these targets with only  $46 \pm 5.3\%$  ( $p=.008$ ) of energy coming from CHO and  $13.4 \pm 4.8\%$  ( $p=.036$ ) coming from NMES. The intakes of NMES in the study population exceed that of the UK population as a whole where intakes of those people aged 65 and over are currently consuming  $11 \pm 5.4\%$  of energy. The participants of this current study do however have higher total

CHO intakes than the UK population who have intakes of  $44.9 \pm 6.8\%$ . Although on the face of it this may seem positive, these higher intakes of CHO are almost certainly attributable to the higher intakes of NMES which is a less positive finding. This along with poor NSP intakes (similar to intakes of the UK population ( $13.5 \pm 4.8$  g for the study population and  $13.3 \pm 4.7$  g for the UK population)) and in combination with the profile of fat intakes suggests dietary intakes for the study population are reflective of a poor quality diet. This is similar to dietary intakes of the UK population as a whole. It is worthy of note that despite this, the deterioration seen in health which would normally result from a poor diet was not apparent in the participants of this current study. The participants had a normal BMI, were healthy along with being active and it is possible that these factors outweigh the fact that they were not meeting recommendations for dietary intake.

As discussed at length previously (section 1.10.1) adequate protein intakes are key to helping maintain muscle mass and potentially muscle function in older adults (Houston et al., 2008). The mean  $\pm$ sd daily protein intakes of the study population of  $73 \pm 16.7$  g exceed that found in the general population ( $69.8 \pm 20.6$  g) when compared to data from NDNS (DoH, 2012). When considered as g/kgBW, protein intakes in the current study population were found to be 0.98 g/kgBW (comparable data is not available for the UK population) and this exceeds the current RNI for protein of 0.75 g/kgBW. It could be argued that these above RNI intakes may have a beneficial effect in terms of muscle mass but there is currently a suggestion that protein intakes in older adults should be as high as 1.2 g/kgBW (Gaffney-Stomberg et al., 2009) or even 1.5 g/kgBW (Wolfe et al., 2008) to optimise muscle synthesis. These suggested intakes are well in excess of protein intakes found in this current study and in the context of the mean weight of the

study population equates to a deficit of 18 - 43 g/day of protein for the male participants and 16 - 36 g/day for the females participants.

In view of this and in terms of muscle mass and function the intakes of the study population may not be adequate. However increasing protein intakes to the recommended level would result in either an increase in overall energy intake which would not be encouraged in view of the impact this would have on weight gain or would result in other nutrients being displaced. Due to the nutritional composition of the diet and dietary protein sources the most likely nutrient to be displaced would be CHO. As the study population already have lower than desirable intakes of starchy CHO this would result in a poorer quality diet overall. The impact of increasing protein intakes to these levels should therefore be considered carefully and should be done so in the context of the overall diet and alongside potential risk factors associated with a poor diet. Dietary protein is however not the sole influence on muscle mass and function and should be considered alongside levels of activity.

Micronutrients were also measured and in particular vitamin D and vitamin C are of interest in terms of functional ability and antioxidant capacity. The mean $\pm$ sd intake of vitamin D in the study population was 3 $\pm$ 1.5  $\mu$ g which is well below the RNI of 10  $\mu$ g per day ( $p < .001$ ) (DoH, 1991). This is of concern as in Scotland there is limited opportunity for people to synthesise vitamin D from sunlight due to the northerly latitude and there is evidence to show that much of the Scottish population have low serum vitamin D levels (MacDonald et al., 2011). The impact of vitamin D status on physical functioning is not clear as conflicting evidence regarding the association between lower serum vitamin D levels and physical functioning exists.

A number of studies have found that poor vitamin D status is associated with poorer physical functioning (Bischoff-Ferrari et al., 2004; Gerdhem et al., 2005; Houston et al., 2007) and other studies have found no association between vitamin D status and functional status (Marantes et al., 2011; Ceglia et al., 2011) in older adults. The role of vitamin D in terms of function is unclear however it has been shown to be important in falls prevention with a meta-analysis suggesting low vitamin D status increases risk of falls in older adults (Annweiler & Beauchet, 2014). It is therefore a key nutrient in the ageing process and may influence a person's ability to live independently for longer through falls prevention. In view of this SACN (2007) recommend that all adults over the age of 65 in, not only Scotland, but across the UK should take a 10 µg vitamin D supplement daily to enable them to meet the RNI. Only one of the study participants was complying with this recommendation meaning that most of the study participants could, depending on their level of sun exposure, potentially be vitamin D deficient thus increasing their risk of falls.

Meeting the RNI for vitamin D through dietary sources is difficult (as there are few dietary sources of vitamin D) and so there is a limit to dietary changes which can be made to increase intakes. As dietary intake alone does not reflect vitamin D status this can really only be assessed through measuring serum vitamin D levels. This was out with the scope of this study although it is worthy of note that the study population are healthy and much of the activity which they engaged in took place outdoors so there were opportunities for this group to be exposed to sunlight although as previously explained this was not measured.



Although serum vitamin D levels were not measured within this study serum antioxidant status was. This is important as it has been shown that that poor antioxidant status is associated with an increased risk of CVD (Arts & Hollman, 2005), dementia (Devore et al., 2010) and stroke (Voko et al., 2003) and these all influence morbidity and mortality influencing the potential for independent living. In addition to this there is an association between plasma antioxidant concentrations and physical performance in particular with vitamin C being associated with greater skeletal muscle strength (Cesari et al., 2004).

In this current study the vitamin C intakes of the study population were well in excess of the RNI for vitamin C ( $103\pm 43$  mg vs 40 mg). This may reflect the dietary intakes of the study population where most participants consumed potatoes (a rich source of vitamin C in the UK) most days and many drank orange juice at breakfast each day. It is well established that many people change dietary habits when they are aware that their dietary intakes are being monitored (Stubbs et al., 2014) and so it is possible that the study population either under-reported dietary intakes or they may have swapped some less healthy foods for foods which would be considered more healthy e.g. fruit and vegetables. As fruit and vegetables are rich sources of antioxidants and many are rich sources of vitamin C this may explain the high intakes. However it is worth noting that intakes were more than twice the RNI for vitamin C and so it is more than possible that high vitamin C intakes are the norm for this population even if under-reporting or dietary intake changed during the recording period.

The most recent NDNS reported that people aged 65 years and over have the highest fruit and vegetable intakes of the UK population consuming 4.4 portions per day

compared to 4.1 portions for the remainder of the adult population (DoH, 2012). The overall intakes in Scotland were lower but the trend for older people to eat more fruit and vegetables was also seen with those people aged 65 - 74 years in Scotland consuming an average of 3.4 portions per day compared to younger adults eating only 2.8 portions per day (The Scottish Government, 2013). In view of these high intakes of vitamin C the antioxidant status of the study population would also be expected to be high and in view of the relationship between vitamin C and muscle strength this may also help partly explain the good functional status of the population.

The antioxidant status of the study population was measured using the ferric reducing antioxidant capacity of plasma (FRAP) (Benzie & Strain 1996). Due to only a limited number of samples being available only 12 samples (4m, 8f) were analysed. In view of these small numbers and lack of normative data for plasma antioxidant levels it is difficult to make any definitive conclusions from the results. The initial work by Benzie & Strain found that in a group of 141 apparently healthy Chinese adults the mean $\pm$ sd plasma FRAP concentration was 1017 $\pm$ 206  $\mu$ mol/l. In separate studies of Turkish older adults the mean $\pm$ sd plasma FRAP level was 889.9 $\pm$ 106.6  $\mu$ mol/l (Mutlu-Turtoglu et al., 2003) and American older adults the median (IQR) was 12.5 (12.0–13.0) mmol/dL (Devore et al., 2010). Whilst these results are not considered normative values, and they relate to a Chinese, Turkish and American populations some comparisons can be made. These should however be interpreted with caution as dietary intakes in these countries differ from the normal Scottish diet. The median (IQR) serum FRAP levels of the population in this study was 1,351 (999, 1,510)  $\mu$ mol/l which is higher than the three previous studies described. This is surprising as Scotland has one of the worst diets in the world and has relatively low fruit and veg intakes even in comparison the rest of the

UK (DoH, 2012). It does however reflect the high vitamin C intakes of the study population and as vitamin C is related to functional ability it may also be reflective of the good functional ability of the study population.

It is well accepted that recording dietary intakes is relatively inaccurate and generally there is either under-reporting of dietary intakes when using food diaries or a change in eating habits when people are aware their intake is being monitored. In a recent study by Stubbs et al. (2014) where dietary intake was objectively measured in a laboratory setting the extent and nature of misreporting of dietary intakes was measured when eating behaviour was continuously monitored. The study involved both overt and covert measurement of food intakes and subjects had ad libitum access to a variety of familiar foods. This study found that subjects decreased energy intake when asked to record their food intake with the effect being statistically significant in women (28%,  $p < .001$ ) but not in men (23%,  $p = .277$ ). In addition the reported energy intake was 5 - 21% lower than the actual intake, depending on the reporting method used with semi-quantitative techniques giving larger discrepancies. These discrepancies were identical in both males and females. It should therefore be acknowledged that measuring dietary intakes is not an exact science however in this current study the problems associated with measuring dietary intake were addressed as far as possible whilst being cognisant of the burden associated with recording dietary intake for the participants. Participants were provided with comprehensive instructions about the completion of the diet diary, were encouraged to provide comprehensive information about recipes used along with the provision of food labels as appropriate and the content of the diet diary was clarified at the end of the recording period.

In view of these known difficulties in estimating dietary intake through self-reported food diaries this current study included a measure of resting energy expenditure (REE) which along with a measure of activity (PAL) can determine total energy expenditure (TEE). Assuming participants were in energy balance, energy expenditure can act as a determinant of predicted energy intake and this can then establish whether the dietary analysis is an accurate reflection of energy intake. To measure REE guidance for best practice is available (Compher et al., 2006) and a number of conditions need to be met namely the subject should be completely rested (before and during measurements), lying down but fully awake, fasted for at least 10 – 12 hours, in a thermo-neutral environment (22 – 26°) and free from emotional stress (Levine, 2005). Meeting these criteria in this population proved difficult.

Despite giving participants explicit instructions about being fasted and rested, many participants had undertaken some form of early morning activity (walking or swimming) or had eaten breakfast. Both of these would have increased metabolic rates and thus influenced REE measurements and as such the measurements were deemed by the researcher to be inaccurate and could not be used with any degree of confidence. Those participants who this referred to preferred not to be re-measured on an alternative occasion. In addition to this it was not possible to measure REE in two participants due to the equipment malfunctioning. As these factors would influence the overall results in an already small sample size alternative methods of establishing the reliability of the diet diaries was sought and well recognised methodology to determine this is available (Goldberg et al., 1991).

It has been postulated that it is possible to estimate the level of under reporting in dietary intakes and in particular attempts have been made to determine the energy intake to basal metabolic rate ratio at which intakes could be deemed implausibly low. These cut-offs have been called the Goldberg cut-offs (Goldberg et al., 1991). These cut-offs compare mean reported energy intake with TEE. TEE is estimated from prediction equations to estimate REE (Schofield et al, 1985) and factored for physical activity using a physical activity level (PAL) factor. The Goldberg cut-offs utilise a PAL factor of 1.55 as Black et al. (1991) suggest that this is an indication of sedentary behaviour. The Goldberg cut-offs suggest that for any given study, the lower 95% confidence limit represents the value below which it is statistically unlikely that the reported mean intake represents either habitual long term intake or a low intake obtained by chance.

Since the original work by Goldberg et al, (1991) and Black et al. (1991) it has been suggested that utilising measured activity levels improves the specificity and sensitivity of the Goldberg cut-off rather than using a generic PAL factor for the population (Black, 2000). In addition SACN (2011) revisited the use of prediction equations for the UK population to determine energy expenditure at an individual and population level. SACN (2011) now suggest that due to limitations within the Schofield equations (Schofield et al., 1985) in that the study population did not include many older adults and had a high proportion of Italian military personnel along with large numbers of hill dwellers these equations are unlikely to reflect the UK population. In view of this SACN (2011) now advise that prediction equations published by Henry (2005) should be used in preference to the Schofield equations (Schofield et al., 1985). As activity levels were measured in the study population it is possible to estimate individual energy

expenditure using the Henry equations (Henry, 2005) based on age, gender and weight to predict REE in combination with the measured PAL factor to predict TEE thus giving an indication of predicted energy intakes.

To establish whether dietary intakes were subject to under reporting (either as under reporting or a result of changes in dietary intakes) mean reported energy intakes were compared to mean predicted energy intakes. This shows that the reported energy intake is statistically significantly lower than the estimated energy expenditure based on prediction equations to estimate REE (Henry, 2005) and measured PAL factors ( $1813 \pm 364$  vs  $2010 \pm 288$  kcal  $p < .001$ ). This result was consistent when considering energy intakes for males and females separately with males reporting mean  $\pm$ sd energy intakes of  $2026 \pm 357$  kcals compared to predicted intakes of  $2310 \pm 221$  kcal ( $p = .002$ ) and females reporting intakes of  $1619 \pm 246$  vs  $1928 \pm 212$ ,  $p < .001$ . This indicates that the participants in the study either under reported intakes or changed eating habits whilst the study was on-going or did a combination of both. It is also worthy of note that the PAL factor utilised to establish TEE was that using METs devised from the *activPAL*<sup>TM</sup> accelerometer. As previously discussed (section 4.2) the use of METs in older adults may underestimate energy expenditure. It is therefore possible that the level of underreporting seen in this current study may be significantly higher than those figure reported above.

Even if this is the case the impact that this under-reporting or change in dietary intake during the recording period has on the interpretation of dietary intakes is not clear. It is not possible to establish whether all nutrients are affected to the same degree as energy and as a result dietary intakes should be interpreted with caution. It is likely that

changes to the diet will reflect a reduction in components of the diet which would be considered less healthy e.g. fat, NMES and alcohol and an increase in components of the diet which would be considered more healthy e.g. NSP and fruit and vegetables. However it should be noted that the content of the food diary was discussed at length with the participants at the end of the recording period and any area of ambiguity was discussed and clarification was sought by the researcher and provided by the participant. As has been reported elsewhere recording of dietary intakes using a self-report methodology is fraught with difficulties and potential inaccuracies (Coulston et al., 2013) but within this study all efforts were made to ensure as accurate reporting as possible including detailed instructions and clarification of dietary recording using a food atlas where necessary.

#### **4.8 ASSOCIATION BETWEEN OF LEVELS OF HABITUAL ACTIVITY AND DIETARY INTAKE.**

The relationships between dietary intakes and habitual activity were also investigated and a number of associations were found. In particular percent energy intake from fat was positively associated with mean daily time sitting and lying (min) ( $r=.572$ ,  $p<.001$ ), mean daily time in sedentary behaviour (min) ( $r=.445$ ,  $p=.002$ ) and percent awake time in sedentary behaviour ( $r=.535$ ,  $p<.001$ ) and negatively associated with mean daily time standing (min) ( $r=-.5$ ,  $p=.001$ ), mean daily time stepping (min) ( $r=-.299$ ,  $p=.049$ ), mean daily number of steps ( $r=-.455$ ,  $p=.002$ ) and total weekly time in activity at MET > 3 (min) ( $r=-.405$ ,  $p=.009$ ). In terms of fat intake when measured as a percentage of overall energy intake it seems that those people who were less active and more sedentary were more likely to have higher fat intakes. Both these lifestyle behaviours are associated with higher risk of NCDs such as CVD and T2DM (Wenger, 2014). In

addition these behaviours are more likely to lead to increased adiposity reflected in a higher BMI ( $\text{kg/m}^2$ ) and higher WC (cm) which are also associated with an increased risk of NCDs (WHO, 2014).

Similar results were found when investigating associations between SFA intakes and levels of activity where higher intakes of SFA (a further risk for CVD) were positively associated with mean daily time sitting and lying (min) ( $r=.429$ ,  $p=.004$ ), mean daily time standing (min) ( $r=.379$ ,  $p=.011$ ), and percent awake time in sedentary behaviour ( $r=.381$ ,  $p=.011$ ) and negatively associated with mean daily number of steps ( $r=-.344$ ,  $p=.027$ ). This is again indicative of poor health behaviour and suggests that those people who are engaging in lower levels of physical activity had overall poorer lifestyles as they also had poorer diets.

As fat is an energy dense nutrient high fat intakes will displace energy from other macronutrients and it is therefore unsurprising to find that CHO intake, when considered as a percentage of total energy intake, was found to have a negative association with mean daily time sitting and lying (min) ( $r=-.385$ ,  $p=.01$ ), mean daily time standing (min) ( $r=-.404$ ,  $p=.006$ ) and percent awake time in sedentary behaviour ( $r=-.314$ ,  $p=.038$ ). In addition there was also a negative association found between percent energy intake from NMES and mean daily time sitting and lying (min) ( $r=-.342$ ,  $p=.023$ ) and percent awake time in sedentary behaviour ( $r=-.314$ ,  $p=.038$ ) and a positive association with mean daily time standing (min) ( $r=.408$ ,  $p=.006$ ) and mean daily time in activity at MET > 3 (min) ( $r=.333$ ,  $p=.031$ )



Similar results have been found in a study of older American woman where active women reported consuming a lower percentage of energy intake from total fat ( $31\pm 8$  vs  $34\pm 8$ ,  $p=0.04$ ) and saturated fat ( $10\pm 3$  vs  $11\pm 3$ ,  $p<0.01$ ) and a higher a higher percentage of energy intake from carbohydrate ( $53\pm 10$  vs  $50\pm 10$ ,  $p=0.04$ ) than sedentary women (Woolf et al., 2008). However other studies have not found results consistent with this as a study by Shahar et al. (2009) found that more active people ate more fat and less carbohydrate relative to less active participants. However this study by Shahar et al. (2009) measured dietary intake by food frequency questionnaire whereas both this current study and the study by Woolf et al. (2008) measured dietary intake by food diary. Food frequency questionnaires have been shown to contain a substantial amount of measurement error with many aspects of dietary intake not measured meaning the quantification of intake is not as accurate as those measured by recall or diet diary (Coulston et al., 2013). This may then explain the difference in the results between studies. As each study measured dietary intake in a different population with this current study measuring intake in a Scottish population, the study by Woolf et al. (2008) measuring intake in a US population based in Arizona and the study by Shahar et al. (2009) measuring intake in a US population based in Pittsburgh and Tennessee it is reasonable to assume that dietary intakes across these geographical areas could differ significantly which would further influence the results.

Despite the likely underreporting seen in this current study through the use of food diaries, any changes in dietary intakes during the recording period were most likely to result in changes to the diet which would result in it being more healthy i.e. reduction in fat intakes. Consistent under-reporting across all participants would have a similar effect on each dietary intake and thus it is unlikely that the associations found would

change. Consideration should however be given to the influence age and or gender may have on these results and this can be determined from results of the partial correlation analysis. As discussed previously, age was associated with measures of habitual activity with older people engaging in lower levels of physical activity and higher levels of sedentary behaviour. There was however no association found between age and dietary intake. It can therefore be concluded that in this current study at least those people who were least active were also most likely to have the poorest diet in terms of CVD risk and risk of developing overweight and obesity. These lifestyle factors in combination are indicative of a poor overall lifestyle and recommendations to improve activity levels should perhaps be given in the context of changes to lifestyle per se in an attempt to also improve dietary intakes and thus diet quality.

The role of both dietary protein and physical activity in maintaining functional status and slowing or preventing the development of sarcopenia has been discussed previously (section 1.10.1). The relationship between these is acknowledged as important as both higher intakes of dietary protein (Paddon-Jones, 2006; Paddon-Jones et al., 2004a) and higher levels of physical activity (DHHS, 2008) have been shown to influence sarcopenia. In this current study a positive relationship was found between protein intake when measured as g/kgBW and mean daily time spent stepping (min) ( $r=.327$ ,  $p=.02$ ) and mean daily number of steps ( $r=.443$ ,  $p=.004$ ). When measured as a percentage of energy intake protein was positively associated with total weekly time in activity at MET > 3 (min) ( $r=.445$ ,  $p=.004$ ) and when measured as absolute mean daily intake protein (g) was also positively associated with total weekly time in activity at MET > 3 when accumulated in blocks of at least 10 minutes (min) ( $r=.350$ ,  $p=.025$ ). When measured as a percentage of total energy intake protein is influenced by energy

from other macronutrients, most notably CHO and fat and so protein reported as a percentage of energy intake is therefore less meaningful as it is both absolute protein intakes and intakes in relation to body weight which will provide more information relative to muscle function.

The relationships found between protein intakes (g/kgBW) and habitual activity levels are therefore encouraging as those people who are most active have higher protein intakes. Higher protein intakes have the potential to prevent muscle breakdown (Paddon-Jones, 2006), promote muscle synthesis (Paddon-Jones et al., 2004a; Paddon-Jones et al., 2004b) and as such have the potential to maintain functional ability or even improve it (Imai et al., 2014). Consideration does however have to be given to the type of protein a person is eating with an emphasis on high biological value protein, i.e. protein rich in essential amino acids, and ensuring dietary protein sources are not coming from predominately high fat sources. These considerations were out with the scope of this study as quantities of high biological value protein relative to low biological value protein were not measured. The relationship between protein intakes (g/kgBW) and physical activity in terms of mean daily time stepping (min) and mean daily number of steps may help explain the fact that the study population are of good nutritional status and that only 2% (n=1) of participants would be considered at risk of sarcopenia. It cannot be determined conclusively from the study due to the nature of the research that higher protein intakes and higher levels of functional activity resulted in a functionally more able group however there was clearly an association found. This is encouraging for an older adult population and increased levels of physical activity supported by higher protein intakes may well be a sensible recommendation for an older adult population.

As with the other correlation analyses these relationships were also controlled for age and gender to establish if these parameters influenced the relationship. Neither age nor gender was associated with protein intakes and so the only influence of age on these associations was as a result of the association between age and measures of habitual activity. There is no obvious reason to suggest that increased activity results in higher protein intakes or indeed that higher protein intakes results in higher levels of activity in older people and there is no research to confirm this is the case. It could however be postulated that higher dietary protein intakes improve function enabling people to be more active. To determine whether in fact this is the case additional research would be required. The relationship is however important in terms of managing sarcopenia although as previously suggested the relationship between protein intake and habitual activity requires further research to establish why it exists and how to best utilise the information to improve the ageing process.

The other key nutrient in terms of function and activity is vitamin D. In this study there was a positive relationship found between vitamin D intake ( $\mu\text{g}$ ) and mean daily number of steps ( $r=.322$ ,  $p=.033$ ), between total weekly time in activity at MET > 3 (min) ( $r=.419$ ,  $p=.006$ ) and between total weekly time in activity at MET > 3 when accumulated in blocks of at least 10 minutes (min) ( $r=.404$ ,  $p=.009$ ). As vitamin D and weight bearing activity are both related to bone health those people who are engaging in higher levels of activity and consuming higher amounts of vitamin D will benefit from improved bone health. This is important in older people who are at increased risk of falls as if a fall occurs this improved bone health may prevent fractures developing. Fractures in older adults are associated with an increased risk of morbidity and mortality (Rubenstein,

2006) and so preventing this is key to maintaining health in older people. The aim of this study was to establish whether relationships exist and not to establish cause and effect however the fact that relationships exist is an important finding as it does have implications for healthy ageing. There is also clearly a relationship between vitamin D intakes and higher intensity activity. This relationship therefore warrants further investigation and particularly after appropriate and advised supplementation with vitamin D.

#### **4.9 FATIGUE**

Levels of fatigue were measured using the Multi-dimensional Fatigue Inventory (MFI) (Smets et al., 1995). There was no difference found between the male and the female participants in any domain of fatigue in this current study. This is contrary to previous studies which have found that older women tend to be more fatigued than older men (Schwarz et al. 2003; Hinz et al., 2013; Vestergaard et al., 2009). The reason for the lack of difference between genders is likely to be attributable to the functional status of the study participants and is discussed further below.

When compared to normative data for adults aged 60 years and over (Schwarz et al, 2003) levels of fatigue in the participants in this current study were lower than expected. The low levels of fatigue in the study population are likely to be attributable to their activity levels. Results from previous studies support this where an inverse relationship with habitual activity and fatigue has been found (Valentine et al., 2011) and evidence that insufficient levels of physical activity are associated with higher reported levels of fatigue in both men and women (Resnick et al., 2006). Whilst not confirmed in older

adults, increasing physical activity has been shown to attenuate perceptions of fatigue in younger adults (Puetz et al., 2006). It is therefore reasonable to assume that this may also be the case in older adults albeit to a lesser degree due to the fact that they are unlikely to be able to engage in similar levels of activity as younger people.

It should be noted however that there was a trend towards statistical significance in differences in levels of general fatigue (which can also be used as a measure of overall fatigue (Smets et al., 1995)) between men and women. In this study men had a median (IQR) score of 9 (6.5,10.5) and women a median (IQR) score of 7(6,9),  $p=.051$ . Although not statistically significant it is possible that with a larger sample size that this would reach a statistically significant level. The reason for this potential difference is not clear but it could be partially explained by the functional ability of the participants or their interpretation and perception of fatigue. As previously discussed, the 60 - 69 year old male participants did not perform as well as expected compared to normative data in the 6MW ( $483\pm 100$  vs 572 m). In addition 57% ( $n=12$ ) of the male participants walked a shorter distance than expected in this test. The results from this study cannot determine the cause of this poorer performance or determine what the cause and effect is between 6MW and fatigue however further research is warranted.

As discussed, when considering the participants of this current study the levels of fatigue are lower than would be expected from normative data. This can be explained not only by the good functional status but also the by the good nutritional status of the study population. Fatigue has been shown to be related to a poorer nutritional status in terms of increased BMI (Valentine et al., 2011), to a decline in functional status (Hardy & Studenski, 2008b) and poorer general health even acting as a predictor of mortality

(Avlund et al., 2006; Hardy & Studenski, 2008a; Ekman et al., 2012; Moreh et al., 2010). As this study population were healthy and of good nutritional and functional status it is therefore less likely that they will experience prolonged and debilitating episodes of fatigue. Intervention studies are required to establish how activity influences levels of fatigue in older adults (or vice versa) and the interrelationship between habitual activity, nutritional status, functional status and levels of fatigue in older adults.

#### **4.10 ASSOCIATION BETWEEN LEVELS OF HABITUAL ACTIVITY AND LEVELS OF FATIGUE**

Negative associations were found between the general fatigue score and mean daily time stepping (min) ( $r=-.344$ ,  $p=.002$ ), mean daily number of steps ( $r=-.374$ ,  $p=.012$ ) and total weekly time in activity at MET > 3 (min) ( $r=-.310$ ,  $p=.048$ ). As discussed earlier these results are similar to those found in other studies (Valentine et al., 2011; Resnick et al., 2006). General fatigue, which is also considered a marker of overall fatigue when using the MFI (Smets et al., 1995) is therefore negatively associated with levels of physical activity. Along with the general fatigue score the physical fatigue domain score was also found to be negatively associated with mean daily time stepping (min) ( $r=-.337$ ,  $p=.025$ ) as was the reduced activity domain score ( $r=-.326$ ,  $p=.025$ ). It is therefore not surprising that these domain scores were also positively associated with mean daily time in sedentary behaviour (min) (physical fatigue  $r=.321$ ,  $p=.034$ ; reduced activity  $r=.332$ ,  $p=.028$ ). This current study has therefore established that there is an association between physical activity and sedentary behaviour and measures of fatigue related to activity i.e. general fatigue, physical fatigue and reduced activity. There was

however no association between mental fatigue and reduced motivation. The physical rather than mental aspects of fatigue are important to consider when considering activity. As the physical domains of fatigue are most closely associated with levels of activity both nutritional status (in terms of muscle mass) and functional status (in terms of muscle strength and function) are also likely to play a role. Future studies to determine this interrelationship are therefore warranted.

A study of older adults found that lower levels of physical activity were associated with higher levels of fatigue ( $r=-0.263$ ,  $p<.001$ ) (Soyuer & Senol, 2011). However although the participants were older adults they were residents of rest homes in Turkey and thus not living independently. It is therefore unlikely that they would be as healthy as the participants in this current study. In addition levels of activity were measured by questionnaire rather than objectively measured by accelerometer. There are limited studies investigating the relationship between fatigue and physical activity in healthy adults however one study has found similar results to this current study. In the study by Valentine et al. (2011) activity was measured by the PASE physical activity questionnaire (Washburn et al., 1993) and fatigue by the MFI (Smets et al., 1995) and an association was found to exist between physical activity and general fatigue ( $r=0.279$ ,  $p<.05$ ), physical fatigue ( $r=0.367$ ,  $p<.05$ ), reduced activity ( $r=0.320$ ,  $p<.05$ ) and reduced motivation ( $r=0.221$ ,  $p<.05$ ) (Valentine et al., 2011). Those results are similar to the findings of this current study although Valentine et al. (2011) also found an association between reduced motivation and levels of activity. The reason for the differences are not clear as Valentine et al., (2011) recruited healthy older adults in the USA who were of a similar age as the participants in this current study (mean $\pm$ sd age  $69.6 \pm 6.5$  vs  $72.8 \pm 5.5$  years) with a similar nutritional status (mean $\pm$ sd BMI  $26.7 \pm 5.2$



vs  $26.8 \pm 2.8 \text{ kg/m}^2$ ). The differences may then lie in the fact that an American population potentially exhibit differences in fatigue levels compared to a Scottish population although this would have to be established. It could also be attributed to the much larger sample size ( $n=182$ ) or the different methodology used to measure levels of activity.

The differing methodologies may also affect results as it is well established that measuring activity by questionnaire has limited reliability (Shephard, 2003). This current study therefore has advantages in that activity was measured directly providing a more robust assessment of the relationship with fatigue. Despite the difference in findings, it can be stated conclusively that there is a positive association between physical activity levels and the physical domains of fatigue as measured by MFI. What is not currently known however is whether fatigue results in reduced activity or whether reduced activity results in fatigue or whether a combination of both exists. In view of this further intervention studies using objective measures of physical activity to establish this are warranted. It also seems apparent that it is the amount rather than the intensity of the activity which is important in terms of levels of fatigue as no association was found between fatigue and activity at  $\text{MET} > 3$  either when considered as a total or when accumulated in blocks of at least 10 minutes. This gives weight to the argument that recommendations for levels of activity in older adults should focus on quantity rather than intensity.

Due to the fact that the method of assessing fatigue produces non-parametric data, partial correlation analysis was not performed and so the influence of age and gender has not been established for the relationship between fatigue and levels of activity.

However it is already established that age influences physical activity levels and a Spearman's rho correlation analysis was performed between age and measures of fatigue to establish if relationships exist. This was also performed for gender. There was a positive association found between age and the reduced motivation score ( $r=.314$ ,  $p=.038$ ) and a negative association found between gender and the general fatigue score ( $r=-.298$ ,  $p=.049$ ). No other relationships were found. As measures of habitual activity were not associated with the reduced motivation score in this population age does not appear to influence levels of fatigue. However gender may influence the relationship between general fatigue and measures of habitual activity.

#### **4.11 LIMITATIONS TO THE STUDY**

There were some limitations to the study which should be acknowledged. The power calculation prior to commencement of the study indicated that taking into consideration a 25% attrition rate the study would require recruitment of 200 participants to enable multiple regression analysis to be performed. Attempts to recruit participants were made through several channels including distribution of posters and flyers at events and establishments attended by older people. This included, but was not exclusive to, churches, bingo halls, leisure centres, university of the third age meetings, probus clubs, charity shops, local cafes and bowling clubs. In addition letters and emails were sent to secretaries or organisers of other groups including golf clubs, social groups for older people and the researcher attended several groups to give talks about the research and to encourage interest in the study. Despite this significant effort, only 44 people volunteered to participate in the study. However all of the recruited participants completed the study.

Difficulties in recruitment of older people to research studies have been reported elsewhere and reasons for recruitment difficulties include older people who have carer responsibilities, lack of private or accessible public transport and mobility or physiological challenges such as frequent urination making travel difficult (Cusak & O'Toole 2013). In addition it has been reported that social isolation, lack of social support along with a general suspicion of research inhibits older people participating in research studies (Lovato et al., 1997). It is not possible to determine whether these were issues with recruitment for this study but certainly due to the nature of the recruitment strategy, those people who were socially isolated were less likely to have been informed of the study and thus not recruited.

Reviews by Carroll & Zajicek, (2011) and Ridda et al. (2010) have summarised and discussed not only difficulties in recruiting older people to research studies but have also suggested strategies to overcome recruitment difficulties. Many common themes emerge including utilising several recruitment strategies, ensuring a flexible approach to the study and being aware of individual needs of participants (Samelson et al., 2008; Forster et al., 2010; Sanders et al., 2009; Mody et al., 2008) all of which were addressed in the recruitment strategy of this current study. There is evidence that recruitment through the NHS may improve participation in research studies involving older people (Mody et al. 2008). Recruitment through GP's promoting the study may have increased participant numbers however the focus of the study was very much on older adults living independently within the community and had GP surgeries been used as recruitment sites the population recruited may not have reflected a healthy older adult population.

The researcher endeavoured to overcome as many potential barriers as possible by offering extensive opportunities to discuss the project and answer any queries and by arranging appointments at times suitable for the participant. In addition where possible and when requested the researcher travelled to the participant to undertake the testing. There was anecdotal evidence that potential participants were unwilling to record dietary intakes for seven days and this resulted in people who were initially interested in the study not then proceeding and volunteering to participate. However those people who were recruited all returned fully completed diet diaries at the end of the recording period and so whether this was a perceived or actual barrier is not known. Finally the study was undertaken on a part-time basis whilst the researcher remained in full-time employment and so there were time restrictions and unavoidable constraints on the recruitment opportunities. Undertaking the study on a full-time basis may have improved the recruitment to the study. Despite the effort put into recruitment, the sample size remained small and so results should be interpreted with caution. This is particularly so where the study population have been stratified by age and gender. Where this is relevant this has been acknowledged and highlighted throughout the text.

This study recruited a healthy population and this may be as a result of the nature of the research in that the focus was physical activity which may have resulted in a perception that people would have to be physically active to participate. In addition it could also be as a result of people who are socially isolated or frailer not being able or willing to take part as they were either not aware of the study or did not feel they would be able to participate. Issues associated with the perception of research and the influence this has on recruitment have been reported elsewhere as a potential barrier to recruitment (Cusack & O'Toole 2013). Whilst the participants recruited met the inclusion criteria for

the study, the interpretation of results should be considered in the context of a healthy older adult population. Due to the heterogeneity of the older adult population it is will not be possible to extrapolate the results to the entire older adult population. However as the population are healthy the results will give an indication of lifestyle factors which could enhance healthy living. In addition the fact that the study population was healthy could also be considered a strength as it gives an indication of levels activity that older people should be striving for.

The initial power calculation suggested that to enable the development of a regression model using 3 to 5 predictors, and taking into consideration attrition, full data should be gathered on 150 older adults. This predicted that an effect size of 0.11 to 0.13 could be estimated. In view of the number of people recruited partial correlation analysis rather than regression analysis was performed utilising only three variables. This was based on Harrell (2002) who suggests that 10 - 20 observations are required per covariate to detect an effect size at an appropriate level of power. This was however not detrimental to the analysis and indeed resulted in a greater effect size than was predicted. Whilst the study sample size is disappointing and full regression analysis could not be performed the study has still produced results which can demonstrate the relationship between habitual activity and nutritional status, functional status, dietary intake and levels of fatigue can enhance the body of evidence in this area of research.

One final consideration when interpreting the results from the study should be given to the characteristics of the population recruited. It can be seen from the Scottish Index of Multiple Deprivation (SIMD) that 91% (n=40) were all from data zones 3 – 5 indicating that participants resided in some of the least deprived areas in Scotland. It is widely acknowledged that those people who live in more deprived areas are likely to have

poorer lifestyles including dietary intakes and are more likely to suffer from higher levels of ill-health and have shorter life expectancies (Black et al., 2014). In terms of ill-health this would appear to be the case for the study population where in the context of non-communicable diseases (NCD) 41% (n=18) reported no co-morbidities and only four participants (3m, 1f) reported having type 2 diabetes (T2DM). Those participants who had T2DM were all taking anti-hypertensive medications and in addition a further two female participants also reported either having been diagnosed with hypertension or to take anti-hypertensive medication. The female participant with T2DM also reported increased cholesterol levels, one of the male participants with T2DM reported having angina and one further male participant reported having undergone a coronary artery bypass graft.

It is therefore acknowledged that the study population was not representative of all SIMD groups and thus did not therefore fully reflect the Scottish population in terms of health status and levels of deprivation. Had more participants been recruited from areas with greater levels of deprivation more co-morbidities are likely to have been reported and this may also have influenced the results of the dietary analysis.

A further limitation of the study was the measurement of resting energy expenditure (REE). In an attempt to ensure the accuracy of dietary reporting REE was measured, which along with a measure of activity (PAL) could be used to establish total energy expenditure (TEE). This would have provided an indication of predicted energy intake and thus whether the dietary analysis was an accurate reflection of energy intake. Despite the researcher endeavouring to follow best practice guidance for measuring REE guidance (Compher et al., 2006), the criteria were not met.

Although explicit instructions about being fasted and rested were provided to participants both verbally and in written format many had undertaken some form of early morning activity or had eaten breakfast. The results of these REE measurements could therefore not be utilised within the study analysis or to provide an indication of dietary reporting. In view of this alternative methodology was required to establish the reliability of the diet diaries. Prediction equations for estimating resting energy expenditure are available (Henry, 2005) which along with measured PAL factors provide an accurate prediction of TEE. These data in combination with the principles described by Goldberg et al. (1991) were then utilised to compare predicted TEE and energy intake. As these methodologies have been previously validated and are routinely used the inability to use measured REE does not detract from the results of this study.

#### **4.13 FUTURE WORK**

This study has highlighted a number of areas for future work and in particular further research is required to better inform the current recommendations for levels of activity in older adults. The current recommendations of 150 minutes of moderate intensity activity each week accumulated in bouts of activity lasting not less than 10 minutes (DoH, 2011) could be questioned. The results of this current study suggest that this may be unachievable for healthy older adults and if this is the case it will certainly be so for frailer or less healthy older adults. An expanded programme of research is required to establish whether 150 minutes of moderate intensity activity is required for an older population bearing in mind that these recommendations are made to focus on CVD risk. This may not be required in older adults where the primary focus is more likely to be functional ability and living independently. In addition the manner in which moderate

intensity activity is accumulated should be considered. As previously discussed (section 4.2.1) shorter bouts of moderate intensity activity may have health benefits (Glazer et al., 2013; Fan et al., 2013) but to date the full impact of this on older people's health has not been investigated. Further research is therefore required to objectively and accurately measure moderate intensity activity including consideration of shorter (less than 10 minutes) bouts of activity and the impact that this has on the health of older adults should be determined. Results from this work has the potential to radically change current recommendations for activity in older people and could result in more achievable targets which continue to beneficially influence a person's health and are potentially more likely to engage the target population.

In addition to further research in the context of recommendations for activity levels, further research is required to increase the information about current levels of habitual activity in older people and the impact this has on energy expenditure. The results of this study demonstrated that in a healthy older adult population objectively measured physical activity levels resulted in a lower PAL factor than that which is currently suggested by SACN (2011). This suggests that a less healthy or frailer older adult population would have an even lower PAL factor. Ensuring reliable PAL factors are utilised in managing nutritional status is vital to ensure a reliable estimation of energy expenditure can be made and thus to inform the energy balance of an individual (as discussed in section 4.7.3). More datasets of habitual activity across a range of older adult populations are therefore required.

This current study has also highlighted the need for further research into the use of WC measurements as a marker of CVD risk in older adults. WC measurements provide an



indication of CVD risk (Jacobs et al., 2010) however results from previous research and this current study suggest that current cut-offs for WC in an older population may not be appropriate and indeed may misclassify CVD risk (Visscher et al., 2001; Molarius et al., 2000). Further research is therefore required to determine the most appropriate cut-offs for WC in older adults.

Functional ability is a primary determinant in a person's ability to live at home independently and a number of areas of future research have been identified to influence this. In particular there is significant emerging evidence about the role of protein in relation to sarcopenia and functional ability (Paddon-Jones et al., 2004a; Paddon-Jones et al., 2004b) and the results of this current study indicate a relationship with habitual activity. This may be as a result of the nutritional and functional status of the participants in this study. However due to the small sample size this cannot be determined. A larger study to determine the interrelationship between habitual activity, nutritional status and functional status is warranted and in addition the influence protein intakes have on this relationship. There is a continuing growing body of evidence to suggest high protein intakes and in particular high animal protein intakes are associated with improved function (Imai et al, 2014). The relationship of habitual activity, nutritional status and functional status within this should be considered.

Finally the impact that fatigue has on levels of habitual activity along with the interrelationship with nutritional status and functional status warrants further study. In particular further research is required to establish the cause and effect relationship between habitual activity and fatigue. This is important as understanding the

relationship will provide information as to how to influence the relationship i.e. whether to influence fatigue to improve activity levels or vice versa.

## CHAPTER 5: CONCLUSIONS

Whilst significant research has been undertaken to establish the role of moderate intensity activity in healthy ageing, the influence of the role of habitual activity and sedentary behaviour has been less well investigated. This study therefore arose out of the uncertainties which currently exist around levels of habitual activity and in particular current levels of habitual activity and sedentary behaviour in older adults. Activity levels clearly influence functional ability however many other factors also influence functional ability including dietary intake, antioxidant status and levels of inflammation. In addition levels of fatigue influence levels of habitual activity. To date no study has investigated the relationship of all these parameters in a Scottish older adult population.

A particular study strength was the methodology utilised to measure habitual activity in that it was measured continuously over a seven day period. Until now there are only limited studies which have done this in an older adult Scottish population (Fitzsimons et al., 2012; Mutrie et al., 2013). Moreover this is the first study to measure sedentary behaviour during waking hours only through the use of an accelerometer and activity and sleep diary and so the levels of sedentary behaviour reported in this study provide baseline data for current levels of sedentary behaviour in a healthy older adult Scottish population. The robust and objectively measured data on levels of habitual activity found in this study therefore significantly add to the body of evidence relating to habitual activity levels in Scottish older adults. Whilst it is not possible to state whether the study population had high or low levels of sedentary behaviour as this has not previously been reported the study has demonstrated that healthy older adults in Scotland may not be meeting recommendations for physical activity (DoH, 2011).

The study has therefore provided some indication that current recommendations for activity levels in older adults have the potential to be improved and further research to establish whether current recommendations for activity levels in older adults are appropriate is needed. In particular the impact of short bursts of moderate intensity activity on the health status of older people should be investigated along with intervention strategies which could reduce sedentary behaviour.

It was hypothesised prior to the study that levels of sedentary behaviour would be positively associated with BMI and WC and this was indeed found. The uncertainty surrounding cut-offs for both BMI (Beck & Ovesen, 1998) and WC (Howel, 2012) should however not be ignored. The study did not establish the hypothesised relationship between body composition and levels of habitual activity. Previous research has demonstrated that muscle strength more so than muscle mass influences functional ability and so the lack of relationship with body composition may reflect that the participants were of good functional status. This is supported by the fact that relationships between levels of activity and functional status were found. A particular strength of this study was the comprehensive methodology utilised to measure habitual activity along with the combination of functional tests used to comprehensively measure functional status. As differences were seen when interpreting results from each measure of function the importance of using a combination of upper body measures of strength function and endurance cannot be overstated. To date no other study has utilised this combined methodology to measure function and so the results from this study provide a more comprehensive overview of the functional status of healthy older adults in Scotland than has been previously reported.

In summary the results from this study indicate that recommendations for activity in older adults should be reviewed. In addition it should also not be overlooked that there appears to be an inevitable change in activity levels with ageing and the focus should be on minimising the reduction in levels of physical activity and increased sedentary behaviour to optimise health. However activity cannot be considered in isolation as there are many factors which influence this including nutritional status, functional status, dietary intake, and levels of fatigue.

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## ACTIVITY DIARY

**An exploratory study to determine the relationship between levels of habitual activity and nutritional status, functional status, dietary intake and fatigue in older adults.**

Participant Number: \_\_\_\_\_

As part of the study you have agreed to participate in you must keep an activity diary for 7 days.

### Guidelines for recording in your activity diary

1. Your activities start from when you get in the morning up and finish when you go to bed at night. You should therefore carry your activity diary with you at all times.
2. You should keep the activity diary for the same 7 day period that you wear the “activPAL” monitor
3. You should include details of all activity from waking to sleeping.
4. You should record your activity in 30 minute blocks and you should include information of all the activities you participated in during those 30 minutes
5. The “activPAL” monitor will record the amount of activity you are involved in and length of time of each activity so you only have to provide a brief description of the type of activity you are involved in over a 30 minute period.

**THANK YOU FOR TAKING THE TIME TO COMPLETE YOUR ACTIVITY DIARY**

**Example of completed Activity Diary:**

DAY 1

Day: Wednesday

Date: 10<sup>th</sup> October 2007

12.00 – 12.30am	Sleeping	8.00 – 8.30am	Read paper Breakfast	4.00 – 4.30pm	Painted garage door
12.30 – 1.00am	Sleeping	8.30 – 9.00am	Breakfast Cleaned up breakfast dishes	4.30 – 5.00pm	Watched TV
1.00 – 1.30am	Sleeping	9.00 – 9.30am	Gardening	5.00 – 5.30 pm	Watched TV
1.30 – 2.00am	Sleeping	9.300 – 10.00am	Gardening	5.30 – 6.00pm	Cooked evening meal
2.00 – 2.30am	Sleeping	10.00 – 10.30am	Gardening	6.00 – 6.30pm	Had evening meal
2.30 – 3.00am	Sleeping	10.30 – 11.00am	Watched TV	6.30 – 7.00pm	Walked to pub Drink in pub
3.00 – 3.30am	Sleeping	11.00 – 11.30am	Watched TV	7.00 – 7.30pm	Drink in pub
3.30 – 4.00am	Sleeping	11.30 – 12.00pm	Read book	7.30 – 8.00pm	Drink in pub
4.00 – 4.30am	Sleeping	12.00 – 12.30pm	Lunch	8.00- 8.30pm	Drink in pub
4.30 – 5.00am	Sleeping	12.30 – 1.00pm	Lunch Drove to supermarket	8.30 – 9.00pm	Walked home Watched TV
5.00 – 5.30 am	Sleeping	1.00 – 1.30pm	Supermarket shopping	9.00 – 9.30pm	Watched TV
5.30 – 6.00am	Sleeping	1.30 – 2.00pm	Supermarket shopping Drove home	9.30 – 10.00pm	Watched TV
6.00 – 6.30am	Sleeping	2.00 – 2.30pm	Unpacked shopping bags and put shopping away	10.00 – 10.30pm	Watched TV
6.30 – 7.00am	Sleeping	2.30 – 3.00pm	Read book	10.30 – 11.00pm	Got ready for bed Read book
7.00 – 7.30am	Showered and dressed	3.00 – 3.30pm	Read book	11.00 – 11.30pm	Asleep
7.30 – 8.00am	Walked to paper shop Read paper	3.30 – 4.00pm	Painted garage door	11.30 – 12.00pm	Asleep

**DAY 1**

Day: \_\_\_\_\_

Date: \_\_\_\_\_

12.00 – 12.30am		8.00 – 8.30am		4.00 – 4.30pm	
12.30 – 1.00am		8.30 – 9.00am		4.30 – 5.00pm	
1.00 – 1.30am		9.00 – 9.30am		5.00 – 5.30 pm	
1.30 – 2.00am		9.300 – 10.00am		5.30 – 6.00pm	
2.00 – 2.30am		10.00 – 10.30am		6.00 – 6.30pm	
2.30 – 3.00am		10.30 – 11.00am		6.30 – 7.00pm	
3.00 – 3.30am		11.00 – 11.30am		7.00 – 7.30pm	
3.30 – 4.00am		11.30 – 12.00pm		7.30 – 8.00pm	
4.00 – 4.30am		12.00 – 12.30pm		8.00- 8.30pm	
4.30 – 5.00am		12.30 – 1.00pm		8.30 – 9.00pm	
5.00 – 5.30 am		1.00 – 1.30pm		9.00 – 9.30pm	
5.30 – 6.00am		1.30 – 2.00pm		9.30 – 10.00pm	
6.00 – 6.30am		2.00 – 2.30pm		10.00 – 10.30pm	
6.30 – 7.00am		2.30 – 3.00pm		10.30 – 11.00pm	
7.00 – 7.30am		3.00 – 3.30pm		11.00 – 11.30pm	
7.30 – 8.00am		3.30 – 4.00pm		11.30 – 12.00pm	

**DAY 2**

Day: \_\_\_\_\_

Date: \_\_\_\_\_

12.00 – 12.30am		8.00 – 8.30am		4.00 – 4.30pm	
12.30 – 1.00am		8.30 – 9.00am		4.30 – 5.00pm	
1.00 – 1.30am		9.00 – 9.30am		5.00 – 5.30 pm	
1.30 – 2.00am		9.300 – 10.00am		5.30 – 6.00pm	
2.00 – 2.30am		10.00 – 10.30am		6.00 – 6.30pm	
2.30 – 3.00am		10.30 – 11.00am		6.30 – 7.00pm	
3.00 – 3.30am		11.00 – 11.30am		7.00 – 7.30pm	
3.30 – 4.00am		11.30 – 12.00pm		7.30 – 8.00pm	
4.00 – 4.30am		12.00 – 12.30pm		8.00- 8.30pm	
4.30 – 5.00am		12.30 – 1.00pm		8.30 – 9.00pm	
5.00 – 5.30 am		1.00 – 1.30pm		9.00 – 9.30pm	
5.30 – 6.00am		1.30 – 2.00pm		9.30 – 10.00pm	
6.00 – 6.30am		2.00 – 2.30pm		10.00 – 10.30pm	
6.30 – 7.00am		2.30 – 3.00pm		10.30 – 11.00pm	
7.00 – 7.30am		3.00 – 3.30pm		11.00 – 11.30pm	
7.30 – 8.00am		3.30 – 4.00pm		11.30 – 12.00pm	

**DAY 3**

Day: \_\_\_\_\_

Date: \_\_\_\_\_

12.00 – 12.30am		8.00 – 8.30am		4.00 – 4.30pm	
12.30 – 1.00am		8.30 – 9.00am		4.30 – 5.00pm	
1.00 – 1.30am		9.00 – 9.30am		5.00 – 5.30 pm	
1.30 – 2.00am		9.300 – 10.00am		5.30 – 6.00pm	
2.00 – 2.30am		10.00 – 10.30am		6.00 – 6.30pm	
2.30 – 3.00am		10.30 – 11.00am		6.30 – 7.00pm	
3.00 – 3.30am		11.00 – 11.30am		7.00 – 7.30pm	
3.30 – 4.00am		11.30 – 12.00pm		7.30 – 8.00pm	
4.00 – 4.30am		12.00 – 12.30pm		8.00- 8.30pm	
4.30 – 5.00am		12.30 – 1.00pm		8.30 – 9.00pm	
5.00 – 5.30 am		1.00 – 1.30pm		9.00 – 9.30pm	
5.30 – 6.00am		1.30 – 2.00pm		9.30 – 10.00pm	
6.00 – 6.30am		2.00 – 2.30pm		10.00 – 10.30pm	
6.30 – 7.00am		2.30 – 3.00pm		10.30 – 11.00pm	
7.00 – 7.30am		3.00 – 3.30pm		11.00 – 11.30pm	
7.30 – 8.00am		3.30 – 4.00pm		11.30 – 12.00pm	



**DAY 4**

Day: \_\_\_\_\_

Date: \_\_\_\_\_

12.00 – 12.30am		8.00 – 8.30am		4.00 – 4.30pm	
12.30 – 1.00am		8.30 – 9.00am		4.30 – 5.00pm	
1.00 – 1.30am		9.00 – 9.30am		5.00 – 5.30 pm	
1.30 – 2.00am		9.300 – 10.00am		5.30 – 6.00pm	
2.00 – 2.30am		10.00 – 10.30am		6.00 – 6.30pm	
2.30 – 3.00am		10.30 – 11.00am		6.30 – 7.00pm	
3.00 – 3.30am		11.00 – 11.30am		7.00 – 7.30pm	
3.30 – 4.00am		11.30 – 12.00pm		7.30 – 8.00pm	
4.00 – 4.30am		12.00 – 12.30pm		8.00- 8.30pm	
4.30 – 5.00am		12.30 – 1.00pm		8.30 – 9.00pm	
5.00 – 5.30 am		1.00 – 1.30pm		9.00 – 9.30pm	
5.30 – 6.00am		1.30 – 2.00pm		9.30 – 10.00pm	
6.00 – 6.30am		2.00 – 2.30pm		10.00 – 10.30pm	
6.30 – 7.00am		2.30 – 3.00pm		10.30 – 11.00pm	
7.00 – 7.30am		3.00 – 3.30pm		11.00 – 11.30pm	
7.30 – 8.00am		3.30 – 4.00pm		11.30 – 12.00pm	

**DAY 5**

Day: \_\_\_\_\_

Date: \_\_\_\_\_

12.00 – 12.30am		8.00 – 8.30am		4.00 – 4.30pm	
12.30 – 1.00am		8.30 – 9.00am		4.30 – 5.00pm	
1.00 – 1.30am		9.00 – 9.30am		5.00 – 5.30 pm	
1.30 – 2.00am		9.300 – 10.00am		5.30 – 6.00pm	
2.00 – 2.30am		10.00 – 10.30am		6.00 – 6.30pm	
2.30 – 3.00am		10.30 – 11.00am		6.30 – 7.00pm	
3.00 – 3.30am		11.00 – 11.30am		7.00 – 7.30pm	
3.30 – 4.00am		11.30 – 12.00pm		7.30 – 8.00pm	
4.00 – 4.30am		12.00 – 12.30pm		8.00- 8.30pm	
4.30 – 5.00am		12.30 – 1.00pm		8.30 – 9.00pm	
5.00 – 5.30 am		1.00 – 1.30pm		9.00 – 9.30pm	
5.30 – 6.00am		1.30 – 2.00pm		9.30 – 10.00pm	
6.00 – 6.30am		2.00 – 2.30pm		10.00 – 10.30pm	
6.30 – 7.00am		2.30 – 3.00pm		10.30 – 11.00pm	
7.00 – 7.30am		3.00 – 3.30pm		11.00 – 11.30pm	
7.30 – 8.00am		3.30 – 4.00pm		11.30 – 12.00pm	

**DAY 6**

Day: \_\_\_\_\_

Date: \_\_\_\_\_

12.00 – 12.30am		8.00 – 8.30am		4.00 – 4.30pm	
12.30 – 1.00am		8.30 – 9.00am		4.30 – 5.00pm	
1.00 – 1.30am		9.00 – 9.30am		5.00 – 5.30 pm	
1.30 – 2.00am		9.300 – 10.00am		5.30 – 6.00pm	
2.00 – 2.30am		10.00 – 10.30am		6.00 – 6.30pm	
2.30 – 3.00am		10.30 – 11.00am		6.30 – 7.00pm	
3.00 – 3.30am		11.00 – 11.30am		7.00 – 7.30pm	
3.30 – 4.00am		11.30 – 12.00pm		7.30 – 8.00pm	
4.00 – 4.30am		12.00 – 12.30pm		8.00- 8.30pm	
4.30 – 5.00am		12.30 – 1.00pm		8.30 – 9.00pm	
5.00 – 5.30 am		1.00 – 1.30pm		9.00 – 9.30pm	
5.30 – 6.00am		1.30 – 2.00pm		9.30 – 10.00pm	
6.00 – 6.30am		2.00 – 2.30pm		10.00 – 10.30pm	
6.30 – 7.00am		2.30 – 3.00pm		10.30 – 11.00pm	
7.00 – 7.30am		3.00 – 3.30pm		11.00 – 11.30pm	
7.30 – 8.00am		3.30 – 4.00pm		11.30 – 12.00pm	

**DAY 7**

Day: \_\_\_\_\_

Date: \_\_\_\_\_

12.00 – 12.30am		8.00 – 8.30am		4.00 – 4.30pm	
12.30 – 1.00am		8.30 – 9.00am		4.30 – 5.00pm	
1.00 – 1.30am		9.00 – 9.30am		5.00 – 5.30 pm	
1.30 – 2.00am		9.300 – 10.00am		5.30 – 6.00pm	
2.00 – 2.30am		10.00 – 10.30am		6.00 – 6.30pm	
2.30 – 3.00am		10.30 – 11.00am		6.30 – 7.00pm	
3.00 – 3.30am		11.00 – 11.30am		7.00 – 7.30pm	
3.30 – 4.00am		11.30 – 12.00pm		7.30 – 8.00pm	
4.00 – 4.30am		12.00 – 12.30pm		8.00- 8.30pm	
4.30 – 5.00am		12.30 – 1.00pm		8.30 – 9.00pm	
5.00 – 5.30 am		1.00 – 1.30pm		9.00 – 9.30pm	
5.30 – 6.00am		1.30 – 2.00pm		9.30 – 10.00pm	
6.00 – 6.30am		2.00 – 2.30pm		10.00 – 10.30pm	
6.30 – 7.00am		2.30 – 3.00pm		10.30 – 11.00pm	
7.00 – 7.30am		3.00 – 3.30pm		11.00 – 11.30pm	
7.30 – 8.00am		3.30 – 4.00pm		11.30 – 12.00pm	

**DAY 8**

Day: \_\_\_\_\_

Date: \_\_\_\_\_

12.00 – 12.30am		8.00 – 8.30am		4.00 – 4.30pm	
12.30 – 1.00am		8.30 – 9.00am		4.30 – 5.00pm	
1.00 – 1.30am		9.00 – 9.30am		5.00 – 5.30 pm	
1.30 – 2.00am		9.300 – 10.00am		5.30 – 6.00pm	
2.00 – 2.30am		10.00 – 10.30am		6.00 – 6.30pm	
2.30 – 3.00am		10.30 – 11.00am		6.30 – 7.00pm	
3.00 – 3.30am		11.00 – 11.30am		7.00 – 7.30pm	
3.30 – 4.00am		11.30 – 12.00pm		7.30 – 8.00pm	
4.00 – 4.30am		12.00 – 12.30pm		8.00- 8.30pm	
4.30 – 5.00am		12.30 – 1.00pm		8.30 – 9.00pm	
5.00 – 5.30 am		1.00 – 1.30pm		9.00 – 9.30pm	
5.30 – 6.00am		1.30 – 2.00pm		9.30 – 10.00pm	
6.00 – 6.30am		2.00 – 2.30pm		10.00 – 10.30pm	
6.30 – 7.00am		2.30 – 3.00pm		10.30 – 11.00pm	
7.00 – 7.30am		3.00 – 3.30pm		11.00 – 11.30pm	
7.30 – 8.00am		3.30 – 4.00pm		11.30 – 12.00pm	

**Higher levels of fatigue are associated with poorer functional status in healthy community dwelling older adults. By J Jones, G Baer and HIM Davidson, Queen Margaret University, Edinburgh EH21 6UU**

It is well established that higher levels of activity increase muscle mass and attenuate the progression of sarcopenia in older adults<sup>(1)</sup>. However there are many barriers to older people engaging in increased activity levels and in particular insufficient activity levels have been associated with fatigue in both men and women<sup>(2)</sup>. Whilst fatigue is commonly reported in older adults<sup>(3)</sup> the relationship with functional status in healthy older adults is not fully understood. The aim of this study was to determine the relationship of levels of fatigue with functional status in healthy older adults.

Healthy older adults (aged 65 years and over) were recruited from a variety of social settings across central Scotland. Participants were screened for sarcopenia using the European consensus statements criteria<sup>(4)</sup> and in those participants without sarcopenia, functional status was measured by handgrip dynamometry (HGD) in the non-dominant arm, the sit to stand five (STS5) test, the six minute walk (6MW) test and gait speed calculated from distance of the 6MW test were measured. Levels of fatigue were measured using the Multi-dimensional Fatigue Inventory (MFI)<sup>(5)</sup> (Smets et al 1995). The MFI measures fatigue across five domains with a maximum score of 20 in each domain indicating the highest level of fatigue. Spearman's Rho correlation analysis was used to identify associations between variables.

Forty three non-sarcopenic older adults (23 females, 20 males) with a mean (sd) age of 72.6 (5.4) years and a mean (sd) BMI of 26.7 (2.8) kg/m<sup>2</sup>. years were recruited. Results of tests for functional status and measures of fatigue are shown in table 1.

Parameter	All n=44		Males n=21		Females n=23		p
	Median	(IQR)	Median	(IQR)	Median	(IQR)	
HGD (kg)	27	20, 38	38.5	34, 44.8	20	17.8, 24	<.001
STS (s)	12.5	11, 16.7	12.2	11.1, 17.1	13.3	11, 15.4	.438
6MW (m)	463	360, 551	440	349, 559	477	360, 547	.438
gait speed (ms <sup>-1</sup> )	1.3	1.0, 1.5	1.2	1.0, 1.6	1.3	1, 1.5	.438
general fatigue	8	6, 10	9	6.3, 10	7	6, 9	.01
physical fatigue	8	5, 10	8	5.3, 10	7	5, 10	.760
reduced activity	8	5, 10	8	5.5, 11	6	4, 9	.711
reduced motivation	6	5, 8	6	5.3, 8.8	6	4, 8	.836
mental fatigue	6	4, 9	6	4, 9.8	6	6, 8	.870

p values – Mann Whitney U males vs females

No statistically significant associations were found between HGD and any measure of fatigue or between mental fatigue and any measure of functional status. However significant positive associations were evident with indices of fatigue and STS5 (general fatigue  $r=.396$ ,  $p=.009$ , physical fatigue  $r=.345$ ,  $p=.024$ , reduced activity,  $r=.320$ ,  $p=.036$ , reduced motivation  $r=.395$ ,  $p=.009$ ) and significant negative associations were evident with 6MW and indices of fatigue (general fatigue  $r=-.424$ ,  $p=.005$ , physical fatigue  $r=-.424$ ,  $p=.005$ , reduced activity,  $r=-.376$ ,  $p=.013$ , reduced motivation  $r=-.378$ ,  $p=.012$ ).

Higher levels of fatigue were associated with poorer functional ability even in non sarcopenic healthy older adults. Fatigue may therefore be an important factor to address when considering appropriate physical activity interventions to prevent the onset or delay in progress of sarcopenia in older adults.

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## Healthy Scottish Elderly Fail To Meet Current Activity Guidelines

Jacklyn Jones MSc Queen Margaret University, Edinburgh, Dr Gillian Baer PhD, Queen Margaret University, Edinburgh, Prof Isobel Davidson, PhD Queen Margaret University, Edinburgh

Sedentary behaviour is a key risk factor for a number of long term conditions. To reduce the risk of co-morbidity all adults including those aged 65 and over are encouraged to participate in higher levels of physical activity. The World Health Organisation guidelines for levels of activity in people aged 65+ include accumulating 150 minutes of moderate intensity activity throughout the week and this should be performed in bouts of at least 10 minutes. Moderately intense activity is that achieving a Metabolic Equivalent of Task (MET) level of 3-6. Individuals who walk 10,000 steps or more daily are more likely to meet these targets and this is also a target for activity.

This study aimed to establish whether a healthy older adult population met guidance on levels of activity

Self-reported healthy, cognitively intact, independent community dwelling adults aged 65+ years were recruited from community networks. Time (minutes) spent in activities of MET > 3 along with number of steps was recorded using an ActivPAL activity monitor for 7 consecutive days.

Thirty six people (18m, 18f) aged 65-86 years (mean 72.8 SD 5.8) with a mean BMI of 26.8kg/m<sup>2</sup> (SD 2.8) were recruited. 31/36 participants accumulated at least 150 minutes of activity at a MET >3 throughout the week (mean weekly time 363 minutes SD 181, mean daily time 45 minutes SD 22). However when considered as activity bouts of at least 10 minutes only 4/36 met the target. 22/36 failed to achieve the recommended target of 10,000 steps (mean 9168 steps (SD 3572).

A healthy Scottish adult population are currently not meeting guidance set for levels of activity for an older adult population. As levels of activity decrease with age this scenario is set to worsen. It may be that current targets for activity are inappropriate.

## **Fatigue Scores Are Associated With Indices Of Physical Function In Older Adults**

Jacklyn Jones MSc Queen Margaret University, Edinburgh, Dr Gillian Baer PhD, Queen Margaret University, Edinburgh, Prof Isobel Davidson, PhD Queen Margaret University, Edinburgh

Fatigue is associated with many chronic diseases and is frequently reported to have a negative impact on activities of daily living. Fatigue increases with ageing even in healthy individuals, but the impact of the various domains of fatigue on physical activity levels is unclear. The timed sit to stand (STS) test can be used as a measure of transfer function and is an indicator of lower limb strength in older adults. The 6 minute walk (6MW) is a widely used submaximal exercise test which correlates well with maximal exercise capacity in older adults

This study investigated whether domains of fatigue as measured by the Multidimensional Fatigue Inventory (MFI) are associated with indices of function in a healthy older adult population.

Self-reported healthy, cognitively intact, independent community dwelling adults aged 65 years and over were recruited from community networks. Levels of fatigue were measured using the MFI and functional status was measured by STS and 6MW. Correlation analysis was performed (Spearman rho) to establish associations between indices of function and domains of fatigue.

Thirty nine people (19 males, 20 females) aged 65-86 years (mean 72.8 SD 5.7) with a mean BMI of  $26.7\text{kg/m}^2$  (SD 2.8) were recruited. STS performance correlated with general ( $r=0.421$ ,  $p<0.01$ ), and physical domains ( $r=0.556$ ,  $p<0.001$ ), reduced activity ( $r=0.449$ ,  $p=0.005$ ) and reduced motivation ( $r=0.546$ ,  $p<0.001$ ) but not with mental fatigue ( $r=0.124$ ,  $p=0.453$ ). The 6MW was associated with general fatigue ( $r=-0.533$ ,  $p=0.001$ ), physical fatigue ( $r=-0.515$ ,  $p=0.001$ ), reduced activity ( $r=-0.397$ ,  $p<0.05$ ) and reduced motivation ( $r=-0.450$ ,  $p<0.005$ ) but not with mental fatigue ( $r=0.058$ ,  $p=0.725$ ).

Indices of motivation, general and physical but not mental fatigue are associated with functional status in a healthy older adult population. It remains to be elucidated whether the MFI could prove to be a quick, sensitive and simple method of predicting levels of function in older adults.

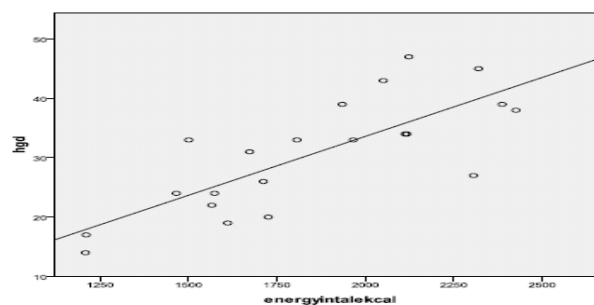


**Grip strength is associated with nutritional status and energy intake in healthy community living older adults.** By J M Jones, G Baer and HIM Davidson, *School of Health Sciences, Queen Margaret University, Edinburgh EH21 6UU*

The UK has an aging population and this will place large demands on future health and social care systems<sup>(1)</sup>. In an attempt to minimise this increase in expenditure it is important to encourage the aging population to optimise their health and ability to live independently. The functional marker grip strength, determined by handgrip dynamometry (HGD), has been shown to be a predictor of all cause mortality<sup>(2)</sup>, disability<sup>(3)</sup> and thus dependency and in older adults. Whilst dietary intake and nutritional supplementation has been shown to improve function in the rehabilitation phase of care<sup>(4)</sup> the association dietary intake has with nutritional and functional status has not been fully investigated in the community dwelling older adult population. Handgrip may provide an indication of health status in this ever expanding population. The aim of the study was to determine whether an association exists between energy intake, nutritional status and HGD.

Healthy, cognitively intact, community dwelling adults aged 65+ years were recruited from community networks. Energy intake (kcal) was recorded by a 7 day self administered unweighed food diary. Anthropometric measurements (weight, height, BMI, waist circumference (WC), tricep skinfold thickness (TSF) and arm muscle circumference (AMC)), were measured using standard methodology. HGD was measured using a Takei grip strength dynamometer in the non-dominant arm. BMI was compared to age specific norms, and TSF, AMC, WC and HGD were compared to gender specific norms. Correlation analysis was used to identify associations between variables.

Twenty one people, 11 men and 10 women, aged 65-82 years (mean 74, SD 4.9), with mean BMI of 27.1kg/m<sup>2</sup> (SD 2.3) were recruited. When compared to a BMI of 27kg/m<sup>2</sup> (considered normal in this population<sup>(5)</sup>) there was no significant difference. With the exception of women in relation to TSF there was no significant difference in, WC(cm), TSF(mm), AMC(cm) and HGD(kg) in comparison to normal values (WC: men mean 104.7, SD 9.8, women mean 87.6, SD 9.8, TSF: men mean 12.4, SD 4.5, women mean 18.9, SD 3.0, AMC: men mean 25.6, SD 2.6, women mean 23.4, SD 2.03, HGD men mean 38.0, SD 5.1, women mean 22.4, SD 5.1). HGD correlated with energy intake ( $r=0.775$ ,  $p<0.001$ ) (see figure).



HGD also correlated with weight ( $r=0.576$ ,  $p<0.01$ ), height ( $r=0.656$ ,  $r<0.01$ ), WC ( $r=0.66$ ,  $p<0.01$ ), TSF ( $r=-0.562$ ,  $p<0.01$ ) and AMC ( $r=0.465$ ,  $p<0.05$ ).

As HGD is simple measure and an important marker in monitoring functional change and predicting functional decline the relationship between HGD and diet, particularly in relation to energy intake, needs further investigation.

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