

**Physical Activity and Nutrition as Modifiable Lifestyle Factors
for Healthy Aging in Older Adults**

by

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ABSTRACT

PHYSICAL ACTIVITY AND NUTRITION AS MODIFIABLE LIFESTYLE FACTORS FOR HEALTHY AGING IN OLDER ADULTS

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Physical activity and nutrition are important modifiable lifestyle factors that are important for healthy aging. This thesis contains three studies in community-dwelling older adults (≥ 60 years) aimed to: (1) evaluate the use of a physical activity questionnaire to predict physical health; (2) compare dietary intake with physical health parameters in an affluent population, and; (3) improve metabolic and physical health parameters.

The first study investigated whether relationships existed between a person's score on the Physical Activity Scale for the Elderly (PASE) questionnaire and health-related body composition, cardiovascular and blood, strength, and flexibility measurements. The only significant relationship was waist circumference (WC), where a minimum PASE score of ~ 140 predicted a favourable WC for males and ~ 120 predicted a favourable WC for females. This relationship may be used encourage older adults to become more physically active by increasing their PASE score to move their WC into a favorable range.

The second study investigated the relationships between physical health parameters and nutrient intake from food and supplement use in a population with high socioeconomic status (SES), typically recruited for research at the University of Guelph. Results demonstrated that adults with high SES have a similar risk of nutrient inadequacies to Canadian population data,

and supplement users do not have higher nutrient intake from food than non-users. Finally, adding vitamin D intake to a predictive model which included age, sex, and body mass index, improved the model's capacity to predict a participant's lean body mass.

The final study investigated the effect of 12 weeks of omega-3 fish oil (O3FA; FO) and olive oil (placebo, PL) supplementation on metabolic and physical health parameters at rest and during exercise. Results demonstrated that O3FA, and not PL, intake increased metabolic rate and fat oxidation at rest (24% males, 16% females) and exercise (11%). The FO group also experienced a lowering of triglyceride levels, and diastolic blood pressure for the males. Finally, females had an increase in lean mass and functional capacity.

Therefore, this thesis demonstrates that modifiable life factors, such as physical activity and diet, influence the healthy aging of older community-dwelling adults.

SUBMITTED MANUSCRIPTS & PUBLICATIONS

This thesis is based on the following publications:

Logan, S.L., Gottlieb, B.H., Maitland, S.B., Meegan, D., & Spriet, L.L. (2013a). The Physical Activity Scale for the Elderly (PASE) Questionnaire; Does It Predict Physical Health? *International Journal of Environmental Research and Public Health*, *10*(9), 3967-3986. Doi:10.3390/ijerph10093967

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Just as iron sharpens iron, so one man's countenance sharpens another (Proverbs 27:17).

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LIST OF ABBREVIATIONS

ADL, activities of daily living

AHA, American Heart Association

ALA, α -linolenic acid

AMDR, acceptable macronutrient distribution range

ATP, adenosine triphosphate

BIA, bioelectrical impedance analysis

BM, body mass

BMI, body mass index

BP, blood pressure

CCHS, Canadian community healthy survey

CGS, combined grip strength

CHMS, Canadian health measures survey

Cho Ox, carbohydrate oxidation

CPAFLA, the Canadian physical activity, fitness and lifestyle approach

DBP, diastolic blood pressure

DHA, docosahexaenoic acid

DNA, deoxyribonucleic acid

DRI, dietary reference intake

E, energy

EAR, estimated average requirement

EAL, everyday physical activities of independent living

Energy Ex, energy expenditure

EPA, eicosapentaenoic acid

Fat Ox, fat oxidation

FFMI, fat free mass index

FLEX, seated flexibility

FM, fat mass

FO, fish oil

HDL-C, high density lipoprotein cholesterol

HOMA-IR, homeostasis model assessment of insulin resistance

HR, heart rate

HRR, heart rate reserve

hs-CRP, high sensitivity c-reactive protein

Ht, height

LC-O3FA, long chain omega 3 fatty acids

LDL-C, low density lipoprotein cholesterol

LM, lean mass

MAP, mean arterial pressure

Mt, mitochondria

MVMM, multivitamin-multimineral

O3FA, omega 3 fatty acids

O6FA, omega-6 fatty acids

PASE, physical activity score for the elderly questionnaire

PEOPL, physical exercise in older persons' lives study

PL, placebo

PP, pulse pressure

QOL, quality of life

RDA, recommended dietary allowance

RER, respiratory exchange ratio

RHR, resting heart rate

RPE, rating of perceived exertion

RSI, relative strength index

SBP, systolic blood pressure

SES, socioeconomic status

SMI, skeletal muscle index

TG, triglycerides

TC, total cholesterol

TUG, timed get up and go test

UL, tolerable upper intake level

VCO₂, volume of carbon dioxide

VDR, vitamin D receptor

Vit, vitamin

VO₂, volume of oxygen

WC, waist circumference

WHtR, waist to height ratio

Wt, weight

30-SCS, 30 second sit to stand test

1, 25OHD₃, 1, 23-dihydroxyvitamin D

CHAPTER 1

REVIEW OF LITERATURE

1.1. HEALTHY AGING

1.1.1. *Healthy Aging Overview*

The proportion of older adults or seniors (aged 65 years and older) continues to increase and is the world's fastest growing segment of society. In Canada, older adults comprise 13% of the population. By 2031 it is estimated this proportion will increase to 25% (Statistics Canada, 2005). A major challenge in this population is to optimize the quality and years of healthy life (Drewnowski et al., 2003). Canada, along with other countries, has developed and is implementing healthy aging initiatives (Health Canada, 2002; Public Health Agency of Canada (PHAC), 2006; World Health Organization (WHO), 2013a). Healthy aging has been defined as “a lifelong process of optimizing opportunities for improving and preserving health, and physical, social and mental wellness, independence, quality of life (QOL), and enhancing successful life-course transitions” (Health Canada, 2002a). In support of these initiatives, health care policy has advocated a shift away from treatment and acute care towards health promotion, prevention, healthy aging, and community support (PHAC, 2006). To accomplish this, a shift in aging research is also needed from a primary focus on outcome measures of morbidity and mortality to a greater focus on behavioural determinants of positive health (Peel et al., 2005). Approximately 90% of Canadian seniors currently reside in the community and wish to remain independent (PHAC, 2006). The transition from independent living in the community to residential living occurs due to poor health and disability in older age, and is largely a consequence of chronic disease (Gilmour & Park, 2006).

1.1.2. *Theories of Aging*

Interest in aging research has surged over the past several decades due to the increasing percentage of older adults in the population, the lengthening of the average human life span, and the increased usage of health care expenditures by this age cohort (Weinert & Timiras, 2003). Aging and ultimately death are characteristic of most living organisms. Aging has been defined by the progressive accumulation of diverse deleterious changes occurring in cells and tissues that increase homeostatic imbalance and the risk of disease and death (Harman, 2003; Kowald & Kirkwood 1996). Aging is highly complex and appears to involve multiple mechanisms at different levels. Despite recent advances in molecular biology and genetics, the mechanisms underlying the aging process are not well understood. In fact, more than 300 aging theories have been proposed (Medvedev, 1990), but there exists no generally accepted theory by gerontologists (Weinert & Timiras, 2003).

For the most part, modern theories of aging fall into two categories: programmed theories and structural damage theories. Programmed theories engage the concept that aging is not a result of random or stochastic process but rather driven by the inevitable consequences of genetically-determined process (Jin, 2010). Damage-based theories, as the name implies, postulate that aging is due to an accumulation of damage caused by the normal toxic by-products of metabolism or by an inefficient repair system (Jin, 2010). These damage-based theories maintain that this damage originates at the molecular level, continues to the tissues and organs, and ultimately results in chronic disease (e.g., arthritis, cancer, dementia, diabetes, heart disease) (Jin, 2010). Aging appears to be a multifactorial process that may involve several or all of these theories (Weinert & Timiras, 2003). This discussion will be limited to a brief description of several of the damage-based theories that may be of relation to this thesis.

Structural damage-based theories include **1) *The Waste Accumulation Theory*** where cells accumulate waste (lipofuscin) as a consequence of normal metabolic processes and this eventually compromises normal cellular functions (Hirsch, 1986). This toxic accumulation in the cell ultimately interferes with cellular communication, disturbs protein synthesis, and lower energy levels (Hirsch, 1986). **2) *The Errors and Repair Theory*** where damage to deoxyribonucleic acid (DNA) occurs and, while over 99% of these point mutations can be repaired, a portion of the errors go unrepaired. Over a lifetime, this results in an accumulation of mutations that eventually results in errors in the generated proteins (Sinclair & Oberdoerffer, 2009). **3) *The Mitochondrial Damage Theory*** postulates that oxidative damage of the mitochondrial (mt) membranes ultimately causes damage and leads to a loss of mt function. Because mt are the sites of energy generation (adenosine triphosphate; ATP), a gradual loss of energy production occurs (Wei et al., 2001). **4) *The Free Radical Theory*** proposes that free radicals (i.e., any molecule with an unpaired electron) cause damage to the macromolecular components by binding and stealing an electron to become stable, resulting in an accumulation of damage and eventual loss of cellular functioning (Harman, 2003; Tosato et al., 2007). However, there is natural production of free-radicals within the body as a result of energy generation in the mt (see the Mitochondrial Theory of Aging). In addition, free radicals preferentially attack the structure of cell membranes, resulting in metabolic waste products (see the Waste Accumulation Theory). The body also produces free radical scavenging molecules (anti-oxidants) to stabilize free radicals. Further, an unhealthy lifestyle (e.g. tobacco and alcohol consumption, inadequate nutrition, sedentary lifestyle, radiation exposure etc.), in addition to aging, may accelerate free radical production within the body (Harman, 2003; Tosato et al., 2007).

Numerous psychosocial theories to characterize aging have also been proposed. Although somewhat beyond the scope of this review, two theories pertinent to this thesis include the Disengagement Theory and the Activity Theory. Briefly, *The Disengagement Theory* views aging as a process whereby older adults voluntarily slow down by retiring, and withdraw from society (Aitken & Rudolph, 2012). Advocates of this theory state that this social withdrawal is an asset to both the older adult and society, while critics argue that, in many cases, this disengagement from society is enforced and not voluntary (Aitken & Rudolph, 2012). *The Activity Theory*, on the other hand, encourages social activity and engagement in society (Aitken & Rudolph, 2012). Proponents of this theory have demonstrated a positive correlation between keeping active and healthy aging. In addition, the concept of mutual social withdrawal is not congruent with the ideals of activity and health encouraged by our society, and may cause depression and loneliness for many older adults (Aitken & Rudolph, 2012).

It appears that aging is not due to a single cause, but is an accumulation of many causes. Therefore, aging is a general term which incorporates the sum of both inerrant genetic predispositions and the structural damage over the life course (Kowald & Kirkland, 1996; Weinert & Timiras, 2003). There are fundamental difficulties in the study of human aging which center around the lack of an adequate model, as many of these theories use rodents, nematodes, etc. In addition, interpretation of the results often leads to controversy since discriminating between cause and effect is usually impractical. For these reasons, no consensus is currently agreed upon as to what causes aging, what drives the rate of aging, or further, what changes occur across the lifespan that increase the likelihood of human mortality by a certain percentage (Tosato et al., 2007). Finally, it is important to emphasize that aging is not a disease. The concept that aging requires treatment is based on the premise that aging is unappealing. In

current society, the term aging has become interchangeable with deterioration, pathology, and death (Hayflick, 2000). It has been estimated that ‘curing’ the leading causes of death in advanced age (cancers, heart disease, etc.) would not lead to immortality, but only to an increased life expectancy of ~15 yrs (Anderson, 1999; Hayflick, 2000). Therefore, a shift is needed in aging research from the current view of aging as a disease and requiring treatment to the resolution of pathology in aging (Hayflick 2004).

1.1.3. *Physiological Changes with Aging and Modifiable Lifestyle Factors*

With advancing age, all physiological functions gradually decline and, depending on the extent of the change, influence independent living by increasing the risk of chronic disease and functional impairment. These physiological declines may result in clinically measurable changes, including, 1) an increase in resting heart rate (RHR) and blood pressure (BP) (particularly systolic) (Lakatta et al., 1987); 2) a decrease in glucose homeostasis (Szoke et al., 2007); 3) an increase in fat mass (FM) and a decrease in lean mass (LM) (Evans & Campbell, 1993); and, 4) a decrease in physical strength and function (Evans & Campbell, 1993). Unhealthy values, as established by governing bodies, result in the increased risk or diagnosis of chronic disease, or risk of functional mobility impairment (due to low LM, strength, and function). Canadian seniors who reside in the community have a high rate of chronic disease, with some 81% suffering from at least one impairment, and 33% suffering from three or more chronic conditions. This is in stark comparison to the 12% of younger adults with a chronic condition (Gilmour & Park, 2006). The resulting costs on the health care system from age related chronic disease represents 67% of the total direct costs in healthcare and 60% of the total indirect costs (\$52 billion), such as early death, reduced productivity, and forgone income (PHAC, 2005). There is, however, growing optimism as evidence is accumulating that suggests a large portion

of chronic conditions associated with aging can be mitigated with lifestyle modification (i.e., physical activity and dietary intake). There are an increasing number of studies suggesting that although an increase in chronic disease is associated with increasing age chronic disease is not an inevitable consequence of aging (Rowe & Kahn, 1997). For example, studies have shown that an active 70 year old man with a healthy body mass (BM), and privileged lifestyle, can have a cardiovascular capacity which exceeds that of an overweight man 15 years his younger (Shephard, 1998). Twin studies, in particular the Swedish Adoption/Twin Study of Aging (SATSA), have provided information toward understanding the importance of both heredity and lifestyle in the development of chronic disease. In this study, ~300 pairs of aging twins (mean age 66 yrs) were enrolled (1/3 monozygotic and 2/3 dizygotic), half of the sets were reared together and the other half were reared apart. Heredity coefficients (amount of the total variance due to genetics) were determined for cardiovascular risk factors. The following heritability coefficients were reported: 0.66 (females) and 0.70 (males) for body mass index (BMI) (Stunkard et al., 1990), 0.28 for triglycerides (TG), 0.32 for total cholesterol (TC) (Heller et al., 1993), and 0.44 for systolic (SBP) and 0.34 for diastolic blood pressure (DBP) (Hong et al., 1994). This suggests that lifestyle factors have an impact on increasing the risk of disease. Determining the contributions of heritability and lifestyle to age-related changes continue to be examined through epigenetic techniques (Petronis, 2010).

Therefore, chronic disease and disability are attributable to non-modifiable (age and heredity) risk factors and the accumulation over the life course of modifiable (physical activity and diet) risk factors (Harvey et al., 2002; WHO, 2005). Clinically unfavorable measures (i.e., high BP, decrease in glucose homeostasis, high FM, low LM, etc.) are risk factors for chronic disease. At the level of the population, even small benefits in the modifiable risk factors, such as

increasing physical activity and consuming a healthier diet, may have a great effect in reducing and preventing the progression from low to high risk of chronic disease and disability (Rose, 1992). Implementing and maintaining positive lifestyle behaviours may manage or reduce the risk of chronic disease and disability and allow older adults to live a healthier and independent lifestyle in the community.

1.2. HEALTHY AGING AND PHYSICAL ACTIVITY

1.2.1. *Benefits of Physical Activity*

The positive relationship between regular physical activity and healthy aging is strong. Although important at any age, regular physical activity for aging adults endows them with increased vitality and QOL, and is a necessary ingredient in healthy aging. The positive influence of regular physical activity is far reaching, and numerous biological mechanisms may be responsible for the health benefits which contribute to reduced risk of chronic disease and premature death. Research has reported reductions in BP (Blair et al., 1984; Farahani et al., 2010; Paffenbarger et al., 1991; Rauramaa et al., 1986; Pescatello et al., 2004), and blood coagulation (National Institute of Health, 1996; Warburton et al., 2006a), and improvements in autonomic tone (Adamopoulos et al., 1992; Tiukinhoy et al., 2003), and coronary blood flow (Hambrecht et al., 2000a); which augment cardiac function (Warburton et al., 1999; 2004) and enhanced endothelial function (Gokce et al., 2002; Hambrecht, et al. 2000b; Kobayashi, et al., 2003; McGavock, et al., 2004). Additionally, regular physical activity results in improvements in body composition by increasing skeletal muscle mass density, resting metabolic rate, reducing adiposity, and increasing LM (Colman & Walker, 2004; Chodzko-Zajko et al., 2009; Hoppeler &

Fluck, 2003; Landi et al., 2010; Warburton et al., 2006a). Components of musculoskeletal fitness, which include strength, endurance, power, and flexibility, have also been shown to increase with regular physical activity (Chodzko-Zajko et al., 2009; Landi et al., 2010). A more favourable blood lipid profile (ie. a reduction in TG and an increase in high-density lipoprotein cholesterol (HDL-C) levels) (Berg et al., 1997; Halle et al., 1996; O'Connor et al., 1995; Warburton et al., 2001a; 2001b) and an improvement in the rate of glucose disposal and insulin sensitivity are also improved with regular physical activity (Kelley & Goodpaster, 1999; Wallberg-Henriksson et al., 1998; Warburton et al., 2001a; 2006). Regular physical activity has been associated with reductions in systemic inflammation, a factor strongly associated with most chronic diseases (Adamopoulos et al., 2001; Nicklas et al., 2005). Regular physical activity has also been shown to safeguard mental health by reducing muscle tension, and its associated stress and anxiety, and by releasing endorphins which have been shown to protect against depression (Colman & Walker, 2004; Dunn et al., 2001; Warburton et al., 2006a). These positive impacts may directly or indirectly explain the reduced prevalence of functional impairment, disability, chronic disease, and premature death among older adults who engage in regular physical activity (Warburton et al., 2006a). Research has also reported health benefits of a single bout of exercise, where a reduction in blood TG and BP (for 12-16 hrs), an increase in HDL-C, and an improvement in glucose homeostasis and insulin sensitivity have been documented (Thompson et al., 2001).

1.2.2. *Physical Activity and Physical Fitness*

Physical activity incorporates all active physical movement. Exercise is a subcategory of physical activity, and is defined as planned, structured, and repetitive physical movement

performed to improve or maintain one or more components of physical fitness (Resnick et al., 2008). Physical fitness in aging research has been defined as a state of physiological well-being required to meet the demands of activities of daily living (ADL; eating, dressing, bathing, using a toilet, transferring out of a bed or chair) (Warburton et al., 2006b). Aerobic and musculoskeletal fitness are subcategories of physical fitness. Aerobic fitness refers to the ability of the body to transport and use oxygen during physical activity or exercise. Musculoskeletal fitness includes muscular strength, endurance, and flexibility (Warburton et al., 2006b). Health-related physical fitness is comprised of the components of physical fitness related to health status. This includes aerobic and musculoskeletal fitness, body composition and metabolism (Warburton et al., 2006b).

1.2.3 *Increased Interest on Musculoskeletal Fitness*

Increasing physical activity levels results in improvements in indicators of health status, which may occur without changes in aerobic fitness. Regular physical activity can improve musculoskeletal fitness and reduce the risk of chronic disease without markedly changing traditional markers of physiologic performance, such as cardiac output and oxidative potential (Chodzko-Zajko et al., 2009; Warburton et al., 2006a). Since many daily activities do not need a large aerobic output but do require many of the components of musculoskeletal fitness, it makes sense that musculoskeletal fitness appears to be related to functional independence (Warburton et al., 2001a; 2006a). Although the general amount of musculoskeletal fitness required to perform ADL for an older adult is currently unknown, it has been speculated that many healthy older adults may be at or near the minimal amount (Warburton et al., 2006a). This minimal amount is known as the ‘threshold of dependence’, where the ability to carry out daily activities is lost

(Figure 1.1.). The decrease in musculoskeletal fitness below the threshold of dependence often results in a loss of independent living and a decrease in physical activity which exacerbates further decreases in musculoskeletal fitness, setting up a cycle of decline. The reverse is also true, in that increases in musculoskeletal fitness result in general increases in functional independence and reductions in disability onset (Warburton et al., 2006a). However, there are issues with Figure 1.1 since it overestimates the age (100 yrs) at which people may cross the threshold of dependence. It has been estimated that the loss of independence in ADL is ~10%/yr in non-disabled, community-dwelling adults aged 75 yrs and older (Gill et al., 1995). In fact, The Framingham Study reported that 45% of women aged 65–74 yrs were unable to lift a 4.5 kg weight, with the proportion increasing to 66% of women aged 75–84 yrs (Jette & Branch, 1981). A relatively recent report attempted to quantify the muscular strength thresholds required to perform ADL independently (Hasegawa et al., 2008). ADL were assessed using the Functional Independence Measure, which contains 18 items in 4 categories of self-care, sphincter management, mobility and executive functioning (Guide for the Uniform Data Set for Medical Rehabilitation, 1997; Hasegawa et al., 2008). A force of 0.7 N/kg for knee flexors, 2.8 N/kg for knee extensors and ankle dorsiflexors, 2.3 N/kg for hip flexors, and 1.7 N/kg for hip extensors was reported. In addition, the hip extensors were found to be the most important of the lower extremity muscles for maintaining independent living (Hasegawa et al., 2008).

Musculoskeletal fitness has also been associated with decreases in the risk of falls, illness, premature death, and chronic disease (diabetes, stroke, arthritis, coronary artery disease and pulmonary disorders); and increases in glucose homeostasis, psychological wellbeing, and QOL (Blair et al., 1995; Brill et al., 2000; Erikssen et al., 1998; 2001; Katzmaryzk & Craig, 2002; Sallinen et al., 2010; Warburton et al., 2010).

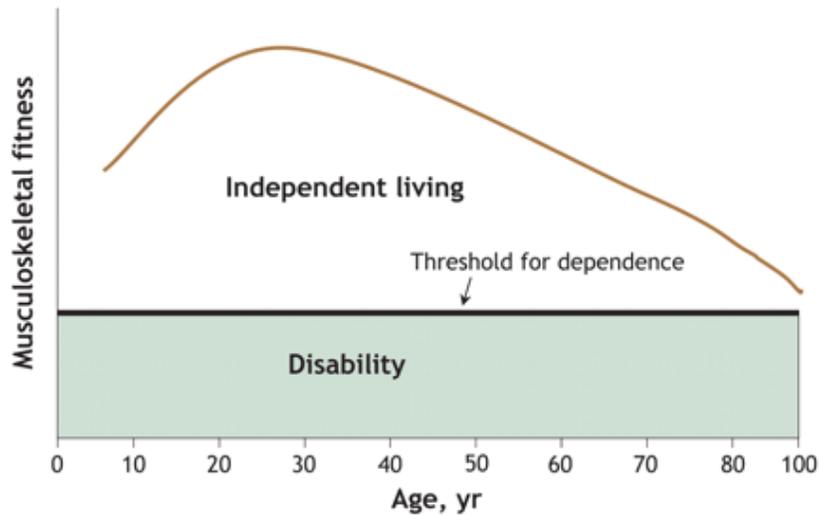


Figure 1.1. The theoretical relationship between musculoskeletal fitness (muscular endurance, strength, and power) and independent living across the lifespan. As age increases, musculoskeletal fitness decreases. If musculoskeletal fitness declines below an unknown amount, known as the ‘threshold of dependence’ then the older adult is at an increased risk of disability (Warburton et al., 2001a; 2006).

1.2.4. Physical Activity Guidelines and Canadian Older Adults

Research clearly demonstrates that physical activity is associated with increased physical function, and decreased risk of physical disability, chronic disease and premature death. To attain these benefits, the Canadian physical activity guidelines for healthy older adults (≥ 65 yrs) recommend a weekly accumulation of 150 min of moderate to vigorous intensity aerobic activity (ie., brisk walking at 5-6 km/hr) in bouts of 10 min or more (Tremblay et al., 2011). In addition, the recommendations include performing 2 d/wk of muscle and bone strengthening activities of the major muscle groups.

The minimal volume of exercise (frequency, duration, and intensity) required for optimal health status has not yet been defined, as the current recommendations are focused on reducing the risk of functional impairment (Tremblay et al., 2011). Health and fitness organizations

generally recommend a minimum volume of exercise that expends 1000 kcal/wk (Lee & Skerrett, 2001). Using metabolic data collected from a population of healthy older adults (Logan & Spriet, unpublished), the amount of moderate to vigorous intensity exercise that is related to this recommended caloric expenditure translates to ~105 min/wk for males and ~155 min/wk for females. This weekly amount of activity is similar to that recommended by Canadian physical activity guidelines for aerobic exercise (Tremblay et al., 2011), and doesn't leave much room for caloric expenditure of muscle and bone strengthening exercises. In addition, the physical activity guidelines are in place for healthy older adults who do not have mobility issues that prevent them from exercise. For those that have poor musculoskeletal fitness, muscle and bone strengthening exercises are of greater initial importance since strength is necessary to perform ADL and to reduce the risk of falls. Researchers have proposed that lower amounts of weekly energy expenditure may have health benefits (Kushi et al., 1997; Paffenbarger et al., 1993), and an amount as low as 500 kcal/wk may be sufficient (Lee & Skerrett, 2001) for those who are frail (low lean muscle mass) or elderly (Blair et al., 2001). The idea that any amount of exercise is better than none at all is key to this idea, however, research is needed to support this claim.

Unfortunately, the majority of the Canadian populace are missing out on the benefits regular physical activity endows; this is especially true in older adult populations (Statistics Canada, 2013). Data collected from the Canadian Health Measures Survey reported that men in general engage in more physical activity than women, and older adults engage in less physical activity than their younger counterparts (Statistics Canada, 2013). Only 11% of older adults aged 60 to 74 yrs achieve their physical activity recommendations, in comparison to 13% of adults aged 40 to 59 yrs, and 19% of younger adults aged 18 to 39 yrs (Statistics Canada, 2013). In fact, after 60 yrs of age, older males (60 - 74) participate in less daily moderate to vigorous

activity (18 min) than males aged 40 to 59 yrs (24 min), and younger males aged 18 to 39 yrs (30 min). Similarly, older women (60 to 74 yrs) accumulate less moderate-to-vigorous activity time (12 min) than women aged 40 to 59 years (18 min) and younger women aged 18 to 39 yrs (24 min) (Statistics Canada, 2013). A similar trend is evident with regard to light physical activity (Statistics Canada, 2013).

Despite the benefits of an active lifestyle, it remains a challenge to persuade older adults to become more physically active, and to sustain this behaviour (Jancey et al., 2007; Resnick & Spellbring, 2000). This may be due to a longer recovery time after a bout of exercise in comparison to younger adults (Shephard, 1998). In fact, the concept of improving or speeding up recovery time for older adults is a relatively untapped field that, in theory, may improve the experience of exercise which may help in attaining fitness goals. Another persuasive tool to increase exercise and retention may be group fitness classes, since research has demonstrated social connectedness to play an important role in attracting older adults to participate in physical activity (Jancey et al., 2007). In fact, Canadian seniors with a strong sense of connection and belonging to their community have been shown to have a greater likelihood of being in good health (62%) in comparison to seniors who felt less connected (49%) (Shields & Martel, 2006).

A meaningful way of being socially engaged in the community is through volunteering (i.e., unpaid work that benefits others). Older adults actively volunteer and accumulate more volunteer hrs than all other age groups (National Seniors Council, 2010). Yearly estimates of average volunteer hrs of seniors in Canada increase slightly with age, from adults 65 to 74 yrs contributing 216 hrs and those aged 75 and older contributing 222 hrs (National Seniors Council, 2010). However, the percentage of the population that volunteers decreases with age, with 40% of seniors aged 65 to 74 yrs volunteering, and 29% of seniors aged ≥ 75 yrs volunteering

(National Seniors Council, 2010). Research is accumulating to suggest health benefits of volunteering, including a decreased incidence of cardiovascular and heart disease, diabetes, and improved mental health (Gerontological Society of America, 2005). While it is clear there appears to be benefits associated with volunteering which may include improving mental health, and increasing physical activity and potentially physical fitness, research to support these associations is needed.

Finally, it has been suggested that adopting and maintaining physical activity routines may be improved with individual coaching to provide encouragement, affirmation, and feedback to the participant (Jancey et al., 2007).

1.2.5. *Monitoring Physical Activity*

Although both physical fitness and physical activity are often measured in epidemiological research, physical fitness is usually regarded as a more accurate measure of physical activity patterns (Williams, 2001), since it is a stronger predictor of health related outcomes (Blair et al., 2001; Myers et al., 2004). As such, existing physical activity guidelines consider fitness to be an alternate measure of physical activity. Health-related physical fitness in Canada is usually assessed using the Canadian Physical Activity, Fitness and Lifestyle Approach (Canadian Society for Exercise Physiology (CSEP), 2003). This approach contains various physical tests with their associated sex and age generated healthy cut-off points, derived from research, to evaluate body composition, aerobic fitness, and musculoskeletal fitness (i.e., strength, endurance, power, and flexibility) (CSEP, 2003). For accurate estimates (criterion or ‘gold’ standard) of physical activity, energy expenditure is typically evaluated by direct observation of movement, or the doubly labelled water technique and indirect calorimetry

method in the laboratory (Sirard & Pate, 2001). However, practical measures of physical activity and energy expenditure are often acquired by motion sensors (accelerometers and pedometers) and heart rate monitors (Berlin et al., 2006). More indirect estimates of physical activity involve activity diaries and self-report activity questionnaires, which are often used in larger epidemiological studies and large-scale trials (Forsen et al., 2010; Warburton et al., 2006b).

In epidemiological or population-based studies, assessing physical fitness is often not practical. Fortunately, studies assessing fitness have consistently shown a decline in adverse health risk with increases in physical activity (Blair et al., 2001). Therefore, from a public health perspective, it is more advantageous to encourage older adults to become more physically active, since it is more likely that sedentary adults will attain physical fitness if they simply engage in physical activity (Blair et al., 2001). The use of a self-report questionnaire to estimate how much physical activity older adults are achieving provides an inexpensive method of assessment and health surveillance (Blair et al., 2001). A challenge in the use of self-report questionnaires is to select one that provides valid and reliable estimates of physical activity in older adult populations (Forsen et al., 2010). In a recent review of the various physical activity questionnaires for older adults, 13 questionnaires were evaluated based on previously developed standards (qualitative attributes and measurement properties of physical activity questionnaires, QAPAQ) to appraise the measurement properties of physical activity questionnaires (Forsen et al., 2010; Terwee et al., 2010). The systemic review concluded that only 3 of the 13 questionnaires used to evaluate physical activity levels were useful in older adult (aged ≥ 55 yrs) populations. These questionnaires included the International Physical Activity Questionnaire-Chinese (IPAQ-C), the Women's Health Initiative-PAQ (WHI-PAQ), and the Physical Activity Scale for the Elderly

(PASE) questionnaire (Forsen et al., 2010). Of these three questionnaires, the PASE appears to be the most useful for a population of predominantly Caucasian men and women. The majority of studies have reported positive reliability and construct validity ratings for the PASE by comparing the questionnaire to both indirect and direct measures of physical activity (Forsen et al., 2010). The PASE is composed of 10 questions that assess the types of activities typically chosen by older adults (e.g., walking, recreational activities, exercise, housework, yard work, volunteer and paid work, and caring for others) (Washburn, et al., 1993). It uses frequency, duration, and intensity level of activity over the previous week to assign a score, ranging from 0 to 793, with higher scores indicating greater physical activity (Washburn et al., 1993).

The majority of past research evaluating the usefulness of physical activity questionnaires has failed to provide adequate descriptive information (socioeconomic status and health) which makes it difficult to compare various studies and draw conclusions. It has been suggested that future research aim to provide thorough descriptive data. This would be of benefit since great heterogeneity exists among the older adult population and the ability to compare studies of similar cohorts may contribute to the furtherance of research in this area (Forsen et al., 2010). With the trend for decreasing physical activity with age and the increasing number of seniors, the need to determine and monitor whether these adults are achieving sufficient amounts of physical activity to support healthy aging is required. For this reason, a physical activity monitoring tool, such as a questionnaire, that correlates well with physical fitness measures, warrants research. Increases in physical activity could be monitored and translated into benefits in physical fitness. It is clear that a physical activity monitoring tool, such as the PASE questionnaire, may be useful for monitoring and prescribing physical activity and fitness, in addition to encouraging older adults to engage in additional physical activity.

1.3. NUTRITION AND HEALTHY AGING

1.3.1. *Benefits of Healthy Eating and Risks Related to Poor Nutrition*

Healthy eating patterns are fundamental to healthy aging. Healthy eating not only provides essential energy and nutrients, but is fundamental to the maintenance of functional independence and general health and in reducing the risk of chronic diseases at older ages (BC Ministry of Health, 2005; Dietitians of Canada, 1998; Health Canada, 2002c).

Nutrition is the intake of food (dietary intake) considered in relation to the needs of the body (World Health Organization (WHO), 2013b). Healthy nutrition is defined as an adequate and well-balanced diet and is required for healthy aging. Poor nutrition may result in increased susceptibility to disease, impaired immunity, and decreased physical and mental functioning (WHO, 2013b). The lowest rates of poor nutrition among seniors are generally found in those who live independently within the community and enjoy good health, while those with poor nutrition already experience compromised health and functional status (Health Canada, 2002c). Poor nutrition is associated with an increased risk of chronic disease and functional impairment in the older adult (WHO, 2013b).

All food contains essential nutrients that are required in the diet for metabolic and physical functioning of the body (WHO, 2013b). Nutrients are divided into 2 categories; those required in larger amounts (macronutrients), and those in smaller amounts (micronutrients) (WHO, 2013b). Standards for daily intake of nutrients, called the dietary reference intakes (DRIs) are based on scientific examination and have been developed by the National Academy of Science (Health Canada, 2013a). The DRIs contain several reference values used in dietary assessment and dietary planning for healthy individuals: the Estimated Average Requirement

(EAR), the Recommended Dietary Allowance (RDA), the Tolerable Upper Intake Level (UL), and the Acceptable Macronutrient Distribution Range (AMDR) (Health Canada, 2013a). The EAR is the value of a nutrient estimated to meet the requirement of 50% of the individuals in an age and sex specific group. The EAR is used in planning and assessing nutrient adequacy in populations. The RDA is the dietary intake level that is sufficient to meet the nutrient requirements of almost all (95%) of the individuals in the group, and is used in planning and assessing intake for individuals. The UL is the maximum level of daily nutrient intake that is not probable to pose risks or adverse health effects to almost all of the individuals in the group. Finally, the AMDR is an intake range for macronutrients (carbohydrate, fat, protein) with respect to total energy intake. Following the DRI guidelines may provide optimal nutrition and reduce the risk of chronic disease (Health Canada, 2013a).

The DRIs were developed to plan and assess the diet of individuals and groups, and are the accepted reference for health professionals and researchers to assess the nutrient adequacy of healthy individuals. These reference values were developed with a focus on functional outcomes related to health and reducing the risk of chronic disease (Health Canada, 2013a). Recent revisions of the DRIs (formally known as the recommended nutrient intakes) resulted in acknowledgement of the great heterogeneity among older adults, in that the needs of a 50 yr old are different than those of a 75 yr old. For this reason, the formally oldest age category (aged >51yrs) was divided into two; those aged 51 to 70 yrs and aged >70 yrs (Health Canada, 2013a). However, nutrient requirements of adults >70 yrs remains inadequately documented, and currently there is little agreement as to how dietary requirements alter as a function of age and not as a consequence of lifestyle choices and medical conditions (Wakimoto & Block, 2001; Wellman, 2010). This is due to the majority of the knowledge on nutritional changes with aging

resulting from cross-sectional studies (where one age group is compared to another) rather than longitudinal studies (individuals followed over time). Longitudinal studies or cohort studies follow individuals over a span of time and provide a better understanding of changes in nutritional choices and habits (Wakimoto & Block, 2001). With increasing age, literature has documented a reduction in appetite and food intake (Drewnowski, 2003; Wakimoto & Block, 2001). Approximations of the decline in energy intake have been reported to be as much as 1000-1200 kcal/d for men, and 600-800 kcal/d for women between the ages of 25 to 70 yrs (Wakimoto & Block, 2001). Although this average decline was not normalized for physical activity, it has been speculated that the decline is less for those who are physically active. Decreases in both the energy expenditure required to perform the basic metabolic and physiological functions, known as resting metabolic rate (RMR) (Poehlman et al., 1993; Tzankoff & Norris, 1978) and the energy expenditure of physical activity (EEPA) (Pannemans & Westerterp, 1995) have been associated with declining caloric intake. In fact, RMR has been proposed to decline by ~1-2%/decade starting at the 2nd decade of life (Keys et al., 1973; Vaughan, 1991).

The decrease in energy expenditure predisposes the older adult to decreased LM and increased adiposity (Calles-Escando et al., 1995). This issue is compounded by evidence documenting that the decline in absolute energy intake increases the likelihood of not attaining adequate amounts of other nutrients, particularly micronutrients (nutrients required in small amounts; vitamins (vit) and minerals) and protein (Wakimoto & Block, 2001). This phenomenon has been termed the ‘anorexia of aging’ (Wakimoto & Block, 2001). Research in older adults has demonstrated that although there is a decrease in the absolute intake amount of most nutrients, the decrease in energy intake is greater. This results in a greater nutrient density

(ie. the consumption of a given nutrient expressed per 1000 kcal) in the diet than that consumed by younger age groups (Wakimoto & Block, 2001). Unfortunately, the higher nutrient density does not necessarily translate into attaining the requirements set out by the DRIs. In fact, evidence suggests that the requirements for several of the micronutrients actually increase (vit D, B-6, and calcium) (Health Canada, 2013a). If nutrient needs are not met, this may lead to malnutrition, which has been defined as the sub-optimal supply of a nutrient that interferes with an individual's growth, development or maintenance of health (Reuben et al., 1995). Over-nutrition, defined by excessive intake of nutrients, mostly macronutrients and calories, is a form of malnutrition. Malnutrition increases the risk of functional decline in addition to the development of many chronic diseases results in decreased body strength, reduced immunity, lower resistance to infection, higher surgical mortality rates, increased acute and long term care admissions and lower QOL due to increased functional dependence (Dietitians of Canada, 1998; Health Canada, 2002c). Although this information all points to the use of a daily supplement (multivitamin-multimineral) to attain these levels, nutrition experts do not necessarily support this. In fact, the Dietitians of Canada (2010) recommend healthy adults consume a diet rich in micronutrient-dense foods rather than relying on supplement intake for daily nutrition, with the exception of vit D and B-12 (Dieticians of Canada, 2010). Reasons supporting this recommendation include the fact that 1) there is enjoyment in food consumption; 2) supplements do not provide important nutrients such as carbohydrates, protein, essential fats, and fiber; 3) natural plant chemicals (phytochemicals) found in fruit and vegetables, whole grains, and nuts and seeds are more effective when eaten as foods rather than as supplements, and; 4) consuming large amounts of supplements can be dangerous if reaching levels at or above the UL (Dietitians of Canada, 2010).

1.3.2 *Contributors to Changes in Food Intake*

Numerous changes occur throughout the body that result in a decrease in energy and nutrient intake. With increasing age, adults experience a decrease in saliva production and changes in dentition that may modify their capacity to chew (Tabloski, 2006). Decreases in gastric acid secretion may reduce the absorption of iron and vit B-12. In addition, altered regulation of appetite and thirst may result in early satiety and a blunted thirst mechanism. Diminished taste and smell take away the appeal of many foods and may lead to a lesser variety of intake and preparing or consuming food that is no longer safe. This may result in an increased risk of malnutrition and risk of sickness (Tabloski, 2006). Peristalsis (contraction of smooth muscles to propel contents through the digestive tract) is slower and constipation may be an issue, and decreases in vision may make daily activities (shopping, food preparation, and even eating) more difficult (Tabloski, 2006). Many other factors that are associated with growing older may influence appetite, what foods are chosen for meals, and the overall nutrition of the individual. Social changes associated with age, including living alone, skipping meals, bereavement, and low socioeconomic (education and income) status contribute to lower intake and/or selecting poor food choices. This ultimately results in an increased risk for malnutrition (Payette & Shatenstein, 2005; Shatenstein et al., 2004). Therefore, addressing these underlying determinants is critical in supporting healthy eating patterns (Health Canada, 2002c; Payette & Shatenstein, 2005).

The changes that occur in food selection and intake with increasing age lead to changes in body composition. Some research indicates that this reduction in food intake may be due to a decline in metabolic efficiency due to lower LM with advancing age. Regardless of which occurs first, these changes observed in older adults result in a reduction in LM (skeletal muscle

and bone) and an increase in FM (Janssen et al., 2002). A low muscle mass due to aging but not related to a disease state (i.e. cachexia), known as sarcopenia, and/or a high body FM may result in decreased physical strength and mobility. The appendicular skeletal muscle of an individual can be approximated using anthropometric measures (height (Ht), BM, age, sex) and LM or resistance (from bioelectrical impedance analysis (BIA)). Two calculations most commonly used are the skeletal muscle index (SMI) (Janssen et al., 2000a; 2004b) and the fat free mass index (FFMI) (Schutz et al., 2002). There are slight differences in the calculation of each, but in general, SMI is typically implemented when using a BIA device, since resistance is required in the calculation; while the FFMI can be used for all body composition measures (ie., BIA, air displacement plethysmography, dual x-ray absorptiometry, magnetic resonance imaging). With respect to appendicular muscle, an individual may be considered sarcopenic if they possess a SMI or FFMI value less than 2 standard deviations below the mean appendicular muscle mass of a young adult reference population (Janssen et al., 2004b; Schutz et al., 2002). Research has reported the prevalence of sarcopenia in the general population to be ~10% for men and ~8% for women between 60-69 yrs, and increasing to ~40% for men and ~18% for women over 80 yrs (Melton et al., 2000). In addition, the decline of appendicular skeletal muscle is greater for men than women, with the predominant losses found in the lower extremities (Janssen et al., 2000b). It has been suggested that decreased activity or altered activity patterns may be responsible for this overall skeletal muscle loss and pattern of muscle loss (lower extremities) seen with aging (Janssen et al., 2000b).

Although sarcopenia most specifically refers to loss of skeletal muscle mass, the relationship between LM, functional ability and strength are well established. Since skeletal muscle is not only involved in movement but is also a metabolically active tissue, sarcopenia

may not only contribute to functional impairment, but may also indirectly exacerbate various chronic diseases (e.g., cardiovascular, cancers, diabetes, and osteoporosis) and increase recovery time from illness (Janssen et al., 2002; Rosenberg, 1989; WHO, 2002a; 2013b). Therefore, predicting and monitoring appendicular muscle mass may be an important tool for clinicians to determine whether an older adult may be at risk of disability. In fact, recent research has suggested that using a combination of strength (maximum handgrip), waist circumference (WC), and balancing and gait measurements can be used to predict ~71% of the variance in FFMI in a population of older adults (n=33, 81.5 ± 7.9 yrs (SD)) (Krause et al., 2012). The same research group went on to develop an even stronger (~93%) predictive equation that included sex, step time, BMI, and time outside of a 95% confidence ellipse to predict FFMI in a sample of older adults (n=85, 49% male, 75.2 ± 5.7 yrs (SD)) (McIntosh et al. 2013).

1.3.3. *Assessment of Dietary Intake*

Physiological and social changes with age are due to numerous complex and interrelated factors that have been found to influence the nutritional status of an individual. For this reason, nutritional assessment involves collecting the following information about the individual; a complete history of the risk factors for malnutrition (nutritional screening), a dietary assessment, a physical examination including anthropometry (i.e., Ht, BM, WC, body composition), and measurement of typical blood markers including insulin, glucose, lipids, and c-reactive protein (Dharmarajan & Kokkat, 2003). The aim of the nutritional assessment is to confirm that may people have inadequate diet and in some cases correct the issue (Dharmarajan & Kokkat, 2003).

Nutritional screening is the process of identifying characteristics known to be associated with becoming malnourished and is assessed using a questionnaire. In Canada one such

screening questionnaire is the SCREEN (Seniors in the Community Risk Evaluation for Eating and Nutrition) (Keller et al., 2000; 2002; 2005). The SCREEN is a validated tool that evaluates nutritional status by asking questions about recent changes in BM and nutritional predictors of poor intake which include living alone, missing meals, general health, chewing difficulties, poor appetite, and limitations in food-related ADL. A numerical value is attached to each answer and a nutrition score is attained, with low scores identifying older adults at risk of malnutrition (Keller et al., 2000; 2005).

Dietary assessment methods include food records (24 hrs - 7 d), dietary recall (usually in the previous 24 hrs), diet history (through interviews, take an hr or more) and food frequency questionnaires (Dharmarajan & Kokkat, 2003; Refai & Seidner, 1999). The food record requires that a person write down everything eaten with as much detail as possible (quantity, brand), before or immediately after finishing a meal. The data are entered into a nutrient database and the nutrient intake can be assessed (Thompson & Subar, 2008). Food records have the potential for providing a greater degree of completeness of food and beverage consumption than other dietary assessment methods, with 7 days of recording being considered the ‘gold standard’ of the dietary log assessments (Thompson & Subar, 2008). Although 7 days may provide a more complete intake estimates increases in incompleteness and underreporting have been found after only 3-4 days of recording. In addition, at least 3-4 days are required to attain adequate information on an individual’s usual intake (Gersovitz et al., 1978; Thompson & Subar, 2008).

The 24 hr recall method asks the participant to answer a series of open-ended questions to collect information on the diet intake during the past 24 hrs (Thompson & Subar, 2008; Yunsheng et al., 2009). Models of food portions can be used to help identify portion sizes. The data is not considered as accurate as a 3-7 day food record since the participant did not measure

or weigh food at time of consumption and reliance is on the memory of food eaten. National population surveys typically examine the nutrient intake of residents using this method (Centers for Disease Control & Prevention, 2010; Health Canada, 2012). Underreporting of food intake often occurs during the first 24 hr recall, so it is recommended that at least 2 additional 24 hr recall interviews be conducted in an attempt to accurately predict dietary intake (Yunsheng et al., 2009). Since accurate dietary assessment may be difficult in older adults due to the presence of cognitive impairments (Dharmarajan & Kokkat, 2003), recording foods and beverages as they are consumed, as in the dietary record method, may be a better approach due to less reliance on memory, and thus a decrease in the amount of omission and increase the amount of detail. Finally, food frequency questionnaires were designed to standardize the collection of dietary intake data for epidemiological studies, and contain anywhere from 60-120 dietary questions that a person answers based on the types of foods/drinks consumed, the frequency of their intake (per d, wk, mo) and approximate portion size (small, medium, large) (Thompson & Subar, 2008).

1.3.4. *Nutrition in Canadian Older Adults*

Several national studies by the National Advisory Council on Aging (NACA) have reported that ~50% of Canadian seniors rate their eating habits as “excellent” or “very good”, while 16% rated “fair” or “poor” (NACA, 2004). However, analysis of dietary intake using the 24 hr recall method and collected by the Canadian Community Health Survey reported that community-dwelling older adults were not meeting the EAR value for calcium, potassium, vit A, B₆, B₁₂, C, D, magnesium, zinc, iron, folate and fibre (Health Canada, 2012). In fact, the majority of older community-dwelling adults \geq 51 yrs consume inadequate ($<$ EAR) amounts of vit D and calcium in their diet (Health Canada, 2012). Further, when the older adults were

divided into DRI age categories, those in the oldest old age category (>70 yrs) had a higher proportion with inadequate intake values of these nutrients than those in the 51-70 yr age cohort. In addition, the majority had inadequate intake of magnesium (Health Canada, 2012). Evidence demonstrated that in comparison to all younger DRI age cohorts, the oldest age cohort has an increased prevalence of inadequate intakes of folate, vit B-6, and zinc. Similar proportions of inadequacy were found in both men and women. Intake of carbohydrate, fat, and protein were within the AMDR range for almost all older adults (Health Canada, 2012).

The consumption of micronutrient dense foods (i.e., foods with a high proportion of micronutrients/kcal) is essential for older adults (Drewnowski, 2005). If nutrient adequacy cannot be achieved by dietary intake, the use of multivitamin-multimineral (MVMM) supplement(s) may be required. Several nutrients are of concern in older adult populations. It has been recommended that older adults take supplemental forms of vit B-12 and D (Institute of Medicine, 2006). Approximately 10 to 30% of people > 50 yrs have difficulty absorbing vit B-12 found in food. Inadequate intake of vit D in older adults is very common due to a decline in intake of foods containing vit D (milk), a decline in the exposure to sunlight and the efficiency of vit D synthesis, and the regular use of sunscreen (Dietitians of Canada, 1998).

Since the cost of supplements is generally less than that of foods containing high amounts of micronutrients (e.g., fruits, vegetables, etc.), supplements facilitate an improvement in the micronutrient intake for people with nutrient poor diets (Darmon & Drewnowski, 2008; Vatanparast et al., 2010). However, research suggests that those that are at risk of nutrient inadequacy are not the ones who take supplements (Balluz et al., 2000). Older adults with low socioeconomic status (SES) and are in poor health are the group that is at the greatest risk (Darmon & Drewnowski, 2008). On the other hand, evidence based on food frequency data

reported that adults with high SES make better food choices (Darmon & Drewnowski, 2008), but this has not been examined with a more detailed form of dietary intake, such as the food record. It is unknown whether individuals with high SES have adequate intake of nutrients, and whether similarities exist in the general population, and whether supplement users in this group consume healthier diets.

1.3.5. *Healthy Aging and Long-Chain Omega-3 Intake*

Seniors who live independently in the community and who enjoy general good health have the lowest rates of poor nutrition (Health Canada, 2002). With advancing age, the risk of poor nutrition increases. A goal of society would be to keep these individuals healthy and living independently in the community. Adults experience metabolic and physical changes with advancing age that may predispose them to an increased risk of functional impairment and chronic disease (Gilmour and Park, 2006; PHAC, 2006). These changes, as previously discussed, include an increase in RHR, BP, and FM; and a decrease in resting metabolic rate, LM, and physical function (Evans & Campbell, 1993; Lakatta et al., 1987). The development of dietary strategies to combat these changes observed with advancing age are important.

A family of nutrients that have gained increasing attention among the public and researchers alike are the omega-3 fatty acids (O3FA). O3FAs are polyunsaturated fatty acids ranging from 18 to 22 carbon atoms in chain length with the first double bonds originating at the third carbon from the methyl end of the fatty acid (Leaf et al., 1999). The shortest O3FA is α -linolenic acid (ALA) which contains 18 carbon atoms and 3 double bonds (C18:3n-3), and is found in various plant sources (ie. flaxseed, soybean, etc.). Numerous longer chain O3FAs exist in nature and are found predominantly in marine oils (Leaf et al., 1999). The most well studied

long chain-O3FAs are docosahexaenoic acid (DHA) which is composed of 22 carbon atoms and 6 double bonds (C22: 6n-3) and eicosapentaenoic acid (EPA) composed on 20 carbon atoms and 5 double bonds (C20: 5n-3) (Leaf et al., 1999). The structures for DHA and EPA are depicted in Figure 1.2. (Holub, 2002).

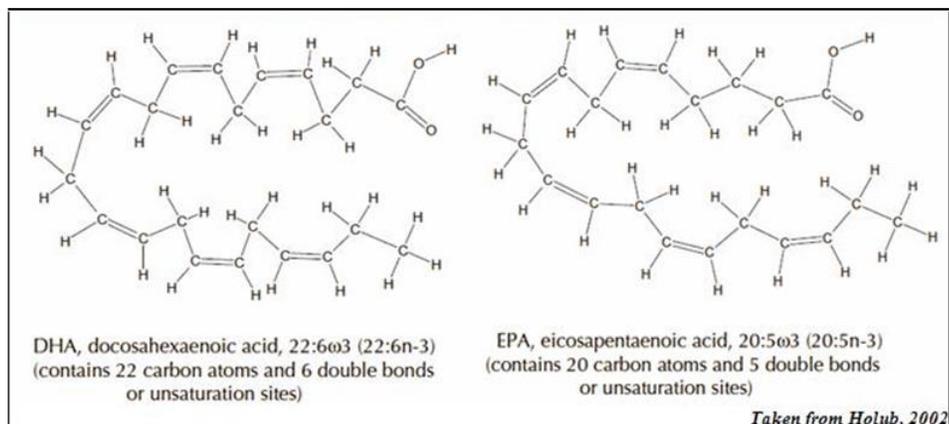


Figure 1.2. The fatty acid structures for docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) (Holub, 2002).

ALA is considered an essential fatty acid since it cannot be produced in the body and must be attained from food. The longer chain O3FAs, EPA and DHA, are considered ‘conditionally essential’ because ALA can be converted to the longer chain derivatives, although the conversion efficiency is low very low for EPA (<5%) and DHA (<0.5%) (Holub, 2002). In fact, this form of conversion provides <10% of the daily EPA and DHA required. Therefore, consuming marine sources of DHA and EPA to attain the amount required in the diet is needed.

Beneficial biological effects have been predominantly attributed to the longer chain O3FAs. Initial interest in O3FAs came from observations of the Greenland Eskimos who consumed high daily intake of marine oils containing EPA and DHA ($3.05 \pm 0.41\text{g}$), and

exhibited very low incidence of myocardial infarction and stroke (Dewailly et al., 2001). Analysis of blood lipids in comparison to Danish controls revealed significantly lower levels of TC, TG, low- and very low-density lipoproteins, and in males, an increased level of HDL-C (Dyerberg et al., 1977). Further, DHA is recognized as an essential nutrient within the brain and retina for optimal neuronal function and visual acuity throughout the lifespan (O'Brien & Sampson, 1965; Stilwell & Wassall, 2003; Youdin et al., 2000). For these reasons, consuming long chain O3FAs in the form of fatty fish or fish oils may be of benefit in the diet (Holub, 2002).

The beneficial effects of O3FAs are preferentially due to their incorporated into cell membranes where their integration influences the overall functioning of the cell. By incorporation into the membrane of cells, changes in membrane properties have been observed. These changes include increased permeability, fluidity, fusion, lipid packing, in addition to altered receptor binding properties and activities of membrane proteins (Siddiqui et al., 2004). Although the exact mechanisms whereby EPA and DHA affect cellular processes are currently unknown, it is likely to be multifactorial and involve their ability to incorporate into the cell membrane, and 1) increase the expression of genes involved in lipid oxidation and protein anabolism (Sampath & Ntambi, 2004; Smith et al., 2011); 2) decrease the expression of lipogenic genes, and; 3) modulate eicosanoid pathways (Seo et al., 2005).

1.3.6. *Omega-3 Fatty Acid Intake in Canadian Older Adults*

The American Heart Association and Health Canada recommend an average daily intake of 500 mg/d (~2 servings/wk or ~8 oz/wk of fish) of EPA and DHA for adults (Health Canada,

2008; Krause et al., 2000). Unfortunately, the mean intake in Western societies (135 mg/d, ~2 servings of fish/mo.) is ~1/4 of the recommended intake (Harris, 2009).

These dietary recommendations have been developed on the premise of reducing the risk factors associated with cardiovascular disease (Balk et al., 2006), although many of the positive health benefits are often associated with doses 6 times this amount (3-4 g/d). The health benefits of consuming O3FAs include decreases in resting BP and HR (Borghetti & Cicero, 2007; De Rosa, 2012; Geleijnse et al., 2002), and in the blood lipid profile (TG, TC, LDL-cholesterol) (Balk et al., 2006; Kris-Etherton et al., 2002). These benefits have been extensively researched in populations with existing disease or at high risk of disease, while little is known about the effect in healthy older adults (Ubeda et al., 2012).

1.3.7. *Health Benefits of Omega-3 Fatty Acid Intake in Aging*

Over 600 studies of O3FA supplementation in older adults have been conducted (Ubeda et al., 2012). However, sufficient detail regarding cognitive and physical function, physical activity, blood chemistry, and general health status is absent in most research, making it difficult to determine whether the data are representative of the effects of O3FAs on usual aging. In addition, much research has been conducted on older populations with chronic disease, and not in populations without (healthy) disease (Ubeda et al., 2012). Of the research conducted on healthy older adults, the majority of the studies have evaluated the effects of supplementation on cognitive function. Studies have demonstrated a positive relationship between O3FA intake or total content in erythrocyte membranes, and cognitive status or a reduction in cognitive decline (Ubeda et al., 2012). Only a few studies have reported no cognitive benefits of O3FA intake, but this may have been due to the use of olive oil as the control oil, since components of olive oil

may also have beneficial properties on cognition (Panza et al., 2010; Rosales, 2011). Research has reported reductions in resting BP and HR (Deslypere, 1992; Geleijnse et al., 2002; Vandongen et al., 1993), and TG (Harris et al., 2008) and TC levels (Balk et al., 2006), although no effect on blood insulin and glucose levels (Balk et al., 2006). Benefits to immune function may also occur as several studies reported a decrease in blood inflammatory markers (Bechoua et al., 2003; Kiecolt-Glaser et al., 2012; Thies et al., 2001a; 2001b; Rees et al., 2006; Wardwell et al., 2008). The immune and cardiovascular benefits of O3FAs are speculated to be due to a number of widespread mechanisms surrounding their preferential incorporation into cell membranes. By integrating into the cell membrane, O3FAs replace omega-6 fatty acids (O6FA; arachidonic acid, AA). By replacing AA, EPA and DHA become the substrate for eicosanoid synthesis, since O3FAs and O6FAs compete for the same eicosanoid producing enzymes. In general, O3FAs possess anti-thrombotic, anti-inflammatory, anti-hemotactic, and anti-vasoconstrictive properties, while those developed from O6FAs are inflammatory and contribute to the formation of thrombi (Benatti et al., 2004; Calder, 2006).

The decrease in systemic inflammation may also benefit strength and physical function (Calder, 2006), since the joints most commonly affected by inflammation are weight-bearing joints, such as feet, knees, hips and spine. A cohort study reported a positive association between handgrip strength and fish intake in older adults ($n = 2983$, 47.5 % females, 66.1 ± 2.8 yrs) (Robinson et al., 2008). The researchers concluded that for each meal of fish consumed/wk, an average increase in grip strength of 0.43 kg for men and 0.48 kg for women was evident (Robinson et al., 2008).

The potential of O3FAs to maintain or increase LM is of interest, since beginning around the 3rd decade of life adults experience an annual decline in muscle mass of 0.26-0.56% which

may result in decreased metabolic and physical health (Visser, 2012). To date, only 3 studies have evaluated the effects of O3FA supplementation on muscle and bone health in healthy older adults, with all reporting positive benefits of supplementation. One study reported that long term intake (4 yrs) of fatty fish (≥ 3 servings/wk) in healthy older adults ($n=854$, 40% male, 67-91 yrs) resulted in the maintenance of femoral neck bone density (Farina et al., 2011). With age, muscle protein synthesis in response to nutritional stimuli (i.e., amino acids and insulin) is weakened, and is thought to be a prominent cause of the progressive loss of muscle mass and strength (Cuthbertson et al., 2005; Rasmussen et al., 2006; Smith et al., 2011). A recent investigation by Smith et al. (2011) reported that supplementation with O3FAs (4 g/d; 1.86 g EPA, 1.50 g DHA) in older adults ($n=16$, 63% females, 71 ± 1 yrs) appeared to be a beneficial and promising strategy to activate protein synthesis. Finally, a study worth noting in a healthy younger adult population (6 males and 16 females; 33 ± 13 yr, mean + SD) demonstrated a decrease in FM and an increase in LM without a change in BM after 6 wks of supplementation (1.6 g/d of EPA and 0.8 g/d of DHA) (Noreen et al., 2010).

In addition to the benefits observed in muscle protein anabolism and physical strength, preliminary research in our laboratory has suggested positive benefits after 12 wks of fish oil supplementation (2 g/d EPA, 1 g/d DHA) in healthy young adults. Although not statistically significant, several subjects demonstrated an increase in resting metabolic rate (RMR) and exercise energy expenditure along with an increase in fat oxidation rate (Gerling & Spriet, unpublished).

Many conflicting results are present in the literature with respect to resting and exercise oxygen consumption and energy expenditure in both humans and rodent models. In fact, the majority of previous studies in younger humans and rodents demonstrate no changes with

supplementation (Huffman et al., 2004; Poprzecki et al., 2009) or a decrease in oxygen consumption, speculating a more efficient use of oxygen in the exercising muscle (Peoples et al., 2008; Peoples & McLennan, 2010). However, several of these studies reported a significant increase in fat oxidation with O3FA intake (Delarue et al., 2003; Huffman et al., 2004). In addition, Couet et al. (1997) reported a significant increase in fat oxidation (22%) and a decrease in FM (-0.88 kg) when 6 g/d of fat in the diet was replaced with FO (1.1 g/d EPA, 0.7 g/d DHA) for 3 wks. An increase in RMR was also reported, but when the increase in LM was accounted for, the RMR increase was not significant; suggesting that the FO may increase RMR by increasing LM (Couet et al., 1997).

The mechanisms by which EPA and DHA modulate energy metabolism are speculated to be due to their ability to activate and bind various PPAR isoforms (Lin et al., 1999). By activating PPARs, changes in energy metabolism may result by influencing mRNA, protein expression, or the activity of various proteins. Proposed changes with EPA and DHA intake include an increase in: **(1)** mRNA expression of fatty acid translocase/Cluster of Differentiation 36 (FAT/CD36), a transport protein to move fatty acids across the sarcolemmal membrane and into the mt (Aas et al., 2006); **(2)** Fatty acid-binding protein (FABPc), an intracellular transport protein that chaperones fatty acids in the cytoplasm for storage or to the mt for oxidation (Clavel et al., 2002); **(3)** mRNA of mt uncoupling protein-3 (UPC3), a transport protein of anions from the inner to the outer mt membrane and the return transfer of protons (Baillie et al., 1999; Bezaire et al., 2005; Gerling & Spriet, unpublished); **(4)** mRNA expression of peroxisomal acyl-CoA oxidase, an enzyme that catalyzes fatty acid oxidation (Baillie et al., 1999), and; **(5)** an increase carnitine palmitoyltransferase I (CPTI) oxidase, a rate-limiting enzyme in fatty acid oxidation (Power & Newsholme, 1997). Finally, O3FAs may also affect energy metabolism

through up-regulation of peroxisome proliferator-activated receptor gamma coactivator 1-alpha (PGC-1 α), a transcriptional coactivator that is involved in regulating the genes involved in energy metabolism and in mt biogenesis and function (Olesen et al., 2010; Wu et al., 1999). This protein may be also involved in regulating blood pressure, cholesterol homeostasis, and in the development of obesity (Entrez Gene, 2013).

The potential for O3FA intake to ameliorate the age-related decrease in RMR, and positively influence body composition, bone health, and physical strength, may be a strategy for older adults to decrease the risk of functional impairment and chronic disease. Therefore, the apparent benefits of O3FA intake in healthy older adults requires additional research and may be a potential strategy to ameliorate the negative physical and metabolic aspects observed with advancing age. In addition, an increase in RMR with O3FA supplementation would be a similar effect that is found in response to exercise (Campbell et al., 1994).

1.4. CONCLUSIONS

The proportion of seniors is projected to increase in Canada in the next several decades. Research into keeping these older adults living independently in the community and aging in a healthy manner is important and timely. With age physiological changes occur, with the most noticeable being the reduction in LM and the increase in FM. A low muscle mass, known as sarcopenia, and/or a high FM may result in decreased physical strength and mobility. Ultimately, a low muscle mass may result in a decreased QOL, and an increased risk of functional impairment and chronic disease, which leads to an increased rate of transition from independent living to assisted living. Many of the physiological and metabolic changes that occur with aging are exacerbated by age-associated decreases in physical activity and changing

nutrient intake. Therefore, physical activity and nutrition are important modifiable lifestyle factors that may maintain or increase the QOL for older adults.

CHAPTER 2

AIMS OF THESIS

The proportion of older adults continues to increase and is the world's fastest growing segment of society. A major challenge in this population is to optimize the quality and years of healthy life (Drewnowski et al., 2003). Ninety percent of Canadian seniors currently reside in the community and wish to remain independent (PHAC, 2006). The transition from independent living in the community to residential living occurs due to poor health and disability in older age, and is largely a consequence of chronic disease (Gilmour & Park, 2006).

With age, physiological functions gradually decline and, depending on the extent of the change, influence independent living by increasing the risk of chronic disease and functional impairment. These physiological declines may result in clinically measurable changes, including, 1) an increase in RHR and BP (particularly systolic) (Lakatta et al., 1987); 2) a decrease in glucose homeostasis (Szoke et al., 2007); 3) an increase in FM and a decrease in LM (Evans & Campbell, 1993); 4) and a decrease in physical strength and function (Evans & Campbell, 1993). Clinically unfavorable measures are risk factors for chronic disease and functional mobility impairment. There is, however, growing optimism as evidence is accumulating that suggests a large portion of chronic conditions associated with aging can be mitigated with lifestyle modification (e.g., physical activity and dietary intake). Implementing and maintaining positive lifestyle behaviours may manage or reduce the risk of chronic disease and disability and allow older adults to live a healthier and independent lifestyle in the community.

With the trend for decreasing physical activity with age and the increasing number of seniors, the need to determine and monitor whether these adults are achieving sufficient amounts of physical activity to support healthy aging is required. Changes in dietary intake also occur with aging and include a decrease in caloric requirements while the need for protein (g/kg BM)

and the recommended dietary allowance for micronutrients remain the same or increase (e.g. vit B-6, vit D, and calcium) (IOM, 2006; Wakimoto & Block, 2001; Williamson, 1993). If nutritional requirements are not met through food consumption, dietary supplement use may be required to ensure that older adults meet their RDA (Murphy et al., 2007). The average Canadian senior, with an annual income of \$31,600, experiences inadequate dietary intake of vit A, C, D, and E, and calcium, folic acid, potassium, and magnesium (Health Canada, 2005; 2012). Research has demonstrated that higher socioeconomic status may be related to healthier food choices (Darmon & Drewnowski, 2008). However, it is unknown whether populations of older adults with higher SES experience nutrient inadequacies similar to those of the average Canadian older adult. In addition, the changes that occur in nutrient intake may lead to changes in body composition (e.g., increase in FM and decrease in LM) and a decline in RMR. A low muscle mass (sarcopenia) and/or a high body FM may result in decreased physical strength and mobility. Since skeletal muscle is not only involved in movement but is also a metabolically active tissue, low LM may not only contribute to functional impairment, but may also indirectly exacerbate various chronic diseases (cardiovascular, cancers, diabetes, and osteoporosis) and increase recovery time from illness (Janssen et al., 2002; Rosenberg, 1989; WHO, 2002b; 2013b). Predicting and monitoring appendicular muscle mass may be an important tool for clinicians to determine whether an older adult may be at risk of disability. Finally, a family of nutrients that has recently gained interest are O3FAs. Research has suggested that O3FA intake may be beneficial in combating the negative metabolic and physical aspects observed with advancing age.

Therefore, this thesis examines the relationships between physical activity, nutrition, and health measures in older Canadian populations.

The specific objectives of study 1 were to determine:

- 1) Whether relationships existed between PASE scores and a variety of health-related measurements (body composition, cardiovascular measures, blood parameters, flexibility scores and strength values) in community-dwelling older adults.
- 2) Whether an optimal PASE score could be predicted that would ensure health measurements fell in desired (clinically healthy) ranges for community-dwelling older adults.

The specific objectives of study 2 were to determine:

- 1) The dietary intake and prevalence of MVMM and other supplement use in a population of older adults with high SES;
- 2) Whether MVMM users have a healthier diet than non-users;
- 3) Whether relationships existed between dietary intake parameters (total energy intake, protein, calcium, vit D) and LM, FFMI, and combined handgrip strength.

The specific objectives of study 3 were to determine if omega-3 (fish oil) supplementation in older adults affects:

- 1) Metabolic rate and substrate oxidation at rest and during exercise;
- 2) Resting and exercise HR and resting BP;
- 3) Fasted blood lipids;
- 4) Body composition, strength, and physical function.

The overall hypotheses of this thesis were:

- 1) Significant relationships would exist between PASE scores and the measured body composition, cardiovascular measures, blood parameters, flexibility scores and strength values. Optimal PASE scores could be predicted to advise older adults in the amount of physical activity required.
- 2) In a cohort of older adults with high SES:
 - a) Low incidence of inadequate nutrient intake from food alone;
 - b) A high proportion of the population take daily supplements;
 - c) Those that consume daily supplements have a healthier diet from food alone than supplement non-users;
 - d) FFMI, LM, and handgrip strength could be predicted using dietary intake parameters (total energy intake, protein, calcium, vit D).
- 3) Fish oil supplementation would:
 - a) Increase metabolic rate and reliance on fat oxidation for energy both at rest and during exercise
 - b) Decrease resting BP and resting and exercise HR;
 - c) Decrease blood lipid values of TC and TG;
 - d) Decrease adiposity and increase LM; and
 - e) Increase handgrip strength and physical function.

CHAPTER 3

THE PHYSICAL ACTIVITY SCALE FOR THE ELDERLY (PASE) QUESTIONNAIRE; DOES IT PREDICT PHYSICAL HEALTH?

Logan, S.L., Gottlieb, B.H., Maitland, S.B., Meegan, D., & Spriet, L.L.
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3.1. ABSTRACT

A lack of physical activity is common in older adults. With the increasing Canadian senior population, identifying the minimum amount of physical activity required to maintain the health of older adults is essential. This study determined whether relationships existed between the Physical Activity Scale for the Elderly (PASE) questionnaire scores and health-related measurements in community-dwelling older adults who were meal delivery volunteers. Based on observed relationships between PASE scores and health parameters, the study attempted to predict an optimal PASE score that would ensure health parameters fell in desired ranges for older adults. 297 community-dwelling older adults (61.3% female) 60–88 yrs (72.1 ± 6.5) completed the PASE and were measured for body composition, cardiovascular and blood parameters, flexibility, and handgrip strength. Significant regression models using PASE were produced for the health-related measures, but the relationships were not meaningful due to low predictive capacity. However, correlational data suggested that a minimum PASE score of ~140 for males and ~120 for females predicted a favorable waist circumference. In conclusion, findings demonstrated that PASE scores cannot be used to predict healthy physical measures, although the relationships between PASE and WC could be used to encourage older adults to become more physically active.

3.2. INTRODUCTION

A lack of physical activity is common in older adult populations residing in industrialized countries (Katzmarzyk & Janssen, 2004; Patterson & Warburton, 2010; Statistics Canada, 2006; WHO, 2002b). Physical inactivity has been identified as a risk factor for the development of several chronic diseases, including: coronary heart disease, stroke, hypertension, type 2 diabetes mellitus, osteoporosis, breast cancer and colon cancer (Gill et al., 1995; Janssen, 2012; Katzmarzyk & Janssen, 2004; Statistics Canada, 2001; Warburton et al., 2006a). Additional risk factors for these diseases include obesity, decreased skeletal muscle mass, elevated blood pressure (BP), and elevated blood glucose and blood lipid levels (Gill et al., 1995). On a global scale, the World Health Organization estimated that physical inactivity causes 2 million premature deaths each year (WHO, 2002a). Whereas most of this information has been obtained from younger populations, some studies have indicated that this problem continues into older populations (Simonsick et al., 1993; Sui et al., 2007).

A second problem with physical inactivity is that it leads to reductions in lean muscle mass and strength. The reduction of muscle mass and strength to levels below proposed thresholds results in limitations in physical functioning and mobility, and reduces the opportunity for independent living in later life. Research has demonstrated that systemic physical activity in older adults, regardless of chronic disease, is related to delayed physical disability and the maintenance of independent living (Spiriduso & Cronin, 2001).

Statistics Canada has estimated that the number of seniors will increase from ~4.2 million in 2005 to ~9.8 million in 2036 and from a proportion of 13% to 25% of the total population (Statistics Canada, 2006). A useful step forward would be to identify the minimum amount of physical activity that is required to maintain the health of older adults, decrease disease risk

factors, and maintain their mobility and quality of life. There have been several self-report questionnaires used to quantify the amount of daily physical activity of older adults. One widely used measure is the Physical Activity Scale for the Elderly (PASE) , designed to assess the duration, frequency, exertion level, and amount of physical activity undertaken over a 7 day period by individuals ≥ 60 yrs (Washburn et al., 1993). This tool is useful and acceptable for field research purposes and provides an inexpensive method of physical activity and health surveillance. Previous research has validated the use of the PASE score by comparing the questionnaire to both indirect and direct measures of physical activity (Chad et al., 2005; Dinger et al., 2004; Saris, 1997; Schuit et al., 1999; Warburton et al., 2006b; Washburn et al., 1993).

The first goal of this study was to determine whether relationships existed between PASE scores and a variety of health-related measurements in community-dwelling older adults. The measured health parameters included indices of body composition, cardiovascular measures, blood parameters, flexibility scores and strength values. Based on observed relationships between the PASE and the health parameters, the second goal of the study was to predict an optimal PASE score that would ensure the measured health parameters were in a desired range for older adults. For each health parameter, we consulted the clinical health guidelines, published by the relevant health agencies, for values associated with good health. For example, we examined the relationship between PASE scores and fat mass (FM) to determine the level of physical activity (PASE score) that corresponded with a healthy FM. In the event that a participant had a high FM and low PASE score, the relationship would predict the increase in physical activity (increase in PASE score) needed to move the FM into the healthy range (Figure 3.1.).

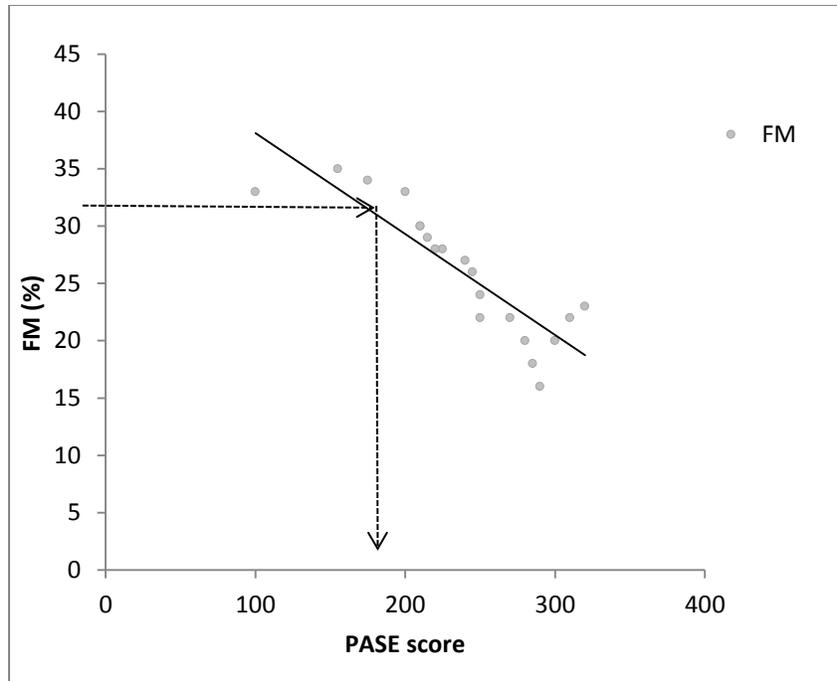


Figure 3.1. Stylized relationship between FM and PASE score. Arrows represent the male healthy cut-point for FM that corresponds to an optimal PASE score. FM = fat mass; PASE = physical activity scale for the elderly.

We attempted to accomplish these goals by measuring the PASE score and several health parameters in 297 older adults who worked as volunteers delivering meals in the community. We hypothesized that significant relationships would exist between PASE scores and the measured body composition, cardiovascular measures, blood parameters, flexibility scores and strength values.

The practical application of this research could impact those individuals who work with older adult populations. With this information, a physical activity coordinator at a retirement center could obtain individual PASE scores and when necessary, advise older adults to increase their daily physical activity in a measurable and directed manner to a higher PASE score, associated with desirable health parameters.

3.3. METHODS

3.3.1. *Participants*

The data in this paper were part of a larger study called the Physical Exercise in Older Persons' Lives (PEOPL) study. Conducted over a period of 3 yrs, from 2009 to 2011, the data reported here are from the baseline testing.

3.3.2. *Recruitment and Inclusion*

The PEOPL study recruited 297 older adult volunteers (115 males and 182 females) from six community support agencies that offered meal delivery services in the province of Ontario. The volunteers met the following eligibility criteria: (i) involved in volunteer meal delivery services with no actual or planned interruption longer than 6 wks over the course of the past and next 12 months; (ii) ≥ 60 yrs of age; (iii) no evidence of dementia; (iv) English literacy; and (v) absence of any self-reported medical diagnoses that entail functional impairment. Following ethics clearance, both oral and written informed consent was obtained from all participants.

3.3.3. *Body Composition Measures*

The protocol for body mass (BM), height (Ht), and waist circumference (WC) measures in this study were performed as outlined in the Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA) document (CSEP, 2003). Ht was measured to the nearest 0.1 cm using a vertical metric wall tape and a horizontal flat edge. BM was measured to the nearest 0.1 kg on a calibrated digital scale (Health O Meter; Model HDM663CD-60x335KP; Health O Meter, Bridgeview, IL, US). WC was measured to the nearest 0.5 cm, and was taken at the top of the iliac crests using an anthropometric tape. A WC of <102 cm for males and <88 cm for females

was considered healthy (CSEP, 2003). Body mass index (BMI) was calculated as BM/Ht^2 . A BMI of $<25 \text{ kg/m}^2$ was considered healthy and $25\text{-}30 \text{ kg/m}^2$ was considered overweight (Health Canada, 2003a). Waist to height ratio (WHtR) was calculated as WC/Ht (Ashwell & Hsieh, 2005). A WHtR of <0.6 for older adults was considered healthy (Aswell & Hsieh, 2005; Schneider et al., 2010). Bioelectrical impedance analysis (BIA) was conducted (Bodystat 1500, Florida, US) to estimate FM (%) and LM (%) and resistance (R, ohms) (Bray, 1993). A FM of $<30\%$ for males and $<42\%$ for females was considered healthy (Bray, 1993). Healthy cut-points for LM were $>70\%$ for males and $>58\%$ for females. Skeletal muscle index (SMI, kg/m^2) was calculated as $[Ht^2/(R \times 0.401) + (\text{sex} \times 3.825) + (\text{age} \times -0.071) + 5.102]/Ht$, where sex = 0 for males and 1 for females (Janssen et al., 2000a; 2004b). SMI was considered healthy if >8.50 for males and >5.75 for females and values lower than the cut-points represent a high risk of physical disability (Janssen et al., 2004b).

3.3.4. Cardiovascular Measures

Resting heart rate (bpm) and systolic and diastolic blood pressure (SBP, DBP, mmHg) were measured using a BP monitor (OMRON IntelliSense; Model HEM-907XL; OMRON Healthcare, IL, US). Participants were seated with their left arm resting on a table for three minutes prior to three BP measurements taken one min apart. The mean of the last two measurements was used for data analysis to ensure the participants were relaxed. Values of <100 for RHR, $<140 \text{ mmHg}$ for SBP and $<90 \text{ mmHg}$ for DBP were considered to be healthy (Abbott et al., 1994; Daskalopoulou et al., 2012). Mean arterial pressure (MAP, mmHg) was calculated as $((2 \times \text{DBP}) + \text{SBP})/3$, and pulse pressure (PP) was calculated as $\text{SBP}-\text{DBP}$ (Franklin et al., 1997). A MAP value of >60 and $<107 \text{ mmHg}$ and a PP of >25 and $<60 \text{ mmHg}$ were identified as healthy (Franklin et al., 1997). For the correlation analysis of BP (SBP, DBP, MAP, PP)

measures and PASE score we included only those individuals who did not take medications to control for hypertensive conditions.

3.3.5. *Blood Measures*

After a minimum 12 hr overnight fast, blood was taken at LifeLabs Medical Laboratory Services (Ontario, CA) and analyzed for serum glucose (mmol/L), insulin (pmol/L), and triglycerides (TG, mmol/L). Blood measurements were considered healthy if glucose was <7 mmol/L, insulin was <210 pmol/L, and TG <1.7 mmol/L (Canadian Diabetes Association, 2008; Chad et al., 2005; Wallace & Matthews, 2002). The homeostasis model assessment of insulin resistance (HOMA-IR) was calculated as $\text{glucose} \times (\text{insulin}/6.945)/22.5$ and a value was considered healthy if <2.60 (Matthews et al., 1985; Wallace & Matthews, 2002). For the correlation analysis of blood measures (insulin, glucose, and HOMA-IR) and PASE score, we included data only from those individuals who did not take medications to control diabetic conditions.

3.3.6. *Flexibility and Strength Measures*

Seated flexibility (FLEX) was measured using a flexometer (University of Guelph, ON, CA) according to protocols outlined by CPAFLA (CSEP, 2003). Two measurements were taken and the higher measurement was used in the analysis. Since seated FLEX scores for adults > 69 yrs of age have not been established, we used the healthy cut-point for adults 60-69 yrs. A FLEX of > 20 cm for males and > 27 cm for females was considered healthy (CSEP, 2003). Combined grip strength (CGS) was measured to the nearest 0.5 kg using a hand-held hydraulic grip dynamometer (Jamar; Sammons Preston Rolyan; Nottinghamshire, England), and was

conducted as outlined in guidelines established by CPAFLA (CSEP, 2003). Three measurements per hand were taken, and the participant alternating hands between measurements to allow ~30 seconds of rest. The highest measurements for each hand were added together to achieve the CGS score. Since CGS scores for adults > 69 yrs of age have not been established, we implemented the healthy cut-point for adults 60-69 yrs. A CGS of ≥ 73 kg for males and ≥ 41 kg was considered healthy (CSEP, 2003). The relative strength index (RSI) was calculated as $(CGS/2)/BMI$ to estimate the loss of muscle strength normalized for BM (Chorquette et al., 2010; Winter, 2009). A healthy RSI cut-point of >2.7 was used, with values lower than the cut-point being associated with increased likeliness of reduced mobility (Chorquette et al., 2010).

3.3.7. Questionnaires

Participants completed the PASE, which is a validated 10-item self-administered document that is designed to measure the amount of physical activity undertaken by individuals over the age of 60. The PASE assesses the types of activities typically chosen by older adults (walking, recreational activities, exercise, housework, yard work, and caring for others) (Washburn et al., 1993). It uses frequency, duration, and intensity level of activity over the previous wk to assign a score, ranging from 0 to 793, with higher scores indicating greater physical activity (Washburn et al., 1993).

The participants also completed the abbreviated Seniors in the Community Risk Evaluation for Eating and Nutrition (SCREEN II) questionnaire, to evaluate the proportion of participants who were at risk of malnutrition. The SCREEN is a validated tool that evaluates nutritional status using changes in weight, food and beverage intake, and nutritional risk factors to identify

older adults at risk of malnutrition (Keller et al., 2000; 2005). The maximum achievable SCREEN II score is 48, with a score <43 indicating nutritional risk (Keller et al., 2005).

The participants completed a third questionnaire that concerned demographic variables (education, annual gross household income, employment status, living arrangements), health behaviours and conditions (illness/disease and medication data, smoking and alcohol consumption), and volunteer roles.

3.3.8. Data Analyses

Data are presented as mean \pm standard deviations (SD), unless indicated otherwise. Descriptive statistics were calculated for demographic information, health variables, and physical measures. The Independent Samples t-test was used to test the difference in physical measures and questionnaire scores between males and females. Pearson product moment correlations were used to test whether a significant relationship existed between PASE scores and physical measures. If a significant relationship was found, 3-step hierarchical linear regression models were used to test whether total PASE score could predict physical measures. In these models, sex was entered at Step 1, age was entered at Step 2, PASE score was entered at Step 3, and the interaction between sex, age, and PASE score was entered in Step 4. All statistics were computed using PASW Statistics 19.0.1 for Windows (SPSS, Chicago, IL, US). Statistical significance was accepted as $p < 0.05$ for all tests, except where other values were noted.

4.4. RESULTS

4.4.1. *Participant Characteristics*

The majority of the participants completed a high school education or more, were retired, and had a gross annual household income averaging >\$30,000 (Table 1). Generally, they also lived with others, were non-smokers, consumed ~5 alcoholic drinks/wk, and volunteered ~4 hr/wk. Hypertension was the most commonly medicated chronic disease among participants (Table 3.1).

For body composition measures, the mean BMI for males and females was in the overweight category, but the mean WC was in the healthy range for males and females. The mean WHtR was in the healthy range for males but in the unhealthy domain for females (Table 3.2.). Both males and females were in healthy categories for mean FM, LM, and SMI. For the cardiovascular and blood parameters, the mean values were in the healthy domains for males and females. The exceptions were that mean HOMA-IR values for males were in the unhealthy range and female values were at the healthy cut-point. The mean flexibility and strength data suggested that males and females were in a positive health category (Table 3.2.). Significant differences between males and females for mean values of body composition measures (WC, WHtR, FM/LM, SMI), cardiovascular measures (RHR, SBP, PP), and flexibility and strength measures (Flex, CGS, RSI) were found. Males had significantly greater mean values for WC, LM, SMI, SBP, CGS and RSI than females, and females had greater WHtR, FM, RHR, PP, and Flex mean values than males (Table 3.2.).

Table 3.1. Participant characteristics, stratified by sex.

Characteristic	Males <i>n</i> = 115 (%)	Females <i>n</i> = 182 (%)
Education (completed)		
Elementary	35 (30.7)	42 (23.2)
High School	39 (34.2)	77 (42.5)
College/University	25 (21.9)	51 (28.2)
Graduate School	15 (13.2)	11 (6.07)
Employment Status		
Retired	110 (96)	162 (89)
Unemployed, looking for work	1 (1)	2 (1)
Never employed	1 (1)	3 (2)
Employed	3 (2)	15 (8)
Gross Annual Household Income		
<\$30,000	13 (12.5)	39 (25.7)
>\$30,000	91 (87.2)	113 (74.3)
Living Arrangements		
Live With Others	103 (90)	114 (62.6)
Volunteer Work *		
Meal Delivery	96 (83)	144 (79)
Other Volunteer Work	30 (26)	53 (29)
Smoking		
Never	78 (69.0)	131 (74.4)
Former	31 (27.4)	40 (22.7)
Current	4 (3.5)	5 (2.8)
Alcohol **		
	77 (69.4)	104 (58.7)
Medications		
Cardiovascular Disease	29 (25.2)	27 (14.8)
Hypertension	54 (47.0)	66 (36.0)
Cancer	6 (5.2)	7 (3.8)
Immune Related	-	2 (1.1)
Hormonal/Endocrine	1 (0.8)	7 (3.8)
Arthritis	27 (23.5)	48 (26.4)
Diabetes	21 (18.3)	17 (9.3)
Asthma/Breathing	11 (9.6)	20 (11.0)
Thyroid	-	1 (0.6)

Data are numbers of individuals with percentages in brackets; * Mean Volunteer Work: Meal Delivery: Males 4.8 h/wk, females 3.7 h/wk, Other Volunteer Work: males 5.6 h/wk, females 3.0 h/wk; ** Mean Alcohol Consumption: Males 6.4 drinks/wk, females 4.3 drinks/wk.

Table 3.2. Participant characteristics, body composition, cardiovascular/bloods, flexibility

/strength, and PASE and SCREEN scores, and healthy cut-points of older community-dwelling older adults.

Measure	Total (<i>n</i> = ~297)	Males			Females			<i>P</i> -value
	<i>M</i> (<i>SD</i>)	<i>n</i>	<i>M</i> (<i>SD</i>)	Cut-points	<i>n</i>	<i>M</i> (<i>SD</i>)	Cut-points	
Age (yrs)	72.1 (6.5)	115	73.2 (6.0)	-	182	71.4 (6.8)	-	0.016 *
Ht (cm)	166.3 (9.0)	115	173.6 (6.8)	-	181	161.1 (6.4)	-	-
Body Composition								
BM (kg)	76.4 (14.4)	115	84.6 (11.8)	-	181	71.2 (13.8)	-	-
BMI (kg/m ²)	27.5 (4.2)	115	28 (3.4)	<25	181	27.4 (5)	<25	0.193
WC (cm)	99.0 (11.4)	114	101.3 (9.0)	<102	179	97.8 (12.7)	<88	0.006 *
WHtR	0.60 (0.37)	114	0.58 (0.05)	<0.60	179	0.61 (0.08)	<0.60	0.002 *
FM (%)	35 (9)	110	28 (5)	<30	169	40 (8)	<42	<0.001 *
LM (%)	65 (9)	110	71 (5)	>70	169	60 (8)	>58	<0.001 *
SMI (kg)	8.71 (2.33)	110	10.16 (1.89)	>8.50	169	7.59 (1.99)	>5.75	<0.001 *
Cardiovascular/Bloods								
RHR (bpm)	70 (11)	114	67 (11)	<100	181	71 (10)	<100	0.002 *
SBP (mmHg)	128 (17)	114	130 (16)	<140	181	126 (18)	<140	0.036 *
DBP (mmHg)	68 (10)	114	68 (10)	<90	181	68 (10)	<90	0.826
MAP (mmHg)	89 (11)	114	90 (11)	>60 & <107	181	88 (11)	>60 & <107	0.200
PP (mmHg)	60 (14)	114	58 (14)	>25 & <60	181	62 (13)	>25 & <60	0.014 *
Insulin (pmol/L)	71 (53)	109	72.7 (50.1)	<210	167	69 (53.4)	<210	0.573
Glucose (mmol/L)	5.6 (1.1)	109	5.7 (1.2)	<7.0	167	5.6 (1.1)	<7.0	0.325
HOMA-IR	2.6 (2.3)	109	2.7 (2.0)	<2.6	167	2.6 (2.5)	<2.6	0.715
TG (mmol/L)	1.4 (0.8)	109	1.4 (0.7)	<1.7	167	1.3 (0.8)	<1.7	0.680
Flexibility/Strength								
FLEX (cm)	35 (12)	110	30 (12)	>20	170	38 (10)	>27	<0.001 *
CGS (kg)	62 (22)	115	80 (16)	≥73	181	47 (11)	≥41	<0.001 *
RSI	3.2 (1.0)	115	3.9 (0.8)	>2.7	181	2.6 (0.6)	>2.7	<0.001 *
PASE Score	155 (66)	111	172 (72)	-	169	139 (58)	---	<0.001 *
SCREEN Score	39 (6)	112	38 (6)	>43	175	39 (6)	>43	0.193

Data are means and standard deviations (*M* ± *SD*). *p*-value is the difference between males and females. * *p* (2-tailed) < 0.05. Ht = height; BM = body mass; BMI = body mass index; WC = waist circumference; WHtR = waist to height ratio; FM = fat mass; LM = lean mass; SMI = skeletal mass index; RHR = resting heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure; MAP = mean arterial pressure; PP = pulse pressure; HOMA-IR = homeostasis model for insulin resistance; TG = fasting triglycerides; FLEX = seated flexibility; CGS = combined hand-grip strength; RSI = relative strength index; PASE =

physical activity scale for the elderly; SCREEN = seniors in the community risk evaluation for eating and nutrition.

The average physical activity (PASE) score suggested that males were significantly more active than females (Table 3.2.). The mean nutritional risk (SCREEN) score suggested that males and females were both at risk for malnutrition, with no significant sex differences (Table 3.2.).

To examine the influence of age on the measured physical parameters, participants were separated into age cohorts of young-old (YOld; 65 to 74 yrs; $n = 150$; 34 males, 116 females) and old-old (Old; 75 to 89 yrs; $n = 122$, 57 males, 65 females). Those who were ≤ 65 yrs of age ($n = 25$) were not included in the remaining analyses. Old males and females demonstrated significantly lower mean SMI, CGS, and physical activity (PASE) scores, and significantly higher mean PP in comparison to their YOld counterparts (Table 3.3). In addition, Old females demonstrated significantly lower mean BM and BMI, while the Old males demonstrated significantly higher mean FM and lower LM (Table 3.3).

3.4.2. Correlation of Physical Measures with PASE Score

For the entire sample, PASE scores were significantly correlated with all the body composition measures, except BMI (Table 3.4.). For the cardiovascular and blood measures, RHR and TGs were significantly correlated. PASE scores were also significantly correlated with GS and RSI, but not with FLEX. Finally, PASE scores were not significantly correlated with SCREEN scores. Although there were many significant correlations between PASE scores and health parameters, very few were meaningful, due to the very low “ r ” values (Table 3.4.). Although many of the health parameters correlated with PASE when separated by sex and when

further divided into age cohorts (data not shown), all correlations were also weak or even weaker for the entire group.

Table 3.3. Participant characteristics, body composition, cardiovascular/bloods, flexibility/strength, and PASE and SCREEN scores, of older community-dwelling older adults separated into sex and age cohorts.

Measures	Males		Females	
	YOld (<i>n</i> = 34)	Old (<i>n</i> = 57)	YOld (<i>n</i> = 116)	Old (<i>n</i> = 65)
Ht (cm)	174.1 (6.6)	173.2 (6.9)	161.5 (6.3)	160.5 (6.6)
BM (kg)	86.2 (12.3)	83.1 (11.1)	72.7 (16.0)	69.3 (11.5) *
Body Composition				
BMI (kg/m ²)	28.4 (3.6)	27.7 (3.2)	28.1 (5.4)	26.1 (4.1) *
WC (cm)	100.7 (9.6)	100.2 (15.7)	97.0 (18.4)	94.7 (16.5)
WHtR	0.58 (0.05)	0.58 (0.09)	0.60 (0.1)	0.59 (0.1)
FM (%)	26.5 (6.0)	30.3 (3.5) *	39.5 (7.9)	41.5 (7.3)
LM (%)	73.2 (6.2)	69.7 (3.5) *	60.5 (7.9)	68.2 (7.5)
SMI (kg)	10.55 (2.41)	9.78 (1.09) *	7.81 (2.26)	7.20 (1.33) *
Cardiovascular/Bloods				
RHR (bpm)	67.9 (10.7)	66.6 (12.1)	71.7 (10.5)	70.4 (10.2)
SBP (mmHg)	128.0 (14.7)	132.6 (16.9)	123.4 (17.9)	130.8 (16.7)
DBP (mmHg)	69.4 (8.3)	67.4 (12.0)	68.6 (10.6)	67.3 (8.8)
PP (mmHg)	58.5 (12.4)	65.2 (13.1) *	54.8 (12.9)	63.5 (14.5) *
MAP (mmHg)	89.0 (9.4)	90.4 (12.0)	87.4 (12.1)	89.2 (9.6)
Glucose (mmol/L)	5.3 (1.6)	5.5 (1.8)	5.1 (2.1)	5.2 (1.5)
Insulin (pmol/L)	76.9 (54.7)	67.3 (45.7)	68.4 (52.7)	70.1 (55.1)
HOMA-IR	2.7 (2.1)	2.4 (1.9)	2.4 (2.6)	2.4 (2.1)
TG (mmol/L)	1.5 (0.8)	1.3 (0.6)	1.4 (0.8)	1.2 (0.6)
Flexibility/Strength				
Flex (cm)	30.8 (12.3)	26.5 (13.1)	35.7 (14.6)	35.1 (12.0)
CGS (kg)	86.9 (13.0)	74.2 (16.1) *	48.3 (11.4)	43.2 (9.6) *
RSI	4.2 (0.7)	3.7 (0.7) *	2.6 (0.7)	2.5 (0.6)
SCREEN Score	37.4.0 (5.1)	39.0 (6.2)	39.3 (6.3)	39.1 (5.5)
PASE Score	184.6 (74.0)	147.9 (76.8) *	139.3 (69.7)	110.5 (54.9) *

Abbreviations as in Table 3.2. Data are means and standard deviations (M ± SD); * *p* (1-tailed) < 0.05. YOld = Young-Old (60–74 yrs); Old = Old-Old (75–88 yrs).

Table 3.4. Pearson product-moment correlations for all participants and unhealthy participants between body composition, cardiovascular/bloods, flexibility/strength, and SCREEN score measures with PASE score.

Measure	All Participants PASE Score				Unhealthy Participants PASE Score		
	<i>n</i>	<i>r</i>	<i>y</i> (Cut-points)	<i>p</i>	<i>n</i>	<i>r</i>	<i>p</i>
Age	279	-0.224	N/A	<0.001	N/A	N/A	N/A
Body Composition							
BMI	279	-0.048	N/A	0.211	212	-0.195	0.002 *
WC	276	-0.110	140 (males)	0.034*	189	-0.055	0.224
WHtR	276	-0.174	145	0.002*	125	-0.338	0.001 *
FM	264	-0.204	-	0.000*	112	-0.177	0.031 *
LM	264	0.197	-	0.001*	114	0.195	0.019 *
SMI	264	0.118	-	0.029*	-	-	-
Cardiovascular/Bloods							
RHR	278	-0.129	-	0.016*	50	-0.215	0.067
SBP	165	0.065	N/A	0.204	32	0.089	0.314
DBP	165	0.008	N/A	0.458	-	-	-
PP	165	0.079	N/A	0.156	119	-0.136	0.072
MAP	165	0.018	N/A	0.411	-	-	-
Insulin	229	-0.085	-	0.100	-	-	-
Glucose	229	-0.061	N/A	0.179	-	-	-
HOMA-IR	229	-0.208	N/A	0.208	76	0.036	0.380
TG	261	-0.116	-	0.031*	66	-0.078	0.267
Flexibility/Strength							
FLEX	265	0.015	N/A	0.403	45	0.021	0.446
CGS	279	0.283	-	0.000*	91	0.321	0.001 *
RSI	279	0.284	59	0.000*	104	-0.024	0.406
SCREEN Score	270	-0.066	N/A	0.139	190	-0.061	0.202

Abbreviations as in Table 3.2. * p (1-tailed) < 0.05.

We also examined whether the relationships between the physical measures and PASE score would be stronger for participants with unhealthy values. In some cases the number of unhealthy participants was low and correlations could not be computed (SMI, MAP, insulin, glucose). Significant correlations were found between all body composition measures, except WC

(Table 3.4.). There were no significant correlations between the cardiovascular and blood measures. CGS was the only measure for the flexibility and strength parameters that was significantly correlated with the PASE score. Many of these same parameters correlated with PASE when separated by sex and when further divided into age cohorts (data not shown), but again all the significant correlations were weak or even weaker for the entire group.

3.4.3. Prediction of Health Measures from PASE Score

We also attempted to derive a regression equation for all health parameters and PASE scores, however, the only significant regression models were for WC, WHtR, LM, FM, RHR, CGS, and RSI (Table 3.5.). The predictive capacity of the models was generally low (adj. $R^2 < 10\%$), except for the CGS and RSI models, where 64% and 52% of the variance in CGS and RSI was explained. However, PASE score contributed very little to the predictive equations for both CGS and RSI, with the majority of influence due to sex differences (Table 3.5.).

Table 3.5. All participant data. Significant ($p < 0.05$) regression models combining sex (S: 0 = female, 1 = male), age (A; year), and PASE score (PS) to predict WC (cm), WHtR, FM (%), LM (%), RHR (bpm), CGS (kg) and RSI.

Model	N	Equation	Adj. R^2	SEE	p
WC	276	$(4.692 \times S) - (0.253 \times A) - (0.034 \times PS) + 120.936$	0.048	11.276	0.001
WHtR	276	$(-0.019 \times S) - (0.001 \times A) - (1.819E-4 \times PS) + 0.725$	0.054	0.0691	<0.001
FM	264	$(-0.028 \times PS) + 39.752$	0.038	8.822	0.001
LM	264	$(0.027 \times PS) + 60.243$	0.035	8.895	0.001
RHR	278	$(-0.021 \times PS) + 73.051$	0.013	10.815	0.032
CGS	279	$(33.301 \times S) + (0.030 \times PS) + 42.656$	0.640	12.663	<0.001
RSI	279	$(1.347 \times S) + (0.002 \times PS) + 2.291$	0.520	0.669	<0.001

Abbreviations as in Table 3.2.

The significant regression models for the unhealthy participant data included WC, WHtR, BMI, and CGS (Table 3.6.). The predictive capacity of WC and BMI was low ($R^2 < 15\%$), while WHtR and CGS were stronger ($R^2 \sim 30\%$ and $\sim 77\%$). However, the contribution of PASE score to the regression equation was similarly weak (Table 3.6.).

Table 3.6. Unhealthy participant data. Significant ($p < 0.05$) regression models combining sex (S: 0 = female, 1 = male), age (A; year), and PASE score (PS) to predict WC (cm), WHtR, BMI (kg/m^2), and CGS (kg).

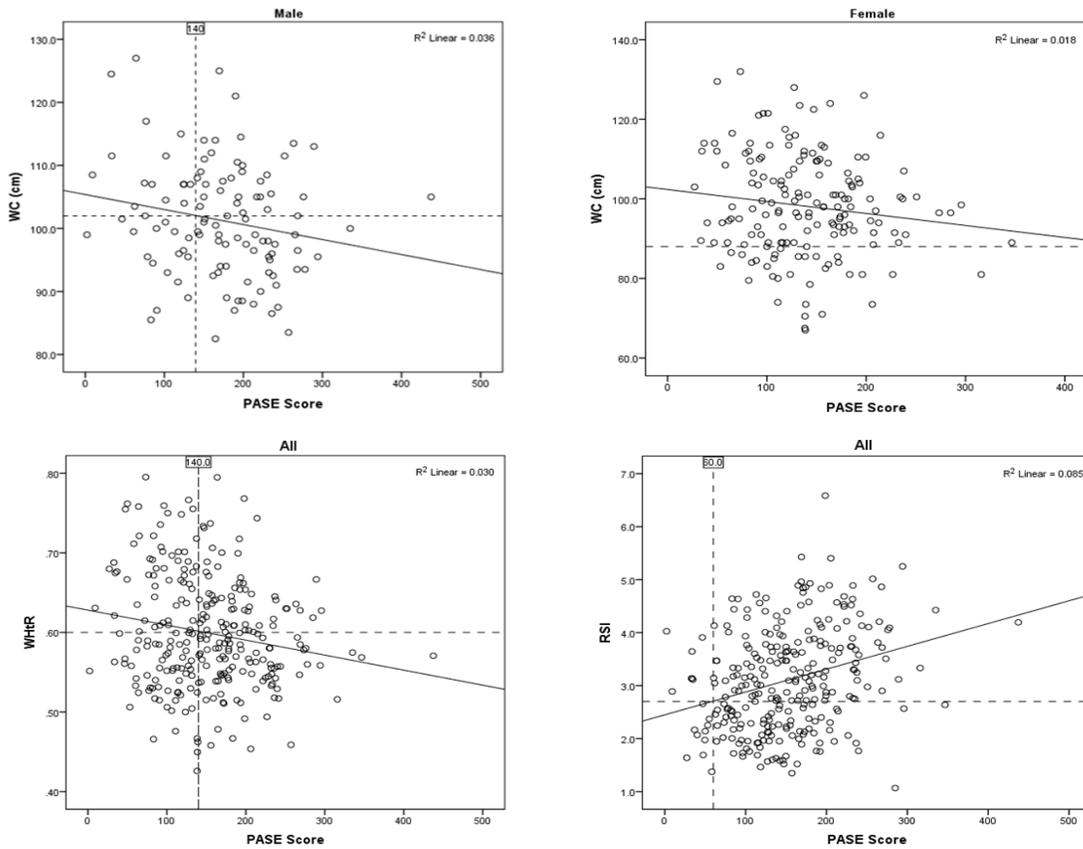
Model	N	Equation	Adj. R^2	SEE	p
WC	189	$(8.879 \times S) - (0.226 \times A) - (0.022 \times PS) + 121.120$	0.134	9.071	<0.001
WHtR	125	$(-0.023 \times S) - (0.003 \times A) - (3.085E-4 \times PS) + 0.907$	0.284	0.041	<0.001
BMI	205	$(-0.176 \times A) - (0.014 \times PS) + 44.310$	0.112	3.498	<0.001
CGS	90	$(25.608 \times S) + (0.038 \times PS) + 30.689$	0.765	7.287	<0.001

Abbreviations as in Table 3.2.

3.4.4. Use of a Cut-Point for PASE Score Based on Prediction Models and Scatterplot Data

PASE score cut-points could not be developed due to the very weak predictive capacity of the regression models. For this reason we generated scatterplots using the correlation data to approximate a PASE score for each significantly correlated health parameter where the healthy cut-point intercepted the trend line. Only WC, WHtR, and RSI generated a meaningful PASE score. A PASE score of ~ 140 and above was related to favorable WC (males) and WHtR (all participants), whereas a PASE score of ~ 60 corresponded to a favorable RSI value (all participants) (Table 3.4., Figure 3.2.(a)). Since there were significant differences in mean WHtR and RSI values between males and females (Table 3.2.), we further separated the WHtR and RSI data by sex (Figure 3.2.(b)).

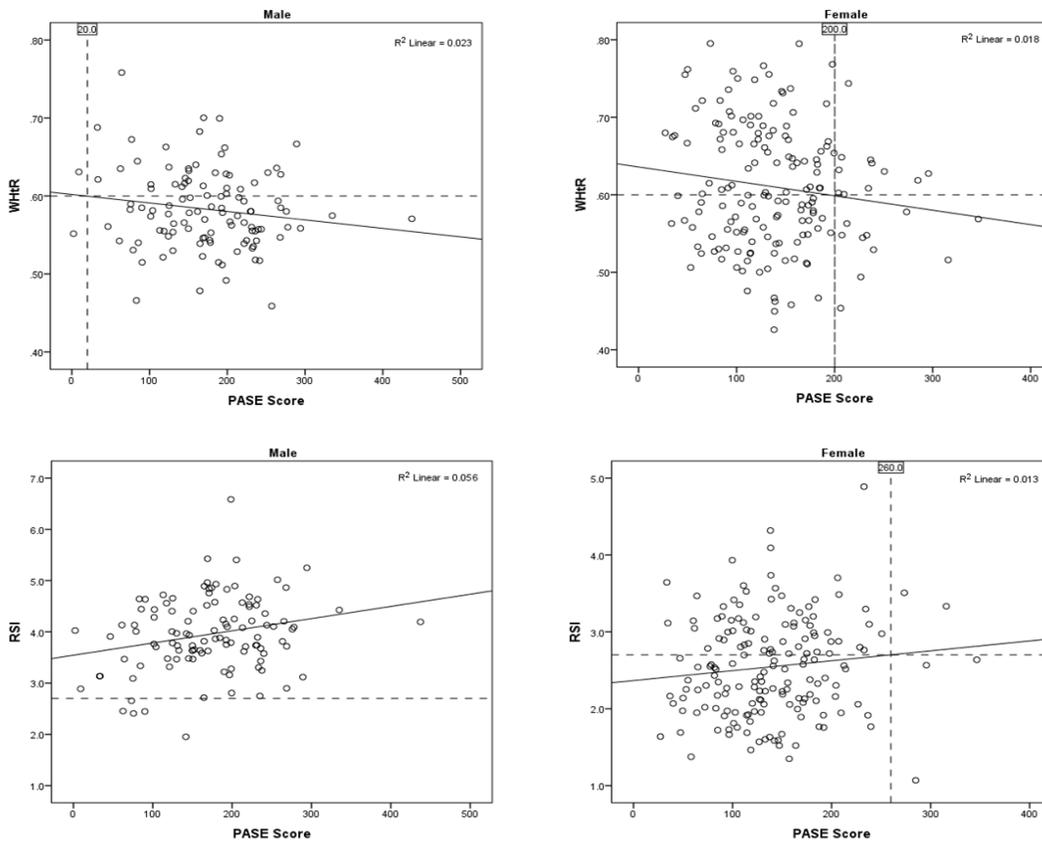
Figure 3.2. Scatter plots and regression lines of the correlation between health parameters and PASE score (a) for all participants and (b) separated by sex. The intersection of the health parameter cut-point and regression line produced the corresponding PASE score cut-point.



WC = waist circumference; WHtR = waist to height ratio; RSI = relative strength index; PASE score = the physical activity scale for the elderly score.

(a)

Figure 3. Cont.



WHtR = waist to height ratio; RSI = relative strength index; PASE score = the physical activity scale for the elderly score.

(b)

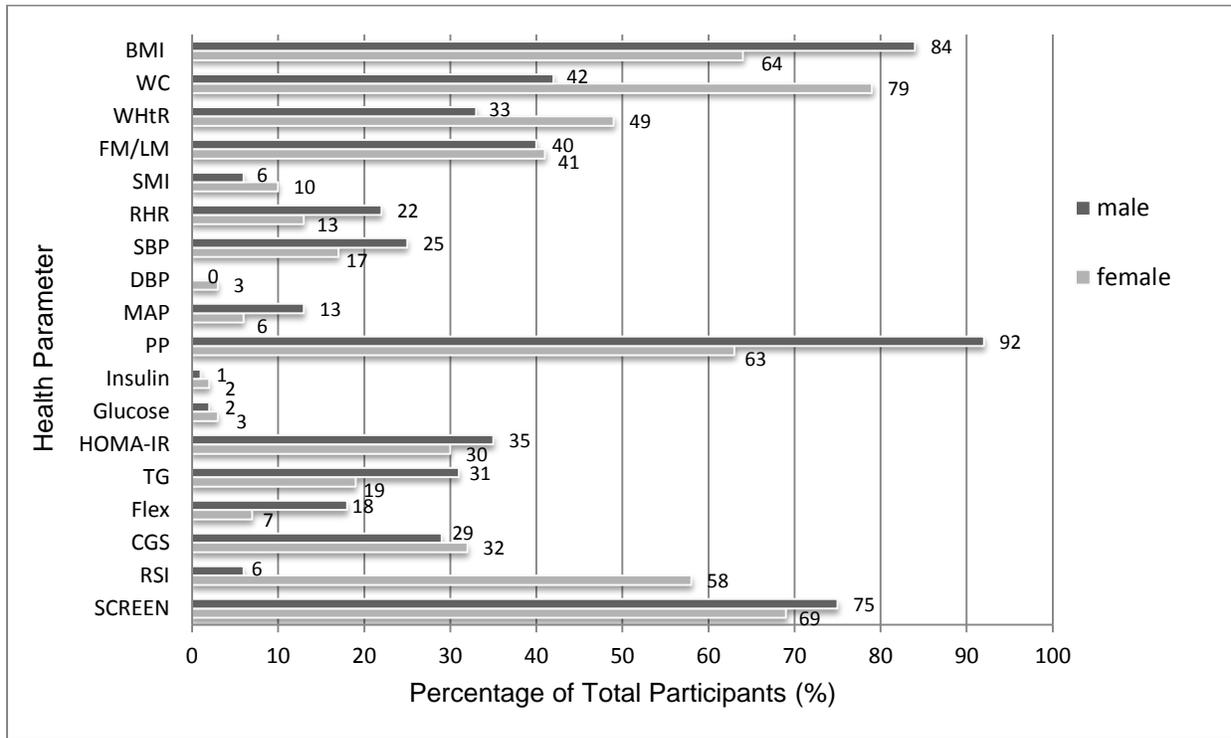
The scatterplot revealed that a PASE score of ~20 for males and ~200 for females indicated a favorable WHtR. For RSI data, a PASE score for males could not be developed because the RSI cut-point did not intersect the regression line. For females, a PASE score of ~260 indicated a favorable RSI value (Figure 3.2.(b)).

3.5. DISCUSSION

The purpose of this study was to determine if the self-reported Physical Activity Scale for the Elderly (PASE) questionnaire would predict physical measures associated with health. Our goal was to use PASE scores to predict the level of physical activity required to ensure that a person's physical measure (e.g., WC) was in the clinically favorable or healthy range. For example, would a relationship between WC and PASE indicate that a PASE score of 155 was necessary to fall in the favorable WC range? People below the desired PASE score, would be advised to increase their physical activity and move their PASE score above the cut-off score for that parameter. Generally, our hypotheses were not supported as the significant correlations between the physical parameters and PASE scores were relatively weak and many of the participants were already in the clinically desirable category (Figure 3.3.). However, we did find what could be a useful relationship between PASE score and WC (males), WHtR (females), and RSI (females) where the PASE score cut point was ~140, ~200, and ~260; respectively (Figure 3.2.(a,b)).

We repeated the analysis only with the people who fell below the favorable cut-off (*i.e.*, unhealthy participants) for each of the measured health parameters, but the data revealed only similarly weak correlations with PASE scores.

Figure 3.3. The percentage of male and female participants in an unhealthy category for measures of body composition, cardiovascular/bloods, flexibility/strength, and SCREEN score.



Abbreviations as in Table 3.2.

3.5.1. Waist Circumference and PASE Score

The mean WC (101.3 cm) of our male cohort was in a favorable WC range (<102 cm). The WC cut-point for males indicated that a PASE score of ~140 or higher would result in a favorable WC. If a man moved his PASE score from 140-170, the result would predict an eventual drop in WC. The scatterplot suggest that a 30-point PASE score increase would result in a ~1.0 cm decrease in WC. To do this, a man would have to increase his weekly activity by 1 hr or more on 5 to 7 occasions a wk by performing moderate to strenuous sport or recreation activities such as bicycling, swimming, or calisthenics.

For females, the mean WC (97.8 cm) was in an unfavorable range (>88 cm). Using the healthy WC cut-point (88 cm), a PASE score could not be produced since the WC cut-point did not intersect the regression line (Figure 3.2.(a)). Research suggests that the current female WC cut-point for older adults may overestimate the health risks of obesity, where a cut-point of 99 cm for females ≥ 70 yrs of age may be more useful (Heim et al., 2011). If we increased the previous WC cut-point to 99 cm, then the WC cut-point would intersect the regression line at a PASE score of ~ 120 . To increase a woman's PASE score to ~ 150 , an increase of 30 points, this would result in an eventual decrease in WC of ~ 1.0 cm. To achieve this, females would have to do the same amount of physical activity as that listed above for males.

3.5.2. PASE and Chronic Health Conditions

Previous research has investigated the relationship between physical activity, as measured by the PASE, and self-reported chronic health conditions in a cohort of Canadian community-dwelling older adults ($n=764$, mean age = 77.4 ± 8.6 yrs). The average PASE score for males (130) was higher than for females (103). Higher PASE scores were also significantly correlated with more favorable health as measured by reporting of fewer chronic health conditions, including musculoskeletal, respiratory, cardiovascular, digestive, neurological, and mental/emotional conditions (Chad et al., 2005). The mean PASE score of the group with the chronic health issue ranged from 86-102; the score for those with no chronic health issue ranged from 110-115 (Chad et al., 2005). The average PASE score in our cohort was higher (155) than those reported by other cohorts, but was similar in that males had higher PASE scores than females (172 and 139; respectively). We generated PASE score ranges associated with self-reported chronic disease using the CVD, arthritis, diabetes, and asthma/breathing data (Table 3.1.). We could not include the other conditions requiring medication (Table 3.1.) because there

was not enough participant data or there was not a significant difference in PASE scores between participants taking medications and those not taking medications. Our data indicated higher PASE score ranges than those previously reported (Chad et al., 2005), with the mean PASE score for those with health conditions ranging from 118-139, and where the health issues were absent ranging from 155-156. Reasons for this discrepancy may be due to a younger mean age (72.1 ± 6.5 yrs) of our cohort, and thus higher PASE ranges, since previous research has reported a decrease in PASE scores with increasing age (Chad et al., 2005; Washburn et al., 1993; 1999).

3.5.3. Comparison of PASE and SCREEN Scores with Other Research

In comparison to healthy, community-dwelling cohorts generally matched for age and sex, our cohort demonstrated a higher mean PASE score (155) than reported in the original PASE article ($n = 396$, mean age = 75 yrs, mean PASE score = 103), and in a recent Japanese article ($n = 325$, mean age = 73 yrs, mean PASE score = 115) and Canadian article ($n = 402$, mean age = 75 yrs, mean PASE score = 102 (males), 72 (females)) (Barake et al., 2010; Hagiwara et al., 2008; Washburn et al., 1993). PASE score has also been shown to decrease with age (Chad et al., 2005; Washburn et al., 1993; 1999) and be higher in males, married or living with others, employed, more highly educated, and those who attain an annual household income $> \$20,000$ (Chad et al., 2005; Washburn et al., 1999). These factors may have contributed to the higher PASE scores in our study because the majority of our participants had those demographic characteristics. Our participants were also active volunteers in the community, which may explain the higher PASE scores; since active volunteer work like meal delivery may be rewarded with points on the PASE questionnaire.

Although our cohort was more active than other cohorts, their nutrition (SCREEN) score did not follow the same trend. The SCREEN score indicated that a high percentage of our cohort; 75% males, 69% females, were at nutritional risk. Other research using similar Canadian community-dwelling cohorts (n=255, mean age=71.7 ± 8.3 yrs) has reported fewer older adults (53% of males and 57% of female) being at nutritional risk (Keller & Hedley, 2002). It has been suggested that caution should be taken regarding the confirmation of nutritional risk, since the SCREEN II has an adequate intra-class correlation(r) of 0.75 (Phillips et al., 2010).

3.5.4. *How Healthy is Our Cohort? Comparison of Our Physical Measures with Population*

Data

The mean physical measures in our cohort are similar to values collected on community-dwelling older adults by the Canadian Health Measures Survey (CHMS, 2007-2009) (Bryan et al., 2010; Shields et al., 2010). Both cohorts have mean BMI in the overweight category, and WC in the unfavorable range, with the exception of our cohort males who had values in the favorable category. Mean RHR, BP, and CGS measures were also similar, but Flex measures were more favorable than those reported in the CHMS (Bryan et al., 2010; Shields et al., 2010). In comparison to Canadian population data on the prevalence of arthritis, diabetes, and hypertension, our cohort took fewer medications, with the exception of male medication use for hypertension (Statistics Canada, 2010a; 2010b; 2011a; 2011b).

To predict the risk of physical disability and mobility impairment, we used SMI and RSI indices. According to the SMI cut-points, previous research has estimated that 10% of adults ≥ 60 yrs have a high risk of physical disability (Janssen et al., 2004b). Our data indicated that 6% of males and 10% of females were at risk of physical disability. Using the recently developed

RSI cut-point (2.7), our data suggested that 6% of males and 58% of females had values that indicated an increased risk of mobility impairment (Chorquette et al., 2010). This prediction appears consistent with that of SMI for males but not for females. If we lower the RSI cut-point for females to 1.7, a similar risk of mobility impairment (9%) to that estimated by the SMI equation (10%) was predicted (data not shown). However, when we used 1.7 as the RSI healthy cut-point on the scatterplot (Figure 3.2.(b)), we still did not find a PASE score cut-point since the RSI cut-point did not intersect the regression line.

In summary, it appears that the present cohort was somewhat healthier than those tested in the CHMS since all measures were similar or more favorable, especially for the males. The risk of mobility impairment was also lower in our cohort in comparison to population estimates. The reason why some of these measures are more favorable may be due to a higher accumulation of activity based on their volunteer work in comparison to other cohorts, as measured by the PASE.

3.5.5. The Importance of Moderate and Intense Activity in Older Adults

The American College of Sports Medicine position stand for Exercise and Physical Activity in Older Adults reports that although any amount and intensity of exercise will result in some gain in health benefits, additional benefits are gained with increasing intensity, duration and/or frequency (Chodzko-Zajko et al., 2009). In addition, other researchers report that moderate to high intensity activity is required to induce any significant benefit to physical health (Patterson & Warburton, 2010). The PASE attempts to assess moderate to high intensity activity in questions 4, 5, 6. When we plotted the PASE score from each of these questions against the health measures we found similarly weak or even weaker relationships (data not shown). We believe this is due to the vast majority of people in this cohort accumulating very little activity in

these intensity categories. Stronger relationships may result between PASE scores for questions 4,5,6 and health parameters if we collected data from adults who regularly engage in moderate and strenuous activities/exercise and exercises to specifically increase muscular strength and endurance.

4.5.6. *Limitations and Next Steps*

The main limitation of our study was that our cohort was relatively healthy. Future research should attempt to recruit adults who are in unfavorable categories of health and investigate the relationship between their activity level and the various health parameters, especially body composition and strength, which may provide stronger relationships between activity level and health. A large intervention study would be optimal to first quantify the amount of physical activity performed over a 7 day period and relate this amount to the participant's PASE score and health parameters. We would further test this relationship by increasing an individual's PASE score by increasing physical activity over a period of time (~12 wks) and measure the influence on the health parameters. This would theoretically provide a monitoring tool to advise adults on the amount of activity needed to move their physical measure to a more favorable health category.

The use of a physical activity monitoring tool which correlates well with actual physical activity and health parameters warrants additional research to determine and monitor whether older adults are achieving adequate physical activity for desirable physical parameters, and to increase awareness regarding the importance of physical activity in maintaining and/or increasing the quality of life. With the trend for decreasing physical activity with age and the increasing numbers of seniors, the need for such a measure is timely.

Research continues to examine the impact of nutrient intake on the health of older adults. The results from the SCREEN questionnaire demonstrated that the majority of these community-dwelling older adults were at risk of malnutrition due to their dietary behaviours. However, it is unknown as to which micronutrients may be contributing to this risk since we did not collect data specifically on dietary intake. Also, very little research has been collected on the oldest age category of the Dietary Reference Intakes, as those defined by adults greater than 70 years of age. For this reason, a future study should aim to determine 1) the micronutrient intake in this population, and 2) the relationship of particular micronutrients to physical parameters of health.

3.6. CONCLUSIONS

The PASE questionnaire cannot be used to accurately predict clinically healthy physical measures of body composition, cardiovascular and blood parameters, and flexibility and strength measures in a cohort of community-dwelling adults 60–88 yrs of age. Body composition measures and PASE score demonstrated the most promise in the development of PASE score cut-points. The only PASE score cut-points that could be approximated include WC for both males and females (using a WC cut-point of 99 cm) and WHtR for females.

3.7. ACKNOWLEDGEMENTS

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CHAPTER 4

NUTRIENT AND DIETARY SUPPLEMENT INTAKE AND MEASURES OF LEAN MASS, FAT FREE MASS INDEX AND STRENGTH IN COMMUNITY-DWELLING ADULTS 70 YEARS AND OLDER WITH HIGH SOCIOECONOMIC STATUS

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4.1. ABSTRACT

With age, physiological changes occur, with the most noticeable being the reduction in LM (skeletal muscle and bone) and the increase in FM. A low muscle mass, known as sarcopenia, and/or a high FM may result in decreased physical strength and mobility, and ultimately a decreased quality of life. These body composition shifts may be exacerbated by inadequate nutrient intake. Previous research has suggested that adults with a higher socioeconomic status (SES) typically select healthier food choices. However, it is unknown whether populations of older adults with higher SES experience nutrient inadequacies similar to those of the average Canadian older adult. In addition, volunteers typically recruited for aging research at the University of Guelph have high SES. Our aims were to: 1) measure the dietary intake and prevalence of multivitamin-multimineral (MVMM) and other supplement use; 2) determine if MVMM consumers have a healthier diet than non-users; 3) determine if relationships existed between dietary intake parameters (total energy intake, protein, calcium, vitamin (vit) D) and lean mass (LM), fat free mass index (FFMI; LM/ht^2), and combined handgrip strength (CGS). We estimated nutrient intake using a 3 day dietary record in 31 females and 31 males between the ages of 71-88 yr (77 ± 4.7). Bioelectrical impedance analysis estimated LM and CGS was measured with a hand-held dynamometer. The majority of males had inadequate dietary intakes from food for vit A (53%), D (90%) and E (90%), and for calcium (61%), magnesium (61%), and zinc (58%). For females, the majority had inadequate dietary intakes of vit D (84%) and E (84%), and for calcium (71%). MVMM's were used by 29% of males and 32% of females, rising to 52% and 61%; respectively, when examining all supplements. Supplement use had no effect on dietary intake from food, except where female supplement users had higher mean intakes of calcium than non-users. When supplement intake

was added to food intake values, participants attained adequate nutrient intake. Significant relationships existed between FFMI and protein for all participants, and total energy intake and vit D for females. LM was significantly correlated with total energy intake, protein, and vit D for females. A regression model using age, sex, BMI, and vit D best predicted LM ($Adj.R^2=0.825$). Vit D intake improved the model by ~2%. In conclusion, 1) older adults with higher SES have a high risk of nutrient inadequacies similar to published Canadian population data with a lower average SES; 2) older adults who take dietary supplements do not have higher nutrient intake from food; 3) adding vit D intake to a predictive equation to estimate a participant's LM provides a modest improvement.

4.2. INTRODUCTION

Nutrition is an important determinant of health in older adults. As humans age, they experience a decrease in caloric requirements while the need for protein (g/kg body mass) and the recommended dietary allowance (RDA) for micronutrients (e.g. vitamins (vit) and minerals) remain the same or increase (e.g. vit B-6, vit D, and calcium) (IOM, 2006; Wakimoto & Block, 200; Williamson, 1993). If nutritional requirements are not met through food consumption, dietary supplement use may be required to ensure that older adults meet their RDA (Murphy et al., 2007). Knowledge of nutrient intake from food and dietary supplements in the oldest age category of the dietary reference intakes (DRI's), defined as individuals >70 yrs of age, is growing but requires additional research (Wakimoto & Block, 2001; Wellman, 2010). Estimates of nutrient intake representative of the Canadian population have been collected in the Canadian Community Health Survey (CCHS; Health Canada, 2005). Inadequate dietary intake of vit A, C, D, E, and calcium, folic acid, potassium, and magnesium have been reported (Health Canada, 2005; 2012). This data reflects the average Canadian senior (≥ 65 yrs), with an annual income of \$31,600 (Statistics Canada, 2012). Research has demonstrated that higher socioeconomic status (SES; annual income and education level) is related to healthier food choices in adult populations (Darmon & Drewnowski, 2008). However, it is unknown whether populations of older adults with higher SES experience nutrient inadequacies similar to that of the average Canadian older adult. This is of interest since many of the participants volunteering for aging research at the University of Guelph (Krause et al., 2012; McIntosh et al., 2013) are from this demographic. For this reason, we have selected to examine a population of older adults residing in the Village by the Arboretum, an active adult lifestyle community in Guelph, Ontario.

Another area of expanding research in older adult populations is the relationship between nutrition and physical changes. One of the most noticeable physical changes is the reduction in lean body mass (skeletal muscle and bone) and the increase in FM (Rosenberg, 1989). A low muscle mass, known as sarcopenia, and/or a high FM may result in decreased physical strength and mobility. This may lead to physical disability and contribute to and exacerbate various chronic diseases (cardiovascular, cancers, diabetes, and osteoporosis) (Janssen et al., 2002; Rosenberg, 1989; WHO, 2003; 2013). Ultimately, low muscle mass results in a decreased quality of life (QOL), and an increased rate of transition from independent living to assisted living (Drewnowski & Evans, 2001). Quantifying and monitoring an individual's lean muscle mass may be an important strategy in order to implement therapies to prevent the reduction in QOL and loss of independence (Drewnowski & Evans, 2001). Various indices have been proposed to quantify the amount of lean muscle mass and estimate the threshold amount needed to support daily activities. One such index, the fat free mass index (FFMI; fat free mass (kg)/Ht(m)²) has been previously examined in the same population as this paper (McIntosh et al., 2013). In addition to FFMI, handgrip strength, which correlates well with overall physical strength, has been shown to be an important indicator of mobility and physical function (Rantanen et al., 1999). Research investigating the relationship between nutrient intake (prevalence of inadequate dietary intake from food, use of dietary supplements, etc.), lean muscle mass (e.g. FFMI) and strength (e.g. hand grip strength) in the DRI oldest age category is of importance to optimize QOL and independence in community-dwelling adults.

Seniors represent the fastest growing age cohort in Canada (Health Canada, 2013b), thus research into the nutrition and physical profile of diverse socioeconomic groups is essential to understand the needs of each group. Understanding these relationships is essential for the

management of the ongoing health of Canadian seniors. Therefore, the aims of this study were to: 1) measure the dietary intake and prevalence of multivitamin-multimineral (MVMM) and other supplement use; 2) determine if MVMM consumers have a healthier diet than non-users; 3) determine if relationships existed between dietary intake parameters (total energy intake, protein, calcium, vit D) and lean mass (LM), FFMI, and combined handgrip strength (CGS). To this end, we assessed the dietary intake and physical measures of LM and strength of 62 community-dwelling older adults >70 yrs of age with a high SES. A subset of this data was previously reported in a study that developed a predictive measurement tool to estimate normalized FFMI, a means of identifying sarcopenia, in community-dwelling older adults (McIntosh et al., 2013).

4.3. METHODS

4.3.1. Recruitment and Inclusion

We recruited 31 females and 31 males from the community of Guelph, Ontario, Canada. Adults who were ≥ 71 yrs and with good cognitive status, as determined by a score above 25 (out of a possible 30) on the Mini Mental State Exam were included (Folstein et al., 1975). Following ethics approval from the University of Guelph, both oral and written informed consent was obtained from all participants.

4.3.2. Physical Measures and Determining FFMI

The protocols outlined in the Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA) document for body mass (BM), height (Ht), and waist circumference (WC) were used in this study (CSEP, 2003). Ht was measured to the nearest 0.1 cm using a vertical metric wall tape and a horizontal flat edge. BM was measured to the nearest 0.1 kg on a calibrated digital scale. WC was measured to the nearest 0.5 cm, and was taken at the top of the iliac crests

using an anthropometric tape. A WC of <102 cm for males and <88 cm for females was considered healthy (Health Canada, 2003a). Body mass index (BMI) was calculated as BM/Ht^2 . A BMI of <25 kg/m^2 was considered healthy, 25 to 30 kg/m^2 was considered overweight, and >30 kg/m^2 was considered obese (Health Canada, 2003a).

Body composition of FM and fat-free mass or LM was estimated using Bioelectrical Impedance Analysis (BIA; model 1500, Bodystat, Douglas, Isle of Man, UK) as previously described (McIntosh et al., 2013). A FM of <30% for males and <42% for females was considered healthy (Bray, 1993). Healthy cut-points for LM were >70% for males and >58% for females. FFMI was calculated using fat free mass and standardizing for Ht (fat free mass (kg)/ Ht^2 (m^2)). Participants were classified as sarcopenic if possessing a FFMI less than 2 standard deviations below the normative value of a young adult reference population (Schutz et al., 2002). A participant was considered to have a normal muscle mass if possessing a value above the sarcopenia cut-off values of 16.3 kg/m^2 for males and 13.1 kg/m^2 for females (Schutz et al., 2002).

Isometric handgrip strength was measured using a digital hand-held dynamometer (Vernier; 60 Hz; Oregon, US). Three measurements per hand were taken, and the highest measurement for each hand was added together to achieve the CGS score. Since healthy CGS cut-points for adults >70 yrs of age have not be established, we used the healthy cut-point for adults 60-69 yrs. A CGS of ≥ 73 kg for males and ≥ 41 kg was considered healthy (CSEP, 2003).

4.3.3. Questionnaires

The participants completed a demographic and a health behaviour and conditions questionnaire to collect information on participant education, marital status, and living arrangements. The participants also completed the Physical Activity Scale for the Elderly

(PASE) questionnaire, designed to measure the amount of physical activity completed in the past 7 days, with higher scores indicative of greater amounts of daily activity (Washburn et al., 1999).

4.3.4. *Assessment of Energy and Nutrient Intake*

The participants recorded their 24 hr food and beverage consumption using a multiple-day food record (version 3; Fred Hutchinson, WA, US) on three consecutive days, which included two weekdays and one weekend day. Detailed training was provided to the participants to ensure accurate recording of dietary intake. The dietary information was then entered into the Food Processor SQL-ESHA database version 10.8.0 (ESHA Research, Salem, OR, US). The brand of MVMM was entered into the participant's nutrient intake (Centrum Silver, Usana, Life Spectrum, One A Day). If the brand was not specified, intake from MVMM supplements was calculated using a default nutrient profile based on Centrum Silver (Pfizer Consumer Healthcare, Mississauga, ON, CA), since this was the most commonly used MVMM among the current cohort.

4.3.5. *Estimating Prevalence of Inadequacy*

The estimated average requirement (EAR) is the daily intake amount of a nutrient estimated to meet the needs of half of the healthy individuals in an age and sex group (IOM, 2000). The prevalence of inadequate dietary intake for nutrients was estimated as the proportion of respondents with intakes below the EAR of nutrients for which the EAR has been established (IOM, 2000). The EAR cut-point method was used to determine the proportion of the population with inadequate intake (IOM, 2000). The tolerable upper limit (UL) is the highest recommended daily intake level of a nutrient likely to pose no risk of adverse health effects, and was used to assess the potential risk of excessive intake.

4.3.6. Statistical Analysis

Data were reported as mean \pm standard error ($M \pm SE$), unless indicated otherwise. Non-normal data was log transformed; however, since transformations to normalize skewed distributions did not generally change the inferences, the untransformed results were reported. Independent samples *t*-tests were used to determine whether significant relationships existed between nutrient intake from food for supplement users and supplement non-users. Pearson's bivariate correlations were implemented to assess the relationship between dietary nutrient status and LM, FFMI, and CGS. If significant relationships were found, stepwise multivariable linear regressions examined the combination of the nutrients that could significantly predict LM, FFMI, and CGS after controlling for predictor variables (sex, age, BMI). The residuals of the final regression models were normally distributed (Shapiro-Wilk test) and the variance inflation factors (VIF) of each variable was less than 1.2. All statistics were computed using SPSS Statistics 20.0.1 for Windows (SPSS, Chicago, IL, US). Statistical significance was accepted as p (2-tailed) < 0.05 for all tests unless otherwise indicated.

4.4. RESULTS

4.4.1. Participant Characteristics

The mean age of the participants was 77 ± 4.7 yrs (4.7) (Table 4.1.). The majority of the participants completed post-secondary education (69%), were married (81%), and lived with others (86%). The mean BMIs were close to 25 (Table 4.1.), however, 16 of 31 males and 14 of 31 females fell in the overweight category. Similarly, the mean WC for males was in the healthy range but 10 of 31 men had unhealthy values. For females, the mean WC was above the healthy cut-point, with 16 of 31 having an unhealthy WC value. Research has suggested that the healthy

WC cut-off of 88 cm may be too low for older female adults, and may potentially be increased to a cut-off of 99 cm (Heim et al., 2011). This higher cut-off is associated with a high risk of adverse health outcomes (pain, mobility limitations, incontinence, knee osteoarthritis, cardiovascular disease, and diabetes) (Heim et al., 2011). If 99 cm is used as the healthy cut-point, the mean WC is in the healthy range and only 4 of 31 females have unhealthy values.

Total energy intake for males was indicative of a low to moderate level of daily activity, and for females implied an active lifestyle (Health Canada, 2011). The mean physical activity level of our cohort, as measured by the PASE score (133.7 males; 138.0 females) (Table 4.1.), was far above the normative mean, stratified by age and sex (102.4 males, 62.3 females) (Washburn et al., 1999). In fact, only 8 males and 6 females were below the normative cut-off values for physical activity level. The average CGS of the males was below the healthy cut-point (≥ 73 kg), and only 13 of 31 males scored above this value. The mean value for females was above the healthy cut-point, with 26 of 31 having a healthy CGS. The mean FFMI for both males and females were above the sarcopenia cut-off values of 16.3 kg/m^2 for males and 13.1 kg/m^2 (Schutz et al., 2002). Using these values, only 3 males and 3 females were considered sarcopenic.

In comparison to similar aged cohorts (Chad et al., 2005; Logan et al., 2013a) (Table 4.1.), the present cohort has a higher education level and a greater percentage of married individuals (Table 4.1.). The present cohort, in comparison to Logan et al. (2013a) had mean values for the males that were higher for LM and lower for BMI, WC, and CGS. For the females, the present cohort had mean values that were similar for LM, lower for BMI and WC, and higher for CGS. In addition, the current cohort had a similar activity level as measured by the PASE score as the Chad et al. (2007) cohort and PEOPL cohort (Logan et al., 2013a).

Table 4.1. Participant characteristics of male and female community-dwelling adults in comparison to values of similar aged cohorts.

Characteristics	All (n=62)	Chad et al. 2007 (n = 351, 77.2 % female)	Male (n=31)	PEOPL data (2013) Male (n = 72)	Female (n=31)	PEOPL data (2013) Female (n = 90)
Age (yrs)	77 (4.7)	65 - 79	79 (4.6)	77 (3.2)	76 (4.5)	77 (4.3)
Mini Mental State Exam (/30)	29 (1.0)	ND	28 (1.1)	ND	29 (1.0)	ND
Education (Highest Level Completed)						
Elementary	1.6 (1)	15.7 (55)	3.2 (1)	19.4 (14)	0	21.2 (19)
Secondary	29.0 (18)	38.2 (134)+	16.1 (5)	33.3 (24)	41.9 (13)	43.3 (39)
Post-Secondary	69.3 (43)	43.6 (153)+	80.6 (25)	33.3 (24)	58.1 (18)	34.4 (31)
Missing	0	2.6 (9)	0	13.9 (10)	0	1.1 (1)
Marital Status						
Married	80.6 (50)	41.9 (147)	83.9 (26)	86.1 (62)	77.4 (24)	47.8 (43)
Widowed	8.1 (5)	39.0 (137)	3.2 (1)	9.7 (7)	12.9 (4)	42.2 (38)
Separated/Divorced	9.7 (6)	7.7 (27)	9.7 (3)	1.4 (1)	9.7 (3)	2.2 (2)
Never Married	1.6 (1)	10.8 (38)	3.2 (1)	1.4 (1)	0	7.8 (7)
Missing	0	0.6 (2)	0	0	0	0
Living Arrangements						
Live Alone	14.5 (9)	38.5 (135)	6.5 (2)	15.3 (11)	22.5 (7)	50.0 (45)
Live With Others	85.5 (53)	37.6 (132)	93.5 (29)	84.7 (61)	77.4 (24)	48.9 (44)
Missing	0	23.9 (84)	0	0	0	1.1 (1)
Total Energy Intake (kcal/d)	2088 (624.7)	ND	2173.8 (627.5)	ND	2002.6 (617.9)	ND
PASE Score	135.9 (62.1)	128.2 (65.7)	133.7 (52.5)	162.5 (71.9)	138.0 (71.3)	119.3 (47.3)
Height (cm)	167.7 (10.0)	ND	175.5 (5.4)	173.2 (7.0)	159.9 (6.8)	160.6 (6.6)
Body Mass (kg)	71.4 (13.6)	ND	79.9 (11.1)	83.3 (12.0)	63.0 (10.3)	67.4 (11.7)
Lean Mass (%)	66.0 (8.0)	ND	72.8 (4.0)	69.9 (3.5)	59.4 (4.4)	59.3 (8.0)
Body Mass Index (kg/m²)	25.4 (3.7)	ND	25.8 (3.5)	27.8 (3.4)	24.9 (3.8)	26.1 (4.1)
Waist Circumference (cm)	93.4 (10.3)	ND	97.8 (9.3)	101.4 (8.9)	89.1 (9.5)	101.4 (8.9)
Combined Hand Grip Strength (kg)	59.1 (16.3)	ND	70.0 (16.9)	75.7 (15.6)	51.5 (12.1)	44.1 (9.0)
Fat Free Mass Index (FFMI)	16.65 (2.72)	ND	18.8 (1.8)	18.5 (4.4)	14.5 (1.5)	14.4 (4.2)

Data are means and standard deviations or percentage of individuals with number of participants in

brackets. ⁺Completed some or all secondary and post-secondary education; ND = not determined.

PEOPL data from Logan et al. (2013a).

4.4.2. Prevalence of Supplement Use

Dietary supplement use was 56% (52% males, 61% females), of which 31% (29% males, 32% females) took a MVMM (Table 4.2.). Vit D was the most commonly consumed supplement (18%), followed by vit C (16%), calcium (15%) and B-complex (15%), omega-3 fatty acids (13%), magnesium (8%), and vit E (7%). More females (61%) consumed supplements than males (52%), except vit E and omega-3 where usage was equal between the sexes. Males and females also consumed equal amounts of ‘other’ supplements (13%), which included supplements that are not required in the diet (no current DRI) (saw palmetto, probiotics, methylsulfonylmethane, glucosamine, and coenzyme Q10) (Table 4.2.).

4.4.3. Nutrient Adequacy

For the total cohort, the majority of males had insufficient intake of vit A (53%), D (90%), E (90%), and calcium (61%), magnesium (61%), and zinc (58%) from food alone (Table 4.3.). When the males were separated into supplement users and non-users, there were no significant differences in mean intake or in mean intake below the EAR from food alone. However, for most nutrients (with the exception of calcium, magnesium, and folate) a greater percentage of supplement users were below the EAR than non-users (Table 4.3.). When dietary supplement values were added to intake from food alone, all supplement users met their EAR value.

For the females, the majority of the cohort had insufficient intake of vit D (84%) and E (84%), and calcium (71%) (Table 4.4.). When the females were separated into supplement users and non-users, there was a significant difference in mean intake for calcium, with the supplement users consuming higher mean intakes from food (965 ± 86) than the non-users (749 ± 66).

However, there were no significant differences in mean intake amount below the EAR from food alone (Table 4.4.). When dietary supplement values were added to intake from food alone, all supplement users met their EAR value.

Table 4.2. Prevalence of dietary supplement use for male and female community-dwelling older adults. Vitamin and mineral supplement intake is independent of daily multivitamin-multimineral (MVMM) intake.

Dietary Supplement	All Participants (n = 62)	Male (n = 31)	Female (n = 31)
Supplement Use	56.4 (35)	51.6 (16)	61.3 (19)
MVMM	30.6 (19)	29.0 (9)	32.3 (10)
B complex	14.5 (9)	12.9 (4)	16.1 (5)
B complex + MVMM	3.2 (2)	0	6.5 (2)
Vitamin C	16.1 (10)	12.9 (4)	19.4 (6)
Vitamin C + MVMM	9.7 (6)	6.5 (2)	12.9 (4)
Vitamin D	17.7 (11)	12.9 (4)	22.5 (7)
Vitamin D + MVMM	16.1 (3)	3.2 (1)	6.5 (2)
Vitamin E	6.5 (4)	6.5 (2)	6.5 (2)
Vitamin E + MVMM	0	0	0
Calcium	14.5 (9)	12.9 (4)	16.1 (5)
Calcium + MVMM	3.2 (2)	3.2 (1)	3.2 (1)
Magnesium	4.8 (3)	3.2 (1)	12.9 (4)
Magnesium + MVMM	1.6 (1)	0	3.2 (1)
Omega-3 Fish Oil	12.9 (8)	12.9 (4)	12.9 (4)
Other	12.9 (8)	12.9 (4)	12.9 (4)

Data are percentage of individuals with numbers in brackets. The ‘other’ category refers to botanical supplements and supplements without daily recommended intake (DRI) values.

The nutrient intake from food alone exceeded the tolerable upper limit (UL) for vit B-3 (10%), folate (6%), and magnesium (39%) for males (Table 4.3.); and vit B-3 (3%) and magnesium (29%) for females (Table 4.4.). When considering nutrient intake from both food

and supplement use, the proportion of the cohort above the UL increased greatly for niacin (46% males, 85% females), folate (15% males and females), and magnesium (62% males, 54% females) (Tables 4.3. and 4.4.). In addition, sodium intake was high in this cohort, with 55% of males and 29% of females exceeding the UL of 2300 mg/d (data not shown).

In comparison to Canadian population data (Health Canada, 2005) the current cohort had higher mean intakes of vit C, calcium, magnesium, and total energy and carbohydrate intake (Tables 4.3. and 4.4.). For females, the present cohort had higher mean intakes of vit A, B-2, B-6, B-12, and folate, similar mean intakes of vit B-1 and D, and lower mean intakes for vit B-3 and zinc with respect to the CCHS female data (Table 4.4.). In contrast to the females, the current male cohort had more nutrients with lower mean intake amounts for vit A, B-2, B-3, B-12, D, and folate and zinc, and similar intakes of vit B-2 and B-6 to the CCHS males (Table 4.3.).

A smaller proportion of the current cohort had inadequate intake as determined by a lower percentage below the EAR for vit A, B-6, and folate (females only), magnesium, and carbohydrate in comparison to the CCHS data (Table 4.3. and 4.4.). A greater percentage of the current cohort was below the EAR for vit B-3, B-12 (females only), C (females only), and folate (males only) and zinc (males only) in comparison to the CCHS data. A similar risk of inadequate intake of vit C was observed for both cohorts (Table 4.3.). Intake above the UL for many micronutrients with established ULs were not reported in the CCHS data, making it difficult to compare the present cohort's data. However, for most nutrients, none of the population or a very small percentage was above the UL for the nutrient in question in the CCHS and for those analyzed, our data was similar.

Table 4.3. Male nutrient intake and percent below the estimated average requirement (EAR) and above the tolerable upper limit (UL) for the current cohort and the CHSS (n= 734) cohort.

Nutrient Intake	n	M ± SE ^a	CHMS, M ± SE ^a	Median	25 th , 75 th Quartiles	EAR	% < EAR	CCHS, % < EAR	UL	% > UL	CCHS, % > UL
Vitamin A RAE^b (µ/d)											
All participants: Food only	31	577 ± 45	655 ± 54	538	387, 774	650	52	61	3000	0	ND
Non-users: Food only	22	597 ± 57		570	378, 807		56				
Users: Food only	9	529 ± 73		485	248, 739		0			0	
Users: Food + Supplements	9	1362 ± 55		1319	1235, 1511						
Thiamine (B₁) (mg/d)											
All participants: Food only	31	1.6 ± 0.1	1.7 ± 0.03	1.4	1.1, 2.1	1.0	16	ND	ND		
Non-users: Food only	18	1.6 ± 0.2		1.4	1.1, 2.3		11				
Users: Food only	13	1.5 ± 0.2		1.4	1.0, 1.9		23				
Users: Food + Supplements	13	3.0 ± 0.2		2.9	2.5, 3.4		0				
Riboflavin (B₂) (mg/d)											
All participants: Food only	31	1.8 ± 0.1	1.8 ± 0.04	1.7	1.3, 2.0	1.1	6	12	ND		
Non-users: Food only	18	1.9 ± 0.2		1.8	1.5, 2.6		6 ^d				
Users: Food only	13	1.5 ± 0.1		1.4	1.3, 1.8		8 ^d				
Users: Food + Supplements	13	3.6 ± 0.2		3.7	3.0, 4.0		0				
Niacin (B₃) (mg/d)											
All participants: Food only	31	19 ± 2	34 ± 0.8	17	14, 22	12	16	<3	35	10	ND
Non-users: Food only	18	22 ± 2		19	16, 26		11			23	
Users: Food only	13	17 ± 1		15	13, 21		23			0	
Users: Food + Supplements	13	37 ± 1		35	33, 41		0			46	
Vitamin B₆ (mg/d)											
All participants: Food only	31	1.8 ± 0.1	1.8 ± 0.04	1.8	1.2, 2.3	1.4	35	21	100	0	0
Non-users: Food only	18	1.9 ± 0.2		1.8	1.3, 2.5		28				
Users: Food only	13	1.6 ± 0.2		1.6	1.0, 2.0		46				
Users: Food + Supplements	13	4.6 ± 0.2		4.6	4.0, 5.0		0			0	
Vitamin B₁₂ (µg/d)											
All participants: Food only	31	3.1 ± 0.3	4.2 ± 0.4	2.8	2.0, 3.6	2.0	23	ND	ND		
Non-users: Food only	18	3.5 ± 0.5		2.9	1.9, 4.6		28				
Users: Food only	13	2.7 ± 0.3		2.8	2.3, 3.5		15				
Users: Food + Supplements	13	27.6 ± 0.3		27.8	27.3, 28.5		0				
Folate DFE^c (µ/d)											
All participants: Food only	31	379 ± 34	421 ± 15	329	235, 520	320	42	29	1000	6	ND
Non-users: Food only	18	381 ± 48		314	239, 497		44			11	
Users: Food only	13	376 ± 49		365	231, 549		38			0	
Users: Food + Supplements	13	788 ± 52		797	635, 959		0			15	
Vitamin C (mg/d)											
All participants: Food only	31	126 ± 12	120 ± 5	118	79, 157	75	26	27	2000	0	0
Non-users: Food only	19	129 ± 14		136	79, 157		21				
Users: Food only	12	124 ± 21		113	68, 176		25				
Users: Food + Supplements	12	383 ± 80**		225	158, 676		0			0	
Vitamin D (µ/d)^e											
All participants: Food only	31	4 ± 1	6 ± 0.4	4	1, 6	10	90	~90 ^f	100	0	<3
Non-users: Food only	19	4 ± 1		4	1, 6		89				
Users: Food only	12	4 ± 2		4	2, 7		92				
Users: Food + Supplements	12	18 ± 2		15	12, 24		0			0	
Vitamin E (mg/d)											
All participants: Food only	31	6 ± 1	ND	5	3, 9	12	90	ND	1000	0	ND
Non-users: Food only	20	6 ± 1		4	3, 9		90				
Users: Food only	11	7 ± 1		7	5, 9		91				

Users: Food + Supplements	11	37 ± 1		37	34, 39		0			0	
Calcium (mg/d)											
All participants: Food only	31	934 ± 73	692 ± 21	845	638, 1089	1000	61	80	2000	0	0
Non-users: Food only	19	916 ±		780	612, 1076		63				
Users: Food only	13	110		968	740, 1213		54				
Users: Food + Supplements	13	958 ± 83		1198	928, 1457		0			0	
		1194 ± 80									
Magnesium (mg/d)											
All participants: Food only	31	350 ± 26	305 ± 7	324	258, 434	350	61	73	350	39	ND
Non-users: Food only	21	360 ± 35		324	275, 434		62			38	
Users: Food only	10	330 ± 36		312	240, 417		60			40	
Users: Food + Supplements	10	424 ± 38		412	336, 455		0			62	
Zinc (mg/d)											
All participants: Food only	31	8.7 ± 0.6	10.2 ±	8.4	6.4, 10.1	9.4	58	41	40	0	0
Non-users: Food only	22	9.0 ± 0.9	0.3	8.5	6.5, 10.9		55				
Users: Food only	9	8.1 ± 0.6		8.0	6.3, 9.8		67				
Users: Food + Supplements	9	23.1 ± 0.6		23.0	21.3, 24.8		0			0	
Total Energy Intake (kcal/d)											
All participants	31	2174 ±	1774 ±	2094	1657,	N/A	ND	ND	ND		
Non-users	22	113	36	2052	2650						
Users	9	2097 ± 140		2195	1570, 2588						
		2361 ± 179			1916, 2720						
Protein (g/kg/d)											
All participants	31	1.10 ±	ND	0.92	0.78, 1.31	0.66	10	ND	ND		
Non-users	22	0.08		0.92	0.74, 1.30		14				
Users	9	1.11 ± 0.11		1.04	0.82, 1.33		0				
		1.06 ± 0.08									
Carbohydrate (digestible) (g/d)											
All participants	31	290 ± 19	230 ± 5	266	195, 395	100	0	<3	ND		
Non-users	22	279 ± 24		261	185, 370						
Users	9	319 ± 30		285	260, 404						

Data are means with standard errors and selected percentiles. ^a SE= Standard error; ^b RAE= retinol activity equivalents; ^c DFE =dietary folate equivalents; ^d Cannot be determined because the sum of the case weights is ≤ 1.0; ^e Vitamin D intake cannot stand alone and consideration for serum 25 OHD levels must be given; ^f Estimates provided only; ND = not determined. * Significant difference between users and non-users for food alone ($p<0.05$); ** Significant difference between users and non-users for food and supplement intake ($p<0.05$). CHSS cohort (Health Canada, 2005; 2012).

Table 4.4. Female nutrient intake and percent below the estimated average requirement (EAR) and above the tolerable upper limit (UL) for the current cohort and the CCHS cohort (n = 1345).

Nutrient Status	n	M ± SE ^a	CHMS, M ± SE ^a	Median	25 th , 75 th Quartiles	EAR	% < EAR	CCHS, % < EAR	UL	% > UL	CCHS, % > UL
Vitamin A RAE^b (µ/d)											
All participants: Food only	31	641 ± 56	611 ± 30	595	402, 797	500	42	40	3000	0	ND
Non-users: Food only	20	610 ± 68		546	394, 743		50				
Users: Food only	10	696 ± 58		742	429, 970		30			0	
Users: Food + Supplements	10	1499 ± 116**		1409	1252, 1479		0				
Thiamine (B₁) (mg/d)											
All participants: Food only	31	1.4 ± 0.1	1.4 ± 0.03	1.5	1.0, 1.7	0.9	23	ND	ND		
Non-users: Food only	18	1.4 ± 0.1		1.3	0.8, 1.8		28				
Users: Food only	13	1.5 ± 0.2		1.5	1.2, 1.7		15				
Users: Food + Supplements	13	3.6 ± 0.5**		3.1	2.7, 3.9		0				
Riboflavin (B₂) (mg/d)											
All participants: Food only	31	1.7 ± 0.1	1.5 ± 0.03	1.7	1.1, 2.2	0.9	10	ND	ND		
Non-users: Food only	18	1.6 ± 0.2		1.5	1.1, 2.1		6 ^d				
Users: Food only	13	1.9 ± 0.2		2.1	1.1, 2.3		15				
Users: Food + Supplements	13	3.6 ± 0.2**		3.6	3.0, 3.8		0				
Niacin (B₃) (mg/d)											
All participants: Food only	31	19 ± 1	29 ± 0.7	19	15, 24	11	16	<3	35	3 ^d	ND
Non-users: Food only	18	19 ± 1		20	15, 24		11			0	
Users: Food only	13	19 ± 2		19	14, 25		23			8 ^d	
Users: Food + Supplements	13	43 ± 3**		41	35, 48		0			85	
Vitamin B₆ (mg/d)											
All participants: Food only	31	1.9 ± 0.1	1.5 ± 0.03	1.9	1.4, 2.5	1.3	19	36	100	0	0
Non-users: Food only	18	1.9 ± 0.2		1.9	1.3, 2.6		22				
Users: Food only	13	1.9 ± 0.2		2.0	1.4, 2.4		15				
Users: Food + Supplements	13	4.9 ± 0.2**		5.0	4.4, 5.4		0			0	
Vitamin B₁₂ (µ/d)											
All participants: Food only	31	3.4 ± 0.4	3.3 ± 0.3	2.9	1.3, 5.1	2.0	39	30	ND		
Non-users: Food only	18	3.1 ± 0.6		2.4	1.3, 4.9		50				
Users: Food only	13	3.7 ± 0.6		3.6	1.8, 5.2		23				
Users: Food + Supplements	13	29.4 ± 0.9**		29.1	27.0, 30.7		0				
Folate DFE^c (µ/d)											
All participants: Food only	31	440 ± 40	353 ± 8	410	249, 636	320	35	44	1000	0	ND
Non-users: Food only	18	487 ± 57		515	251, 671		33				
Users: Food only	13	380 ± 52		354	240, 510		38				
Users: Food + Supplements	13	751 ± 60**		728	609, 910		0			15	
Vitamin C (mg/d)											
All participants: Food only	31	129 ± 11	116 ± 4	122	88, 180	60	19	16	2000	0	0
Non-users: Food only	16	122 ± 16		128	60, 173		13				
Users: Food only	15	138 ± 15		120	91, 202		27				

Users: Food only	15	328 ± 59**		227	149, 613		0			0	
Users: Food + Supplements											
Vitamin D (µ/d)^e											
All participants: Food only	31	5 ± 1	5 ± 0.2	4	2, 9	10	84	~90 ^{f,g}	100	0	0
Non-users: Food only	17	5 ± 1		3	1, 8		80				
Users: Food only	15	6 ± 1		4	1, 9		88				
Users: Food + Supplements	15	22 ± 3**		20	13, 28		0			0	
Vitamin E (mg/d)											
All participants: Food only	31	8 ± 1	ND	7	4, 11	12	84	ND	1000	0	ND
Non-users: Food only	19	8 ± 1		7	3, 12		74				
Users: Food only	12	7 ± 1		7	4, 10		100				
Users: Food + Supplements	12	37 ± 1**		37	34, 40		0			0	
Calcium (mg/d)											
All participants: Food only	31	847 ± 56	678 ± 18	795	587, 1028	1000	71	87 ^f		0	<3
Non-users: Food only	17	749 ± 66		689	546, 953		88				
Users: Food only	14	*		1005	690, 1148		50			8 ^d	
Users: Food + Supplements	14	965 ± 86		1255	914, 1538		0				
Users: Food + Supplements		1366 ± 165**									
Magnesium (mg/d)											
All participants: Food only	31	310 ± 21	275 ± 6	311	218, 377	265	42	52	350	29	ND
Non-users: Food only	18	329 ± 27		314	226, 396		33			33	
Users: Food only	13	282 ± 33		260	214, 355		54			23	
Users: Food + Supplements	13	374 ± 35**		360	289, 455		0			54	
Zinc (mg/d)											
All participants: Food only	31	8.2 ± 0.6	8.5 ± 0.2	8.0	4.8, 10.4	6.8	35	32	40	0	0
Non-users: Food only	21	7.8 ± 0.7		7.9	4.8, 10.3		43				
Users: Food only	10	8.9 ± 1.2		8.1	6.3, 11.4		20			8 ^d	
Users: Food + Supplements	10	23.9 ± 1.2**		23.1	21.3, 26.4		0				
Total Energy Intake (kcal/d)											
All participants	31	2002 ± 111	1521 ± 24	1923	1568, 2248	ND			ND		
Non-users	21	1914 ± 124		2041	1547, 2141						
Users	10	2030 ± 175			1506, 2340						
Protein (g/kg/d)											
All participants	31	1.33 ± 0.07	ND	1.34	1.10, 1.52	0.66	3 ^d	ND	ND		
Non-users	21	1.28 ± 0.08		1.34	1.04, 1.52		5 ^d				
Users	10	1.44 ± 0.12		1.34	1.21, 1.87		0				
Carbohydrate (digestible) (g/d)											
All participants	31	251 ± 17	199 ± 3	223	187, 275	100	0	<3	ND		
Non-users	21	242 ± 21		209	186, 267						
Users	10	268 ± 29		252	211, 314						

Data are means with standard errors and selected percentiles. ^a SE = Standard error; ^b RAE = retinol

activity equivalents; ^c DFE = dietary folate equivalents; ^d Cannot be determined because the sum of the

case weights is ≤ 1.0 ; ^e Vitamin D intake cannot stand alone and consideration for serum 25 OHD levels must be given; ^f Estimates provided only; ND = not determined. * Significant difference between users and non-users for food alone ($p < 0.05$); ** Significant difference between users and non-users for food and supplement intake ($p < 0.05$). CCHS cohort (Health Canada, 2005, 2012).

4.4.4. Correlation of FFMI and Strength to Dietary Intake

Correlations of dietary intake and LM (kg), FFMI, and CGS (kg) were analyzed on the total cohort separated by sex (Table 4.6.). Since significant relationships existed between BMI and LM and CGS for both males and females, BMI was controlled for. Dietary intakes of protein (g/kg) ($r = -0.441$) were correlated with FFMI for males. For females, FFMI and LM were both correlated with total energy intake ($r = 0.306$, $r = 0.388$), protein (g) ($r = 0.341$, $r = 0.377$), and vit D ($r = 0.366$, $r = 0.383$); respectively (Table 4.5.). No nutrients were correlated with CGS for males and females.

4.4.5. Predictive Capacity of Dietary Intake and FFMI and LM

Regression models were attempted using the nutrients that were significantly correlated with LM and FFMI (Table 4.5.) while adjusting for sex (1 = male, 2 = female), age, and BMI (LM only). Vit D was the only nutrient that increased the predictive capacity of the models. For the first model (Table 4.6. (a)), age ($\beta = -0.247$) and sex ($\beta = -0.839$) explained 65% of the variance in FFMI (Adj. $R^2 = 0.646$). When vit D was added to the model, age ($\beta = -0.241$), sex ($\beta = -0.880$), and vit. D ($\beta = 0.178$) explained 67% of the variance (Adj. $R^2 = 0.672$) in FFMI (Table 4.6. (a)). For the second regression model, age ($\beta = -0.133$), sex ($\beta = -0.880$), and BMI ($\beta = -0.181$) explained 81% of the variance in LM (Adj. $R^2 = 0.810$). When vit. D was added to the model, age ($\beta = -0.129$), sex ($\beta = -0.912$), BMI ($\beta = 0.179$), and vit. D ($\beta = 0.132$) predicted 83%

of the variance in LM ($Adj. R^2 = 0.825$) (Table 4.6. (b)). Therefore, the incorporation of vit. D increased the predictive capacity of the models by 2%.

Table 4.5. Pearson product-moment correlations between nutrient intake and lean mass (LM; kg), fat free mass index (FFMI), and combined handgrip strength (CGS; kg) for male and female participants. For LM and CGS, Body mass index (BMI; kg/m^2) was controlled.

Nutrient	Males						Females					
	LM		FFMI		CGS		LM		FFMI		CGS	
	<i>r</i>	<i>p</i>										
Total Energy (kcal)	-0.143	0.221	-0.228	0.108	-0.118	0.137	0.388	0.016*	0.306	0.044*	0.005	0.489
Protein (g)	0.024	0.449	-0.179	0.167	-0.211	0.132	0.377	0.018*	0.341	0.028*	0.007	0.485
Protein (g/kg)	0.125	0.256	-0.441	0.006*	0.154	0.208	0.209	0.130	0.144	0.216	0.018	0.461
Vit D (mcg)	0.263	0.080	0.170	0.180	0.017	0.465	0.383	0.017*	0.366	0.020*	0.010	0.479
Calcium (mg)	-0.044	0.818	-0.251	0.175	0.040	0.419	0.113	0.272	0.012	0.475	-0.168	0.365

**p* (1-tailed) < 0.05.

Table 4.6. (a). Multivariate regression model combining age (yrs), sex (male = 1, female = 2), and vitamin D (mg), intake from food and supplements to predict fat free mass index (FFMI) (*n* = 62).

Predictor Variables	DF	Parameter Estimate	SE	β value	Pr > <i>t</i>	VIF	Adj. R^2
Intercept	1	33.999	3.571	0	<0.0001	0	
Age	1	-0.139	0.043	-0.241	<0.0001	1.072	
Sex	1	-4.726	0.415	-0.880	0.0020	1.128	
Vit D	1	0.045	0.019	-0.178	0.0210	1.063	0.672

DF = degrees of freedom; SE = standard error of the estimate; VIF = variance inflation factor; *Adj. R*² = adjusted *R*²; Pr > |*t*| = 2-tailed.

Table 4.6. (b). Multivariate regression model combining age (yrs), sex (male = 1, female = 2), body mass index (BMI; kg/m²), and vit D (mg) intake from food and supplements to predict lean mass (LM; kg) (*n* = 62).

Predictor Variables	DF	Parameter Estimate	SE	β value	Pr > t	VIF	Adj. R ²
Intercept	1	88.542	13.957	0	<0.0001	0	
Age	1	-0326	0.144	-0.129	0.0281	1.154	
Sex	1	-21.451	1.358	-0.912	<0.0001	1.177	
BMI	1	0.582	0.182	0.178	0.0021	1.098	
Vit D	1	0.145	0.060	0.132	0.0190	1.063	0.825

DF = degrees of freedom; SE = standard error of the estimate; VIF = variance inflation factor; Adj. R² = adjusted R²; Pr > |t| = 2-tailed.

4.5. DISCUSSION

The purpose of this study was to examine, in a cohort of community-dwelling adults 70 yrs of age and older with high SES, the dietary intake and risk of inadequate intake of nutrients from food alone. We also determined the prevalence of dietary supplement use and whether those that supplemented their diet consumed a healthier diet than those who were non-users. Finally, the relationships between nutrient intake and LM, FFMI, and CGS were investigated, since research has previously reported a decrease in lean muscle mass and strength with age (Rosenberg, 1989), and research is accumulating to support the role of diet in LM and strength.

4.5.1. Nutrient intake and Comparison to Other Research

The majority of males in the present cohort were at risk for inadequate intake (< EAR) from food alone of vit A (53%), D (90%), E (90%), and calcium (61%), magnesium (61%), and

zinc (58%); and the majority of females for vit D (84%) and E (84%) and calcium (71%). Previous research has indicated that individuals with a higher SES tend to select healthier food choices (Darmon & Drewnowski, 2008). However, the percentage at risk in this cohort was similar to nationally representative studies in Canada (CCHS) (Health Canada, 2005; 2012) for many of the nutrients examined. The present male cohort had a higher risk of inadequate intake of vit B-3 (16% vs. <3%), B-6 (35% vs. 21%), folate (42% vs. 29%), and zinc (58% vs. 41%), and a lower risk of inadequate intake of calcium (61% vs. 90%) and magnesium (61% vs. 73%) than the CCHS population. For females, the present cohort had a lower risk of inadequate intake of vit B-6 (19% vs. 36%) and calcium (71% vs. 91%) than the CCHS data (Health Canada, 2003a; 2012). Similar risks of inadequate intake for vit D were observed for both cohorts. Caution must be taken when interpreting inadequate intakes of vit D, since it can also be synthesized by the body from UV radiation. Although there appears to be a high prevalence of inadequate intake of vit D, widespread deficiency has not been shown to be present in the population (Langlois et al., 2010; Whiting et al., 2011). Finally, we were unable to compare our cohort values of vit E intake with those from the CCHS, since it was not analyzed for risk of inadequate intake. In general, we were surprised to find that this cohort with a high SES was at a similar nutrition risk as those from lower socioeconomic profiles.

4.5.2. *Dietary Supplement Use*

The prevalence of dietary supplement use in our cohort was 56%, with the most frequently reported supplement being a MVMM (31%). A greater percentage of females (61%) reported supplementing their diet than males (52%). Research collected from CCHS reported similar values, with 51% of adults >50 yrs of age taking supplements, and a greater percentage of females supplementing their diet than males (Xiaoyan et al., 2009). When the cohort was

separated into supplement users and non-users, both groups of males were found to consume similar diets, since there were no significant differences in mean intake values or risk of inadequate intakes. For females, supplement users consumed similar intakes of micronutrients from food, with the exception of calcium where a greater mean intake from food alone was consumed by supplement users than non-users. This is in contrast to numerous studies documenting that more nutritious diets are consumed by supplement users than non-users (Bailey et al., 2012; Ervin et al., 2002; Sebastian et al., 2007). The high educational level of the current cohort may be a potential reason for this discrepancy (Harrington et al., 2011; Herne, 1995), since nutrition experts have focused on educating Canadians to consume a diet rich in micronutrient-dense foods rather than relying on supplement intake for daily nutrition, with the exception of vit D and B-12 (Dieticians of Canada, 2010). Even in higher SES backgrounds, it appears to still be a challenge to achieve the EAR values for many nutrients in the oldest age category of the DRIs. This may be due to the decrease in caloric needs with age, or merely selecting foods with lower micronutrient profiles.

With the increased use of dietary supplements over the past decade, there is concern that supplement users may exceed the tolerable upper limit (UL) of nutrients. In the current study, the use of supplements led to intakes above the UL for niacin (46% males and 85% females), folate (15% males and females), and magnesium (62% males and 54% females). Previous studies have reported similar percentages, with the addition of intakes above the UL for vit A and iron (Murphy et al., 2007; Shakur et al., 2012). However, it has been recommended that caution must be taken when interpreting risk above the tolerable UL since these levels are based on limited research (Carriquiry & Camano-Garcia, 2006; IOM, 2000; 2006). Sodium consumption was also very high in this population, with 55% of males and 29% of females

consuming amounts above the UL (2300 mg/d). CCHS data has reported higher intakes, with 77% of males and 45% of females >70 yrs of age consuming amounts above the UL (Garriguet, 2007). Excessive intake of sodium above the UL has been implemented in hypertension, a major risk factor for cardiovascular disease, stroke, and renal disease (Barr, 2010).

4.5.3. Nutrient Intake and LM, FFMI, and CGS

When evaluating the relationships between nutrient status and LM and FFMI, higher total energy, protein, and vit D intake were correlated with greater LM and FFMI for females. For males, protein was the only nutrient correlated with FFMI, and none of the nutrients were correlated with LM. We did not find any significant relationships between nutrient intake and CGS for both males and females. Two regression equations were produced to predict LM and FFMI using dietary intake of vit D while accounting for age, sex, and BMI (LM only). The strongest model predicted LM and explained 83% of the variation within the cohort. Previous research has reported significant correlations between intake of protein and lean muscle mass, which is not surprising, given the necessity of amino acids for protein synthesis (Roubenoff & Castaneda, 2001). Inadequate intake of vit D is common in older adults, since this age group typically consumes lower amounts of vit D from dietary sources (reduced intake of milk with age), and few dietary sources of vit D exist. In addition, older adults experience a reduced cutaneous synthesis of vit D when exposed to ultraviolet B radiation, and have a decreased number of nuclear 1, 25 vit D receptors (VDR) in the muscle (Marian & Sacks, 2009). Skeletal muscle VDR may bind 1, 23-dihydroxyvitamin D (1, 25OHD₃), the active form of vit D and promote protein synthesis (Marian & Sacks, 2009). Research has demonstrated that VDR polymorphisms are associated with lower LM and strength (Houston et al., 2007; Scott et al., 2010; Szulc et al., 2004). Further, we found that vit D intake along with age and sex can predict

FFMI in the current cohort. However, we found no association between vit D status and CGS. In addition to protein and vit D, magnesium, selenium, and zinc intake were also positive predictors of FFMI for females (data not shown). Mechanisms by which these nutrients are associated with muscle mass have been suggested to be multifactorial, in that these nutrients mediate age-related hormonal or immunological changes that are involved in skeletal muscle anabolism (Roubenoff & Castaneda, 2001).

Since vit D is obtained in very small amounts in food and very few foods contain vit D, it is difficult to attain the RDA requirements from food alone without supplementation. In our cohort, the majority of males and females did not attain the EAR requirements through diet. Since we have found that low vit D intakes are related to low FFMI, it is important that older adults consume at least 10 mcg/d to meet the EAR, or more optimally, 20 mcg/d to meet the RDA (IOM, 2000).

In addition, more research is accumulating to suggest a beneficial role of omega-3 polyunsaturated fatty acid intake in the diet, specifically eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). We were interested to find that this population of high SES had very low intake (~230 mg/d) of EPA and DHA in comparison to dietary guideline amounts (500 mg/d) (Krause et al., 2000; Health Canada, 2009). Intakes of DHA and EPA have been reported to have far reaching benefits to older adult populations (cognition and cardiovascular health) (Balk et al., 2006), and research in younger adults has suggested benefits to metabolic rate and body composition (Couet et al., 1997; Noreen et al., 2010); benefits which clearly contribute to older adult health.

4.5.4. Future Studies

The influence of nutrition on physical parameters in older adults is best explored through intervention designs. Future studies could attempt to provide additional research into whether vit D supplementation in older adults with low vit. D serum levels results in an increase in muscle fibre area and overall muscle mass over a period of time. Limitations to the current study include the cross-sectional design, small sample size, and the use of self-reported dietary intake. Further, research should continue in the direction of nutritional strategies to support lean mass and strength in healthy, community-dwelling older adult populations.

4.6. CONCLUSION

In general, many older adults face the challenge of consuming fewer calories from food while the need for micronutrients remains the same or increases. For these reasons, consumption of micronutrient dense foods is essential, and if this cannot be achieved, the use of dietary supplements may be needed. In the current cohort, the majority of male participants consumed inadequate dietary intakes from food of vit A, D, E, and calcium, magnesium, and zinc. For females, these micronutrients included vit D and E, and calcium. When we examined the influence of supplement use on nutrient intake, supplement users did not consume more healthy diets than supplement non-users, with the exception of calcium for females. Further, we were unable to conclude that our cohort with higher socioeconomic status has an overall less risk of inadequate intake from food in comparison to data collected by the CHMS (Health Canada, 2005; 2012). However, it appears that higher socioeconomic status may be associated with less risk for inadequate intake of calcium and magnesium for males and calcium for females, but an increased risk of inadequate intake for vit B-3, B-6, folate, and zinc for males. Finally, a participant's age, sex, BMI, and vit D intake from food and supplements was used to

successfully predict FFMI. Understanding these relationships is essential for the management of the ongoing health of Canadian seniors.

4.7. ACKNOWLEDGEMENTS

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CHAPTER 5

OMEGA-3 FATTY ACID SUPPLEMENTATION FOR 12 WEEKS INCREASES RESTING AND EXERCISE METABOLIC RATE IN HEALTHY COMMUNITY- DWELLING OLDER MALES AND FEMALES

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5.1. ABSTRACT

The proportion of older adults in the population is increasing in Canada. With age, adults experience metabolic and physical changes which include an increase in resting heart rate and blood pressure, increased fat mass and decreased lean mass, and a decrease in resting metabolic rate and physical function. These changes predispose older adults to age-related diseases and functional impairment, ultimately resulting in an overall decrease in quality of life. Research has suggested that long chain omega-3 fatty acids (O3FA), found predominantly in fatty fish, may provide benefit to healthy older adults to reduce these changes. Therefore, the objective of this study was to evaluate the effect of fish oil (FO) supplementation in a cohort of healthy, community-dwelling older adults on 1) metabolic rate and substrate oxidation at rest and during exercise; 2) resting blood pressure and resting and exercise heart rates; 3) measures of body composition; 4) strength and physical function and, 5) blood measures of insulin, glucose, C-reactive protein, total cholesterol, and triglycerides. Forty-one (17 males, 24 females) older adults (67 ± 1 yrs) were recruited for this research and were randomly assigned to receive either FO (5 g/d; 2g EPA and 1 g DHA) or placebo (PL; olive oil, 3 g/d) for 12 wks. The physical and exercise metabolic measures were evaluated before and after 12 wks of supplementation, and the resting metabolic measures were taken before, midway (6 wks) and after 12 wks of supplementation.

In relation to baseline values, FO supplementation significantly increased resting metabolic rate by 24% in males and 16% in females, with the majority of the changes were present after 6 wks of supplementation. There were no changes in the PL group. Energy expenditure during exercise significantly increased by 11% in both the FO male and female groups, with no change in PL. FO intake significantly increased the rates of fat oxidation during

rest (64% males, 23% females) and exercise (47% males, 33% females) with no change in the PL group. The FO consumption also significantly reduced diastolic blood pressure (8% in males), and lowered triglyceride levels by 32% for the males and 23% for the females. Finally, a significant increase in lean mass (4%) and in functional capacity (7%) was observed in the females. In conclusion, O3FAs found in FO may be a strategy to improve age-related metabolic and physical changes in healthy older adults.

5.2. INTRODUCTION

The proportion of seniors in Canada is predicted to increase from 13% of the total population in 2005 to 25% in 2036 (Statistics Canada, 2006). With age, adults experience metabolic and physical changes, including an increase in heart rate, blood pressure, fat body mass, and a decrease in resting metabolic rate (RMR), lean body mass (LM), and physical function (Evans & Campbell, 1993; Lakatta et al, 1987). These changes predispose older adults to age-related diseases and functional impairment, ultimately resulting in an overall decrease in quality of life (QOL). There are several strategies to maintain the health and independence of older adults, including increasing cognitive and physical activity, exercise, as well as optimizing nutrition (Drewnowski & Evans, 2001; Williams & Kemper, 2010). We are interested in the relationship between nutrition and metabolic and physical health in community-dwelling older adults.

A family of nutrients that has gained attention are the long-chain omega-3 fatty acids (O3FAs); specifically, eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3). Since the body can only synthesize limited amounts of EPA and DHA from alpha-linolenic acid (C18: 3n-3), these fatty acids must be obtained from the diet or through supplementation (Muskiet et al., 2004). The main dietary source of EPA and DHA is seafood, with the highest concentrations found in fatty fish. The American Heart Association (AHA) and Health Canada recommend that adults consume 500 mg/d (~2 servings/wk or ~8 oz of fish/wk) of EPA and DHA (Krause et al., 2000; Health Canada, 2009). However, the mean intake in Western society is ~135 mg/d (~2 servings of fish/mo) (Harris, 2009). Research in our laboratory has observed low intakes of O3FAs even in affluent populations (~230 mg/d) (Logan

et al., 2013b) who have been previously reported to select healthier foods (Darmon & Drewnowski, 2008).

The benefits of O3FAs are far reaching due to their integration into cell membranes. The current dietary recommendations have been developed on the premise of reducing the risk factors associated with cardiovascular disease (Krause et al, 2000; Balk et al., 2006), with the positive health benefits often seen with doses higher (3-4 g/d) than the AHA recommendations. Decreases in resting blood pressure and heart rate (Borghi & Cicero, 2007; De Rosa, 2012; Geleijnse et al., 2002) and in the blood lipid profile (triglyceride, total cholesterol, LDL-cholesterol) (Balk et al., 2006; Kris-Etherton et al., 2002) have been extensively researched in populations with disease or at high risk of disease.

With increasing age, research has documented a decrease in RMR and the shift in body composition from a profile of greater LM to one of decreased LM and increased adiposity with aging (Evans & Campbell, 1993; Visser, 2012). The decrease in RMR and LM begin around the 3rd decade of life and result in declines of ~1-2% per decade for RMR (Vaughan, 1991) and ~0.26 to 0.56% per annum for LM (Visser, 2012). The decline in RMR and LM are speculated to be due to numerous factors, which include declining physical activity and nutrient intake, such as insufficient protein intake (Campbell et al., 2001).

Skeletal muscle is the largest mass in the body and is responsible for ~20% of the metabolic rate at rest and up to ~80% to support the contracting muscle during exercise (Zurlo et al., 1990). Research has suggested that O3FA intake, particularly EPA and DHA may increase metabolic rate during rest and exercise, and substrate oxidation to favour a greater usage of fat. Although not of significance, research in our laboratory has demonstrated a trend in this direction after 12 wks of FO supplementation in healthy young adults (Gerling & Spriet,

unpublished). Research in other labs has reported similar effects (Couet et al., 1997; Noreen et al., 2010), although there is currently no research available on the effects of supplementation in healthy older adult populations.

The metabolic rate during exercise is a good representation of what is occurring in the muscle, since the contracting muscle is the predominant source of oxygen consumption. Recently, Gerling & Spriet (unpublished) demonstrated for the first time, that EPA and DHA intake resulted in the incorporation of these fatty acids into the sarcolemmal and the mitochondria (mt) membranes in human skeletal muscle, but this did not translate to an increase in whole body oxygen consumption and energy expenditure. However, it may be the case that this was not observed since the participants were young and healthy, and we may observe the proposed whole body effects in a population who have consumed very low intakes of EPA and DHA over a life time.

Mechanisms whereby EPA and DHA may affect energy metabolism are likely to be multifactorial and involve their ability to incorporate into the cell membrane and regulate cellular processes by altering gene expression, mainly through acting as a ligand for peroxisome proliferator-activated receptors (PPARs) (Seo et al., 2005). PPARs play an important role in energy homeostasis through regulating a wide array of genes involved in glucose and lipid metabolism (Kota et al., 2005).

The potential for O3FAs to increase metabolic rate, promote fat oxidation, and positively influence body composition may be a strategy for older adults. Low muscle mass and a high fat mass are associated not only with increased risk of many age-related disease processes, but also with mobility impairment (Drewnowski & Evans, 2001; Rosenberg, 1989). The physical function of older adults is not only influenced by declining RMR and body composition changes

but also by age-related neuronal changes. These neuronal changes decrease the velocity of axonal conduction, the ability of the muscle to generate torque, and the rate at which the torque is developed (Hughes et al., 2001). It has been reported that O3FAs may benefit nerve health. Cohort research in adults (n=827, 53.6% female, 68.2 ± 2.5 yrs) reported the association between low DHA intake and accelerated decline of peripheral nerve function (conduction and generation of action potentials) over a 3 yr follow-up period (Lauretani et al., 2007). Another study reported the association between high fish intake and greater handgrip strength in older adults (n=2983, 47.5% females, 66.1 ± 2.8 yrs) (Robinson et al., 2008). Increases have also been reported in older women (n=45, 64 ± 1.4 yrs) after a 90 d exercise training protocol where greater strength and functional capacity was evident in the FO group (2 g/d; 0.4 g EPA, 0.3 g DHA) in comparison to those not receiving supplementation (Rodacki et al., 2012). However, the effect of EPA and DHA intake on physical strength and functional capacity independent of exercise is currently unknown.

Whether these benefits occur in relatively healthy (no medication use or very low dose medications for blood pressure, cholesterol, arthritis, asthma) older adults who consume low dietary O3FAs is currently unknown. For these reasons, we investigated the effect of dietary intake of EPA (2 g/d) and DHA (1g/d) via FO supplementation for a 12 wk period on metabolic and physical health parameters of community-dwelling older adults. We hypothesized that FO supplementation would result in 1) an increase in metabolic rate and a greater reliance on fat oxidation for energy both at rest and during exercise; 2) a decrease in resting blood pressure and resting and exercise heart rates; 3) a decrease in adiposity and an increase in lean body mass; 4) an increase in handgrip strength and physical function, and; 5) more healthy blood measures of cholesterol and triglycerides. A placebo (PL) group supplemented with 3 g/d of olive oil was

included to reduce the effects of confounding variables, such as seasonal variations in diet and exercise.

5.3. METHODS

5.3.1. Recruitment and Inclusion

Forty-three adults (17 males and 26 females) between the ages of 60-76 yrs (males = 68 ± 1 ; females = 66 ± 1) were recruited from the community of Guelph (Guelph, ON, CA). Adults who met the following inclusion criteria were included in the study (1) between the ages of 60 to 74 yrs; (2) good cognitive status, as determined by a score above 25 (out of 30) on the Mini Mental State Exam (Folstein et al., 1975); (3) consumed one meal or less of fish/wk and did not take a omega-3 supplement; (4) took no prescription medications or very low dose medications (hypertension, hypercholesterolemia, hormonal); and (5) absence of any self-reported medical diagnoses that entailed functional impairment (inability to walk or engage in a 30 min cycling bout). Following Research Ethics Board approval from the University of Guelph, both oral and written informed consent was obtained from all participants. Consent was also attained from the participant's medical practitioner. For the study duration, participants were instructed to maintain their current diet and physical exercise regime. Forty-one adults completed the study, as two of the females dropped out prior to supplementing, due to difficulty with the time commitment and personal issues with the metabolic and blood measures.

5.3.2. Experimental Protocol

After screening and recruitment, the participants reported to the laboratory on 7 separate occasions over a 12 wk period. Prior to all visits, participants were instructed to abstain from athletic activities and consume a mutually agreed on 'normal' diet [~ 50 E% from CHO, ~ 30 E%

from fat, and ~20 E% from protein] on the preceding day. During the first visit, participants completed the PASE questionnaire and the Rand Short Form-36 (SF-36) Health Survey. Anthropometric (height (Ht), body mass (BM), waist circumference (WC), body composition), cardiovascular (resting heart rate (RHR) and blood pressure) and blood (fasting insulin, glucose, c-reactive protein, cholesterol, triglycerides), strength (handgrip strength) and physical capacity (Berg Balance, Dynamic Index, Timed Get Up and Go (TUG), and 30-Second Chair Stand (30-SCS) test were measured. Participants also completed a cycling practice trial on an electronically braked cycle ergometer (LODE Excalibur; Quinton Instrument, Groningen, The Netherlands) to determine the power output needed to maintain the participant's heart rate (HR) within a zone of low to moderate intensity. The exercise HR zone was determined using the heart rate reserve (HRR) calculation (Karvonen et al., 1957):

$$\text{HRR} = (\text{maximal HR} - \text{resting HR}) + \text{resting HR}$$

Low intensity was 40% of HRR and moderate exercise intensity was set at 50% HRR. The participants also evaluated their cycling intensity during all exercise trials using the Rating of Perceived Exertion (RPE) Scale (Borg, 1982), and we also ensured that participants' RPE was between 8 to 11 out of 20-point scale. If the RPE was above 11, then the power output was lowered.

During the second visit, participants reported to the lab following a 12-hr overnight fast and were instructed to lay supine in a darkened room for 30 min. Participants provided breath samples during the last 15 min to measure RMR. The volume of oxygen consumed (VO_2 ; mL/min) and carbon dioxide produced (VCO_2 ; mL/min), breathing frequency (breaths/min), tidal volume (mL), and ventilation rate (L/min), were determined using a metabolic cart (MOXUS metabolic system; AEI Technologies, Pittsburgh, PA, US). Since no differences with

supplementation were noted for breathing frequency, tidal volume, and ventilation in either groups they were not included in the results. HR was recorded every 5 min with a heart rate monitor (Polar Electro, Inc., Port Washington, NY, US). After the RMR trial, body composition was analyzed for fat mass (FM) and fat-free mass or lean mass (LM) using bioelectrical impedance analysis, and a venous blood sample was taken.

At least 2 days later, participants reported to the laboratory for a third visit to complete a 30 min exercise trial. Participants were instructed to eat a mutually agreed upon breakfast (~50% of energy (E%) from CHO, ~30 E% from fat, and ~20 E% from protein (~350 kcal)) 2 hrs before arriving to the laboratory and drink 500 mL of water within the 2 hrs before arrival to ensure hydration. The participants then completed 30 min of low to moderate cycling exercise at the power output established from the first visit. HR was recorded every 5 min and 4 min respiratory gas measurements were collected every 6 min during the exercise. Following the third visit, the participants were matched by sex, age, BMI, and medication use, and then were randomly assigned in a single-blinded manner to one of two supplement groups: fish oil (FO, 9 males, 12 females) or placebo (PL, 8 males, 12 females). The FO group took 5 g/d of FO (Omega-3 Complete, Jamieson Laboratories Ltd., Windsor, ON, CA) administered in 5 capsules, with each capsule providing 400 mg of EPA and 200 mg of DHA. The PL group took 3 g/d of olive oil (Swanson EFAs, Certified Organic Olive Oil, Swanson Health Products, Fargo, ND, US) administered in 3 capsules. To reduce any minor side-effects of the oils (burping, indigestion), the participants were instructed to take the supplements frozen and with meals; with the FO group taking 1 capsule at breakfast, 2 at lunch, and 2 at supper; and the PL group taking 1 capsule at each meal. To encourage compliance, the first month of supplements were provided in daily packets. After the first 4 wks, the capsules were allotted in weekly amounts. In addition

to picking up the supplements, participant compliance was encouraged with periodic phone calls or email reminders, and picking up their supplements. Following 6 wks of supplementation, participants completed the 12 hr overnight fasted and resting protocol from the second lab visit, without the blood sample. After 12 wks of supplementation, the participants repeated the protocol from visits 2, 3 and 4, with the exception of the balance measures from visit 2. Compliance was assessed by monitoring dietary intake and physical activity records at the start and end of the study. Dietary intake was assessed by the completion of a multiple-day food record and physical activity by the Physical Activity Scale for the Elderly (PASE) (Washburn et al., 1993).

At the end of the study period the participants were asked which supplement group they believed they were in. The majority of the participants taking FO (65%) and PL (55%) correctly identified the supplement group. The only reported symptoms were belching and heartburn. In fact, 70% of the FO participants reported belching on ~1-2 d/wk and 10% of the FO reported heartburn on ~3-4 d/wk. Overall, the PL supplement was well tolerated, with one participant reporting heartburn on ~3-4 occasions/wk during the last 6 wks of supplementation.

5.3.3. *Physical Measures*

All body composition (Ht, BM, WC) and grip strength measures were conducted as outlined in the Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA) (CSEP, 2003). Briefly, Ht was measured to the nearest 0.1 cm using a vertical metric wall tape and a horizontal flat edge. BM was measured to the nearest 0.1 kg on a calibrated digital scale (Health O Meter; Bridgeview, IL, US). WC was measured to the nearest 0.5 cm, and was taken at the top of the iliac crests using an anthropometric tape. A WC of <102 cm for males and <88 cm for females was considered healthy (Health Canada, 2003a). Body mass index (BMI) was

calculated as BM/Ht^2 . A BMI of $<25 \text{ kg/m}^2$ was considered healthy and $25\text{-}30 \text{ kg/m}^2$ was considered overweight (Health Canada, 2003a).

Bioelectrical Impedance Analysis (Bodystat 1500, FL, US) was completed directly after the 12-hr fasted and RMR measures, where the participant continued to lay supine with limbs abducted, and leads were attached according to manufacturer's instructions (BodyStat Limited, 2013). A FM of $<30\%$ for males and $<42\%$ for females, and a LM $>70\%$ for males and $>58\%$ for females was considered healthy (Bray, 1993). Fat free mass index (FFMI) was calculated using LM and standardizing for height ($LM \text{ (kg)} / Ht^2 \text{ (m}^2)$) (Schutz et al., 2002). Participants were classified as sarcopenic if possessing a value below 16.3 kg/m^2 for males and 13.1 kg/m^2 for females (Schutz et al., 2002). Isometric handgrip strength was measured using a hydraulic hand-held dynamometer (Vernier Jamar; Sammons Preston Rolyan; Nottinghamshire, ENG, UK). Three measurements per hand were taken and the participant alternated hands between measurements to allow $\sim 30 \text{ s}$ of rest. The highest measurement for each hand was added together to achieve the combined grip strength (CGS) value.

To assess functional capacity, the Berg Balance, Dynamic Gait Index, TUG, and the 30-30-SCS tests were employed as described elsewhere (Berg et al., 1989; Podsiadlo & Richardson, 1991; Rikli & Jones, 1999). A Berg Balance score of >45 (out of 56) has been shown to be a cut-off for safe independent ambulation (Berg et al., 1992). A Dynamic Gait Index score of > 19 (out of 24) was considered healthy, with lower scores indicated a high risk of falls (Shumway-Cook et al., 1997). A TUG measure of $<9.0 \text{ s}$ was considered healthy (Bohannon, 2006), and a 30-SCS value >12 for males and >11 for females was considered healthy (Rikli & Jones, 1999). Since the functional capacity of the cohort was high, as determined by the Berg Balance and Dynamic Gait Index tests, we only repeated the TUG test and the 30-SCS post-supplementation.

5.3.4. Cardiovascular and Blood Measures

Resting systolic and diastolic blood pressure (SBP, DBP; mmHg) were measured using a blood pressure monitor (OMRON IntelliSense; Model HEM-907XL; OMRON Healthcare, IL, US). Participants were seated with their left arm resting on a table for three min prior to three blood pressure measurements taken one min apart. There was no significant difference between the three rested values so the mean of all measurements were used for data analysis. Values of <140 mmHg for SBP and <90 mmHg for DBP were considered healthy (Abbott et al., 1994; Daskalopoulou et al., 2012).

After a 12 hr overnight fast, venous blood was collected and analyzed for serum glucose, insulin, high sensitivity C-reactive protein (hs-CRP), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein (HDL-C), and triglycerides (TG; mmol/L). The bloods were analyzed at LifeLabs Medical Laboratory Services (Guelph, ON, CA). Blood measurements were considered healthy if glucose was <7 mmol/L, insulin was <210.0 pmol/L, hs-CRP was <3.0 mg/L, total-C was <5.18 mmol/L, LDL-C was <3.34 mmol/L, HDL-C was >1.0 mmol/L for males and >1.3 mmol/L for females, and TG <1.7 mmol/L (American Heart Association, 2013; Canadian Diabetes Association, 2008; Miller et al., 2011; Ridker, 2003).

4.3.5. Metabolic Calculations

For both the rested and exercise trials, the VO_2 and VCO_2 were measured and were used to calculate the respiratory exchange ratio (VCO_2/VO_2 , RER) (Saltin, 1990) and whole body carbohydrate oxidation (Cho Ox) and fat oxidation (Fat Ox) by using the non-protein RER table and the following equations (Ferrannini, 1988; Saltin, 1990):

$$\text{Cho Ox (g)} = (4.585 \times VCO_2) - (3.226 \times VO_2); \text{ and}$$

$$\text{Fat Ox (g)} = (1.695 \times \text{VO}_2) - (1.701 \times \text{VCO}_2).$$

The respiratory data were collected for the last 15 min and averaged for the resting trial, and collected every 6 min for 4 min intervals and then averaged for the exercise trial. The RMR or energy expenditure (Energy Ex) was calculated using the thermal equivalent of VO_2 consumed based on non-protein respiratory quotient table and the following equation (Leonard, 2010):

$$\text{Energy Ex (Kcal)} = \text{VO}_2 (\text{L/min}) \times \text{RER cal equiv (Kcal/L)} \times \text{Time (min)}.$$

5.3.6. Questionnaires

The participants completed the PASE questionnaire, designed to measure the amount of physical activity engaged in over the past 7 days, with higher scores indicative of greater amounts of daily activity (Washburn et al., 1993). The SF-36 was also completed and used to measure participant QOL, with 100% being the highest or best possible level of functioning (Ware & Shelbourne, 1992; Ware & Gandek, 1998). The SF-36 measures QOL across eight emotional and physical domains, including physical functioning, role limitations due to physical health, role limitations due to emotional problems, energy/fatigue, emotional well-being, social functioning, pain, and general health (Ware & Shelbourne, 1992; Ware & Gandek, 1998).

5.3.7. Assessment of Dietary Intake

The participants were asked to record their food and beverage consumption using a multiple-day food record (version 3; Fred Hutchison, WA, US) on three consecutive days of the week, which included two weekdays and one day on the weekend. Detailed instructions were provided to the participants to ensure accurate recording of dietary intake. The dietary information was then entered into the Food Processor SQL-ESHA database version 10.8.0 (ESHA Research, Salem, OR, US).

5.3.8. Statistical Analysis

After determining data normality and variance homogeneity, preliminary analysis of variance (ANOVA) was performed to examine whether differences existed between the supplement groups for physical and metabolic values at the time points. ANOVAs (2-way repeated measures) and Tukey's post hoc tests were used to evaluate the effect of time on the physical and metabolic measures. The Bonferroni-corrected *t* test was used to determine where the differences occurred. BM, dietary intake, and physical activity were controlled for in the analysis if significant changes occurred between baseline and study completion. Data are presented as means \pm SEMs. Statistical significance was accepted as $p < 0.05$ for all tests. All statistics were computed using PASW Statistics 19.0.1 for Windows (Chicago, IL, US).

5.4. RESULTS

5.4.1. Participant Characteristics

The participant data (Table 5.1.) indicated that the cohort was generally in good health, although the body composition data denoted that the cohort was overweight. The mean FFMI values indicated that the participants had healthy amounts of skeletal muscle; with only 2 of the males and 1 of the females being classified as sarcopenic (Schutz et al., 2002). The cohort was high functioning according to the balance, TUG, and 30-SCS tests, and possessed healthy CGS values. The physical activity level of the cohort (PASE score) was above average in comparison to sex and age matched normative data for older adults (Washburn et al., 1993) (Table 5.1.). The SF-36 data indicated a high QOL for general health, physical functioning, energy level, social functioning and emotional well-being. The nutrition data demonstrated that the total energy intake for males was indicative of a low to moderate level of daily activity, and low levels of daily activity for females (Health Canada, 2011). The participants also consumed healthy

amounts of fat, carbohydrate, and protein (Table 5.1.) (Health Canada, 2006), and the average energy intake did not significantly change over the supplementation period. The cardiovascular data indicated that the mean SBP was in the healthy range for the females and PL males, while the FO males had a mean unhealthy value (Table 5.1.). Further, the mean DBP values for all participants were in the healthy range. The fasted blood data indicated that all of the participants had healthy insulin, glucose, HDL-C, and TG values. However, the hs-CRP and TC values for the males were in the high risk zone for cardiovascular disease, while a lower level of risk was evident for the females (Table 5.1.). Finally, the use of medication was low in the cohort, with 39% (6 males, 10 females) taking any form of low-dose medications.

The groups were well matched for the baseline physical measures ($p > 0.05$), with the exception of TUG and blood measures of fasted insulin and TG for the males, and hs-CRP for the females. The FO group had significantly lower mean values than the PL group ($p < 0.05$) for TUG, insulin and TGs, and the FO females had significantly higher baseline values of hs-CRP than the PL group (Table 5.1.). For the metabolic measures, there were significant differences between the baseline values for resting and exercise HR, RMR, and resting Fat Ox among the males, with the FO group having lower values than the PL males. There were no differences among the female groups.

5.4.2. *Influence of Supplementation on Physical and Blood Measures*

After 12 wks of supplementation, a significant increase in LM of 1.6 (± 0.7) kg and decrease in TUG speed of 0.5 (± 0.2) s were found in the FO females. No significant changes

Table 5.1. Participant health and physical measures at 0 and 12 wks of supplementation with placebo (olive oil) or fish oil.

	Male Placebo (n=8)		Male Fish Oil (n=9)		Female Placebo (n=12)		Female Fish Oil (n=12)	
	0 Wks	12 Wks	0 Wks	12 Wks	0 Wks	12 Wks	0 Wks	12 Wks
Body Composition & Cardiovascular								
Body Mass (kg)	81.9 ± 3.3	82.0 ± 3.9	81.3 ± 3.6	81.0 ± 3.5	69.1 ± 3.0	69.0 ± 3.1	72.9 ± 3.0	73.3 ± 3.7
Body Mass Index (kg/m ²)	27.2 ± 1.2	27.5 ± 1.3	26.7 ± 1.1	26.6 ± 1.0	26.3 ± 1.0	26.3 ± 1.1	27.9 ± 1.3	28.0 ± 1.2
Waist Circumference (cm)	101.3 ± 3.3	100.3 ± 4.6	97.2 ± 3.1	95.8 ± 3.0	91.4 ± 3.1	90.2 ± 2.7	92.6 ± 2.3	92.1 ± 2.9
Fat Mass (kg)	25.8 ± 1.9	25.4 ± 2.6	24.9 ± 1.8	23.7 ± 2.1	29.6 ± 1.9	28.9 ± 2.0	32.6 ± 2.0	31.3 ± 2.2
Lean Mass (kg)	56.1 ± 1.7	56.6 ± 1.1	56.4 ± 2.4	57.3 ± 2.3	39.5 ± 1.4	40.1 ± 1.6	40.3 ± 1.2	41.9 ± 1.3*
Systolic Blood Pressure (mmHg)	119 ± 3.4	117 ± 7.0	125 ± 3.8	123 ± 4.7	119 ± 3.3	116 ± 4.9	117 ± 4.8	115 ± 3.8
Diastolic Blood Pressure (mmHg)	73 ± 1.9	72 ± 2.2 ⁺⁺	72 ± 1.8	66 ± 2.2*	72 ± 1.9	72 ± 2.6	70 ± 3.5	66 ± 2.6
Function & Strength								
Combined Grip Strength (kg)	84.9 ± 4.9	83.6 ± 4.3	89.0 ± 4.3	88.0 ± 4.5	57.4 ± 2.3	57.1 ± 2.4	49.9 ± 2.8	51.5 ± 3.4
Timed Up and Go Test (s)	8.8 ± 0.4 ⁺	8.6 ± 0.3 ⁺⁺	7.5 ± 0.4	7.2 ± 0.6	7.3 ± 0.2	7.1 ± 0.2	7.6 ± 0.2	7.1 ± 0.2*
30-Second Sit To Stand (# Completed)	17 ± 1.2	18 ± 1.4	18 ± 1.2	20 ± 2.4	15 ± 0.9	17 ± 1.1	15 ± 1.7	17 ± 1.9
PASE	152 ± 32	163 ± 29	129 ± 24	132 ± 26	120 ± 21	124 ± 22	149 ± 15	152 ± 18
Dietary Intake								
Total Energy Intake (kcal)	2463 ± 133	2347 ± 139	2324 ± 125	2282 ± 135	1926 ± 166	2009 ± 155	1867 ± 107	1924 ± 140
Fat (g)	79 ± 6	76 ± 9	77 ± 7	83 ± 8	64 ± 6	71 ± 9	59 ± 6	64 ± 6
Protein (g)	93 ± 4	96 ± 6	90 ± 5	86 ± 7	72 ± 5	81 ± 6	81 ± 5	86 ± 4
Carbohydrate (g)	331 ± 23	320 ± 30	318 ± 23	298 ± 23	258 ± 28	261 ± 17	253 ± 25	269 ± 21
Fasted Blood	n=6		n=9		n=6		n=11	
Insulin (pmol/L)	81.2 ± 15.0 ⁺	68.3 ± 17.4 ⁺⁺	61.9 ± 10.0	49.4 ± 7.8	65.6 ± 21.3	61.2 ± 15.8	52.1 ± 4.4	49.4 ± 6.6
Glucose (mmol/L)	5.35 ± 0.32	5.47 ± 0.31	5.61 ± 0.32	5.69 ± 0.36	5.0 ± 0.3	4.96 ± 0.26	5.04 ± 0.13	5.12 ± 0.13
C-Reactive Protein (mg/L)	4.93 ± 2.57	6.93 ± 2.76 ⁺⁺	3.16 ± 1.29	2.12 ± 0.80	1.75 ± 0.33 ⁺	1.67 ± 0.25 ⁺⁺	3.28 ± 0.70	3.29 ± 0.59
Total Cholesterol (mmol/L)	5.01 ± 0.45	4.74 ± 0.39	5.17 ± 0.27	4.67 ± 0.27	5.63 ± 0.38	5.52 ± 0.43	5.58 ± 0.23	5.80 ± 0.26
LDL-Cholesterol (mmol/L)	3.05 ± 0.33	2.89 ± 0.30	3.06 ± 0.25	2.68 ± 0.27	3.37 ± 0.34	3.25 ± 0.34	3.28 ± 0.20	3.66 ± 0.23
HDL-Cholesterol (mmol/L)	1.20 ± 0.04	1.14 ± 0.06	1.59 ± 0.15	1.62 ± 0.17	1.71 ± 0.13	1.76 ± 0.17	1.72 ± 0.08	1.77 ± 0.10
Triglycerides (mmol/L)	1.68 ± 0.33 ⁺	1.56 ± 0.38	1.15 ± 0.19	0.78 ± 0.12*	1.19 ± 0.15	1.13 ± 0.13	1.30 ± 0.14	1.01 ± 0.14 *

Data are means (±SE). PASE = physical activity score for the elderly questionnaire. Significant difference *within groups at 0 and 12 wks, and between groups at ⁺0 wks and ⁺⁺12 wks.

were found in the FO males or the PL groups for LM or TUG. For the cardiovascular and blood measures, DBP significantly decreased by $6 (\pm 2)$ mmHg in the FO males, although there were no significant changes present in the FO females or the PL groups. Lastly, there was a significant decrease in TG values by $0.37 (\pm 0.09)$ mmol/L for the FO males and $0.29 (\pm 0.07)$ mmol/L for the FO females, while no significant changes were found in the PL groups. Similarly, there were no significant changes in any of the other body composition, physical function and strength measures for both the FO and PL groups (Table 5.1.).

5.4.3. Influence of Supplementation on Resting Metabolic Measures

Significant increases in VO_2 by $42.0 (\pm 10.3)$ and $51.1 (\pm 10.6)$ mL/min occurred in the males after supplementing with FO for 6 wks and 12 wks; respectively (Table 5.2., Figure 5.1. A). FO females also experienced an increase in VO_2 by $20.1 (\pm 8.9)$ mL/min after 6 wks, and by $27.6 (\pm 8.0)$ mL/min after 12 wks of supplementation (Table 5.2., Figure 5.1. B). There were no significant changes noted in the PL groups. Resting VCO_2 followed a similar trend, with a significant increase of $27.0 (\pm 13.3)$ mL/min for the FO males and $18.4 (\pm 5.73)$ mL/min for the FO females after 12 wks of supplementation, while no changes were noted in the PL groups (Table 5.2.). A significant decrease in RER by $0.07 (\pm 0.04)$ after 6 wks and $0.06 (\pm 0.03)$ after 12 wks of FO supplementation occurred in the males, while no changes were noted in the FO females or in the PL groups (Table 5.2.). The changes in VO_2 and RER resulted in significant increases in the RMR of $0.18 (\pm 0.05)$ kcal/min after 6 wks and $0.23 (\pm 0.06)$ kcal/min after 12 wks of FO supplementation in the males. Similarly, the females had a significant increase in RMR of $0.10 (\pm 0.04)$ kcal/min at 6 wks and $0.13 (\pm 0.04)$ kcal/min after 12 wks of FO supplementation (Table 5.2., Figure 5.3. A). No changes in RMR were evident in the PL groups

Table 5.2. Resting metabolic measures at pre, 6 wks and 12 wks, post supplementation with placebo (olive oil) or fish oil.

Measure	Male						Female					
	Placebo (n=8)			Fish Oil (n=9)			Placebo (n=12)			Fish Oil (n=12)		
	0 Wks	6 Wks	12 Wks	0 Wks	6 Wks	12 Wks	0 Wks	6 Wks	12 Wks	0 Wks	6 Wks	12 Wks
VO ₂ (mL/min)	235.0 ± 12.1	237.2 ± 12.9	230.5 ± 13.7	197.1 ± 7.4	239.1 ± 7.8*	248.2 ± 8.0**	179.9 ± 7.6	180.2 ± 8.0	183.0 ± 7.6	169.4 ± 6.8	189.5 ± 7.1*	197.0 ± 7.4**
VCO ₂ (mL/min)	180.1 ± 15.6	185.2 ± 15.4	177.6 ± 15.5	159.1 ± 6.3	177.4 ± 6.6	186.1 ± 6.9**	132.4 ± 5.8	134.0 ± 4.9	134.1 ± 5.0	129.3 ± 6.8	144.8 ± 7.4	147.7 ± 7.0**
Respiratory Exchange Ratio (RER)	0.77 ± 0.03	0.78 ± 0.02	0.77 ± 0.02	0.81 ± 0.03	0.74 ± 0.01*	0.75 ± 0.02**	0.73 ± 0.02	0.74 ± 0.02	0.73 ± 0.02	0.76 ± 0.01	0.76 ± 0.01	0.75 ± 0.02
Resting Heart Rate (bpm)	65 ± 2 ⁺	64 ± 2	64 ± 2 ⁺⁺	62 ± 2	60 ± 2*	60 ± 2**	65 ± 2	66 ± 2	66 ± 2 ⁺⁺	63 ± 2	60 ± 2*	60 ± 2**
Rate of Fat Oxidation (mg/min)	91.9 ± 13.8 ⁺	87.0 ± 12.5	88.6 ± 11.5 ⁺⁺	63.5 ± 6.8	103.5 ± 5.9*	104.1 ± 6.2**	79.7 ± 6.6	77.5 ± 7.1	82.2 ± 7.5	67.2 ± 6.3	74.9 ± 6.4	82.7 ± 6.6**
Rate of Carbohydrate Oxidation (mg/min)	67.8 ± 20.1	83.9 ± 20.7	70.7 ± 23.8	93.7 ± 16.9	42.1 ± 14.3*	52.6 ± 16.0**	26.7 ± 12.5	33.1 ± 11.6	24.4 ± 11.8	46.3 ± 11.7	52.6 ± 13.5	41.7 ± 12.6
RMR (kcal/min)	1.12 ± 0.06 ⁺	1.13 ± 0.06	1.11 ± 0.07	0.95 ± 0.04	1.13 ± 0.04*	1.18 ± 0.03**	0.85 ± 0.04	0.85 ± 0.06	0.86 ± 0.09 ⁺⁺	0.80 ± 0.05	0.90 ± 0.04*	0.93 ± 0.04**
RMR Normalized for Body mass (kcal/kg)	0.20 ± 0.03	N/A	0.20 ± 0.03	0.17 ± 0.01	N/A	0.22 ± 0.01**	0.18 ± 0.01	N/A	0.19 ± 0.02	0.17 ± 0.01	N/A	0.19 ± 0.01**
RMR Normalized for Lean Mass (kcal/kg)	0.30 ± 0.04	N/A	0.29 ± 0.04	0.25 ± 0.02	N/A	0.31 ± 0.01**	0.33 ± 0.02	N/A	0.32 ± 0.03	0.30 ± 0.01	N/A	0.33 ± 0.01**

Data are means (±SE). RMR = resting metabolic rate. The data in the table are the last 15 min of a 30 min rest period. Significant

difference within groups *at 0 and 6 wks, **at 0 and 12 wks, and between groups at ⁺0 wks and ⁺⁺12 wks

Finally, RMR remained significantly increased in the FO males and females when normalized for BM and LM (Table 5.2., Figure 5.3. B).

The substrate oxidation data indicated that FO supplementation resulted in significant changes in the rate of Fat Ox, where males had an increase of 40.0 (\pm 20.1) mg/min after 6 wks and 40.6 (\pm 16.6) mg/min after 12 wks, while females had an increase of 15.5 (\pm 5.7) mg/min at 12 wks of supplementation (Table 5.2., Figure 5.2. A, B). No significant changes in the rate of Fat Ox were found in the PL groups. The rate of Cho Ox significantly decreased in the FO males by 51.6 (\pm 20.3) mg/min after 6 wks, and by 41.1 (\pm 16.6) mg/min after 12 wks of supplementation, while no significant changes were found in the FO females and PL groups (Table 5.2.). Finally, significant changes were noted in RHR in response to FO supplementation, where a decrease of 2 (\pm 1) bpm for the males and 3 (\pm 1) bpm for the females occurred after 6 wks of supplementation without any further decreases in RHR at 12 wks. RHR remained significantly unchanged in the PL groups (Table 5.2.).

5.4.4. Influence of Supplementation on Exercise Metabolic Measures

The average power output during the exercise trial was 58 (\pm 7) W for PL males, 46 (\pm 8) W for the FO males, 36 (\pm 4) W for the PL females, and 25 (\pm 6) W for the FO females. For exercise VO_2 , significant increases of 148.5 (\pm 51.8) mL/min for males and 99.2 (\pm 19.7) mL/min for the females occurred after 12 wks of FO supplementation, while no changes were evident in the PL groups (Table 5.3., Figure 5.1. C, D). Exercise VCO_2 followed a similar trend where significant increases of 77.0 (\pm 30.1) mL/min for the males and 60.7 (\pm 20.1) mL/min for the females in response to FO supplementation occurred, while no changes were found in the PL groups (Table 5.3.). RER decreased significantly in the FO males by 0.04 (\pm 0.02) while no significant changes were noted in the FO females or the PL groups.

Table 5.3. Exercise metabolic measures pre and post 12 wks supplementation with placebo (olive oil) or fish oil.

Measure	Male				Female			
	Placebo (n=8)		Fish Oil (n=9)		Placebo (n=12)		Fish Oil (n=12)	
	0 Wks	12 Wks	0 Wks	12 Wks	0 Wks	12 Wks	0 Wks	12 Wks
VO ₂ (mL/min)	1274.3 ± 83.2	1269.2 ± 94.2 ⁺⁺	1230.8 ± 73.6	1379.3 ± 79.2*	854.1 ± 50.1	847.5 ± 54.8 ⁺⁺	846.4 ± 43.9	945.6 ± 42.4*
VCO ₂ (mL/min)	1092.6 ± 61.2	1098.2 ± 84.6 ⁺⁺	1072.5 ± 65.1	1149.5 ± 68.9*	728.9 ± 41.2	730.8 ± 41.1 ⁺⁺	731.0 ± 34.2	791.7 ± 36.2*
Respiratory Exchange Ratio (RER)	0.86 ± 0.01	0.87 ± 0.02 ⁺⁺	0.87 ± 0.02	0.83 ± 0.02*	0.85 ± 0.02	0.86 ± 0.02	0.86 ± 0.01	0.84 ± 0.02
Heart Rate (bpm)	110 ± 2 ⁺	112 ± 3 ⁺⁺	106 ± 2	103 ± 2*	103 ± 3	101 ± 3	106 ± 1	104 ± 1*
Total Fat Oxidation (g)	9.0 ± 1.4	8.5 ± 1.7 ⁺⁺	7.8 ± 1.5	11.5 ± 1.6*	6.2 ± 1.3	5.8 ± 1.6 ⁺⁺	5.8 ± 1.1	7.7 ± 1.2*
Rate of Fat Oxidation (g/min)	0.30 ± 0.05	0.28 ± 0.06 ⁺⁺	0.26 ± 0.04	0.38 ± 0.05*	0.21 ± 0.04	0.19 ± 0.05 ⁺⁺	0.19 ± 0.04	0.26 ± 0.04*
Total Carbohydrate Oxidation (g)	27.0 ± 2.1	28.2 ± 3.5 ⁺⁺	28.4 ± 2.0	24.6 ± 2.0*	17.6 ± 2.5	18.5 ± 2.4	18.6 ± 2.1	17.4 ± 2.0
Rate of Carbohydrate Oxidation (g/min)	0.90 ± 0.07	0.94 ± 0.12 ⁺⁺	0.95 ± 0.06	0.82 ± 0.07*	0.59 ± 0.08	0.62 ± 0.08	0.62 ± 0.07	0.58 ± 0.07
Total Energy Ex (kcal)	186.4 ± 10.3	186.1 ± 11.6 ⁺⁺	180.4 ± 8.1	200.2 ± 8.9*	124.6 ± 7.0	123.9 ± 7.1 ⁺⁺	123.8 ± 6.3	137.6 ± 6.5*
Rate of Energy Ex (kcal/min)	6.21 ± 0.34	6.20 ± 0.39 ⁺⁺	6.01 ± 0.27	6.67 ± 0.30*	4.15 ± 0.23	4.13 ± 0.24 ⁺⁺	4.13 ± 0.21	4.59 ± 0.22*
Energy Ex Normalized for Body mass (kcal/kg)	2.3 ± 0.1	2.3 ± 0.1 ⁺⁺	2.2 ± 0.1	2.5 ± 0.1*	1.8 ± 0.1	1.8 ± 0.1	1.7 ± 0.1	1.9 ± 0.1*
Energy Ex Normalized for Lean Mass (kcal/kg)	3.3 ± 0.2	3.3 ± 0.2 ⁺⁺	3.2 ± 0.1	3.5 ± 0.2*	3.2 ± 0.2	3.1 ± 0.2 ⁺⁺	3.1 ± 0.2	3.3 ± 0.2*

Data are means (±SE). Ex = expenditure. The data in the table are the values of a 30 min low to moderate intensity exercise trial. The average power output (W) was 58 (±7) for PL males, 46 (±8) for FO males, 36 (±4) for PL females, and 25 (±6) for FO females. Significant difference *within groups at 0 and 12 wks, and between groups at ⁺0 wks and ⁺⁺12 wks.

For the total Energy Ex, significant increases were found in the FO groups, where an increase of 19.8 (± 8.1) kcal for the males and 13.8 (± 2.5) for the females occurred (Table 5.3., Figure 5.3. C, D). When expressed as a rate, an increase of 0.66 (± 0.27) kcal/min for the FO males and 0.46 (± 0.08) kcal/min for the FO females occurred. No changes were found in response to the PL supplementation. Energy Ex remained significantly increased when normalized for BM and LM (Table 5.3.).

The substrate oxidation data indicated that FO supplementation resulted in significant increases in Fat Ox of 3.7 (± 1.3) g for the males and 1.9 (± 0.6) g for the females (Table 5.3.). When calculated as a rate, an increase 0.12 (± 0.04) g/min for the FO males and 0.07 (± 0.02) g/min for the FO females occurred (Figure 5. 2. C, D), while no significant changes were found in the PL groups (Table 5.3.).

Finally, significant decreases in HR by 3 (± 1) bpm for the males and the females occurred in response to FO supplementation (Table 5.3.), while no significant changes were found in the PL groups.

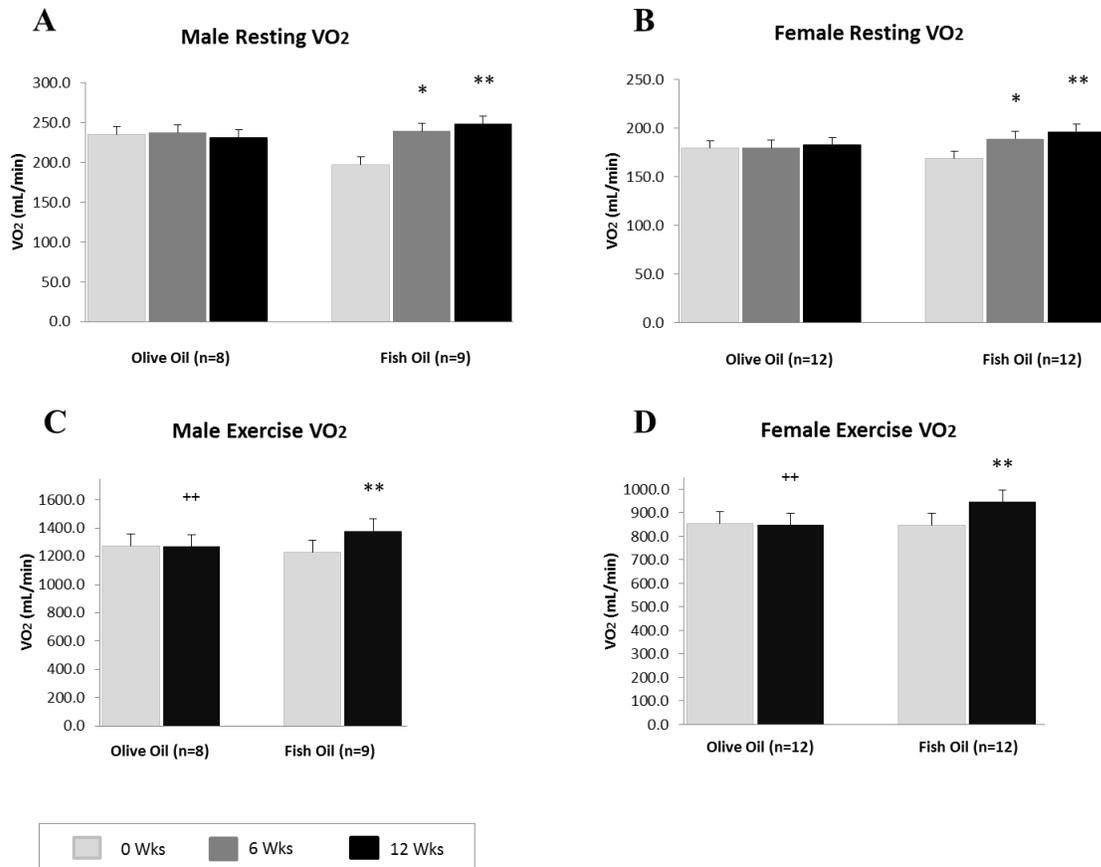


Figure 5.1. Oxygen uptake measures at rest (A, B) and during exercise (C, D) at baseline (0 wks), and after 6 and 12 wks of placebo (olive oil) or fish oil supplementation. Significant difference within groups *at 0 and 6 wks, **at 0 and 12 wks, and between groups at ⁺0 wks and ⁺⁺12 wks.

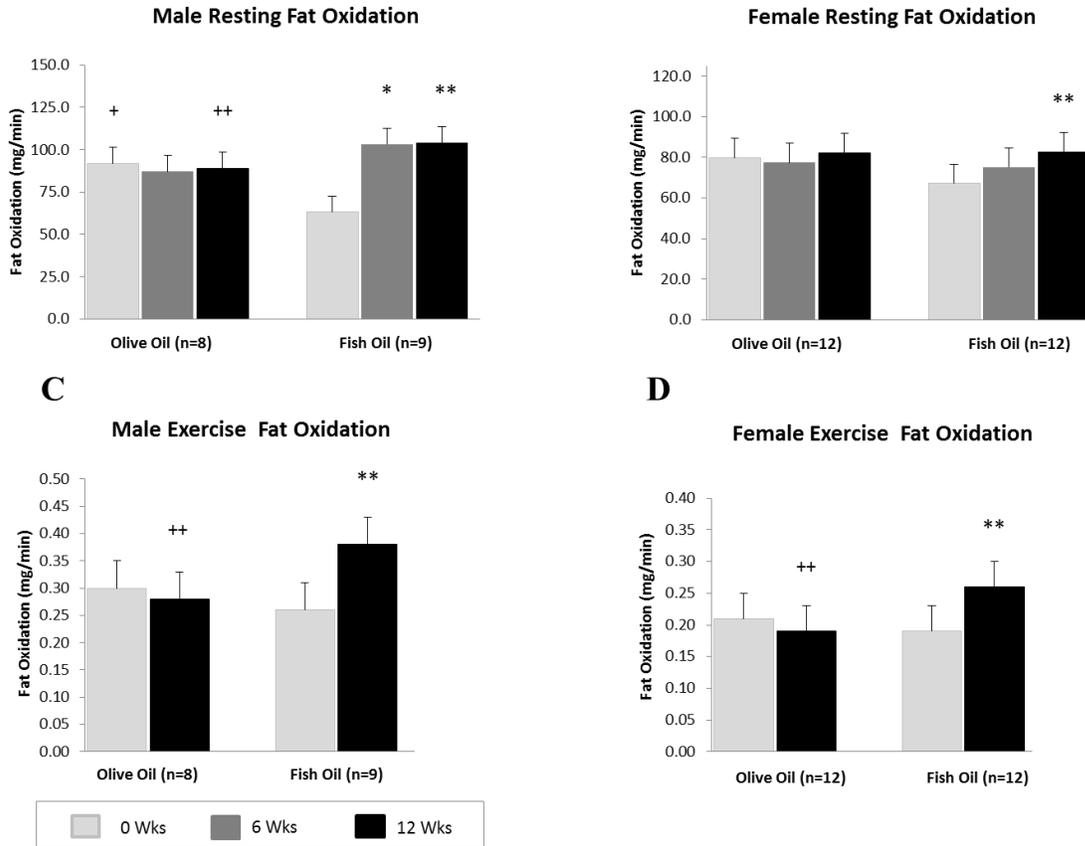


Figure 5.2. Fat oxidation at rest (A, B) and during exercise (C, D) at baseline (0 wks), and after 6 and 12 wks of placebo (olive oil) or fish oil supplementation. Significant difference within groups *at 0 and 6 wks, **at 0 and 12 wks, and between groups at +0 wks and ++12 wks.

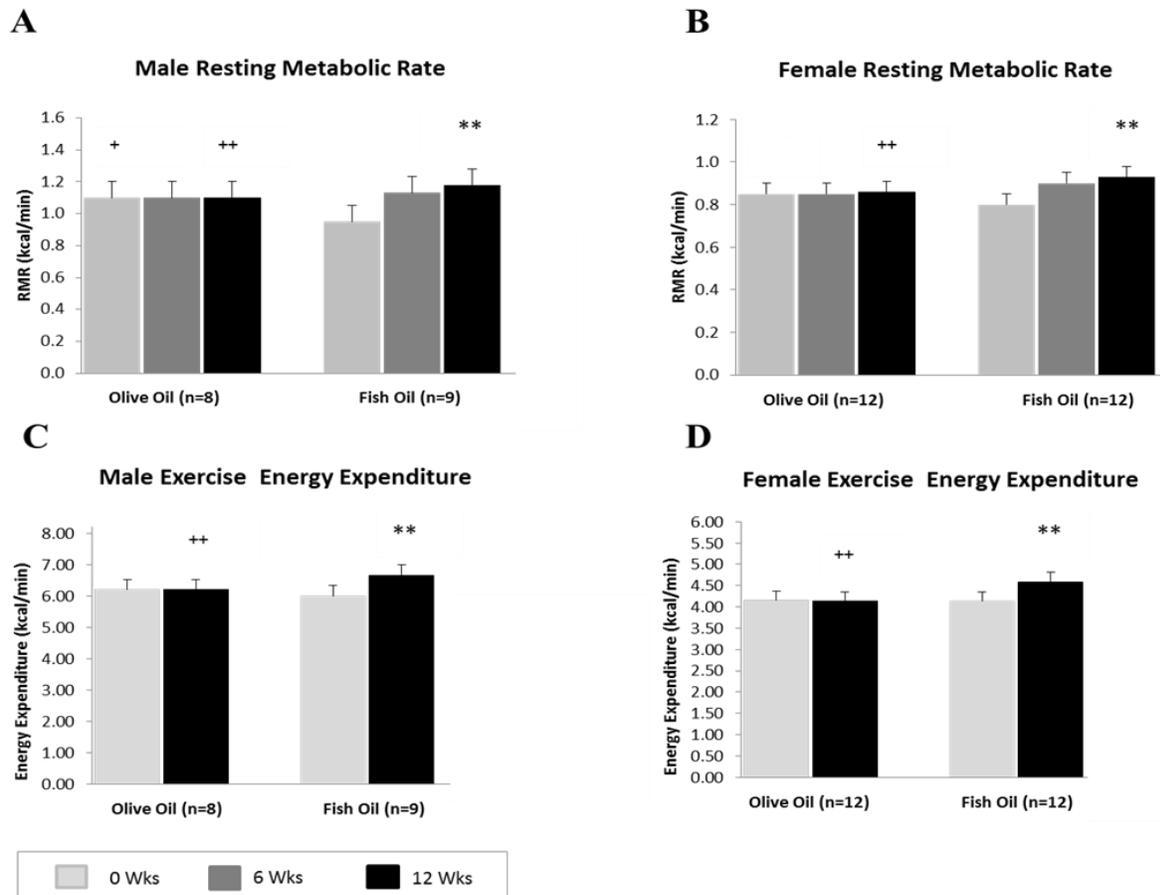


Figure 5.3. Metabolic measures of energy expenditure at rest (A, B) and during exercise (C, D) at baseline (0 wks), and after 6 and 12 wks of placebo (olive oil) or fish oil supplementation. Significant difference within groups *at 0 and 6 wks, **at 0 and 12 wks, and between groups at ⁺0 wks and ⁺⁺12 wks.

5.5. DISCUSSION

This study demonstrated that FO supplementation, and not PL, results in 1) increased metabolic rate and fat oxidation both at rest and during exercise; 2) decreased resting and exercise heart rate; 3) increased lean mass and physical function for the females; 4) decreased diastolic blood pressure for the males, and; 5) decreased fasted blood triglycerides.

5.5.1. Influence of Supplementation on Metabolism

To our knowledge, this is the first study to evaluate and demonstrate an increase in resting and exercise metabolic rates after 12 wks of FO supplementation in healthy older adults. The increase in RMR following FO supplementation was impressive in both the males and the females after 12 wks of supplementation (24% males, 16% females), with the majority of the significant changes present after 6 wks (19% males, 13% females). Extrapolated to a 24 hr period, this translates into an increased expenditure of ~331 kcal/d for the males and ~187 kcal/d for the females. Further, we observed an increase in resting Fat Ox of 64% for the males and 23% for the females, and a decrease in resting Cho Ox by 44% for the males; although no significance was apparent for the females, there was a trend for a decreased value. Similar results occurred in response to the exercise challenge, although the effects were ~2-fold less than the resting measures. Energy Ex increased significantly in the males and females after 12 wks of supplementation (11%), and Fat Ox increased in the FO groups (47% males, 33% females while Cho Ox decreased (13% males, 6% females).

Many conflicting results are present in the literature with respect to supplementing with FO and resting and exercise oxygen consumption and energy expenditure in humans (Huffman et al., 2004; Poprzecki et al., 2009). Similar results to our resting data have been reported in younger adults (n=5 males, 1 female, 23 ± 2 yrs) where a significant increase in fat oxidation (22%) and a decrease in FM (0.9 kg) when 6 g/d of fat in the diet was replaced with FO (1.1 g/d EPA, 0.7 g/d DHA) for 3 wks (Couet et al., 1997). An increase in RMR was also reported, but when the increase in LM was accounted for, the RMR increase was not significant; suggesting that the FO may increase RMR by increasing LM (Couet et al., 1997). This is contrary to our results where the increase in energy expenditure at rest and during exercise remained significant

when normalized for BM and LM (Table 5.2. and 5.3.), suggesting that the increase in LM was not the main factor influencing the increase in energy expenditure. Although the tissues predominantly involved in the increase in metabolic rate in this study are unknown, skeletal muscle is likely to be involved. Skeletal muscle comprises ~20% of energy expenditure at rest and increases to ~80% of oxygen use during exercise (Zurlo et al., 1990). However, other metabolically active tissues (heart, lungs, kidneys, brain and liver, etc.) (Elia, 1999) may be contributing to this increase in metabolic rate, since during exercise we observed less of an increase in energy expenditure in comparison to the amount in the rested state.

The mechanisms by which EPA and DHA modulate energy metabolism are speculated to be due to their ability to activate and bind various PPAR isoforms (Lin et al., 1999). By activating PPARs, changes in energy metabolism may result by influencing mRNA, protein expression, or the activity of various proteins. Proposed changes with EPA and DHA intake include an increase in **1)** mRNA expression of fatty acid translocase/Cluster of Differentiation 36 (FAT/CD36), a transport protein to move fatty acids across the sarcolemmal membrane and also into the mt (Aas et al., 2006); **2)** Fatty acid-binding protein (FABPc), an intracellular transport protein that chaperones fatty acids in the cytoplasm for storage or to the mt for oxidation (Clavel et al., 2002); **3)** mRNA of mt uncoupling protein-3 (UPC3), a transport protein of anions from the inner to the outer mt membrane and the return transfer of protons (Baillie et al., 1999; Bezaire et al., 2005; Gerling & Spriet, unpublished); **4)** mRNA expression of peroxisomal acyl-CoA oxidase, an enzyme that catalyzes fatty acid oxidation (Baillie et al., 1999), and; **5)** an increase carnitine palmitoyltransferase I (CPTI) oxidase, a rate-limiting enzyme in fatty acid oxidation (Power & Newsholme, 1997). Finally, O3FAs may also affect energy metabolism through up-regulation of peroxisome proliferator-activated receptor gamma

coactivator 1-alpha (PGC-1 α), a transcriptional coactivator that is involved in regulating the genes involved in energy metabolism and in mt biogenesis and function (Olesen et al., 2010; Wu et al., 1999). This protein may be also involved in regulating blood pressure, cholesterol homoeostasis, and in the development of obesity (Entrez Gene, 2013).

Much remains unknown regarding how O3FAs influence oxygen consumption and energy expenditure by incorporating into the membrane. Several theories have been proposed to explain the mechanisms of O3FAs. The pacemaker theory proposes that an increase in membrane unsaturation is associated with an elevated metabolic rate by increasing membrane proteins or membrane associated processes. In fact, elevated DHA content in cell membranes has been associated with higher amounts of Ca²⁺-ATPase and Na⁺/K⁺-ATPase proteins which use adenosine triphosphate (ATP) on a continual basis (Hulbert et al., 2005), resulting in an increased ATP consumption and thus a higher metabolic rate (Hulbert, 2007). Another theory suggests that the incorporation of O3FA intake into mt membranes results in an increased oxygen consumption and energy expenditure. This is speculated to occur due to a proton leak across the inner mt membrane via increased UCP3 protein content, which reduces the energy coupled to ATP production and ultimately results in a reduced energy yield (Hulbert et al., 2005).

5.5.2. *Influence of Supplementation on Physical Measures*

The potential of O3FAs to maintain or increase LM is of interest, since beginning around the 3rd decade of life adults experience an annual decline in muscle mass of 0.26 to 0.56% which may result in decreased metabolic and physical health (Visser, 2012). Our results demonstrated a significant increase in LM of 1.6 (\pm 0.67) kg for the FO females without a significant change in BM. Although not significant, a trend for an increase in LM was evident in the FO males 0.9

(± 0.74) kg, while no significant differences were noted in the PL groups. Because O3FA intake has been speculated to increase post-prandial satiety, which may decrease caloric intake and lead to a decreased BM (Buckley & Howe, 2010), we ensured that dietary intake and physical activity (PASE score) remained significantly unchanged during the study period since we were interested in body composition shifts (Table 5.1.). To our knowledge, this is the first study to report an increase in LM with fish oil supplementation in healthy older adults, since most research in older adults has studied the effects in diseased populations (cancer cachexia) (Murphy et al., 2012). One study in a healthy younger adult population (6 males and 16 females; 33 ± 13 yr, mean + SD) demonstrated a decrease in FM and an increase in LM without a change in BM after 6 wks of supplementation with 1.6 g/d of EPA and 0.8 g/d of DHA (Noreen et al., 2010). Our findings are also in agreement with observations in rodents where O3FA intake resulted in an increase in LM without a significant change in body mass when controlling for diet and physical activity (Su & Jones, 1993). The use of a more precise measurement of body composition, such as dual x-ray absorptiometry or magnetic resonance imaging, is needed to detail where this increase in LM is occurring.

Very little research has been conducted regarding the role of FO supplementation on strength and physical function. Although we did not observe significant increases in combined grip strength, the FO females did experience a small but significant (7%) increase in physical function, as determined by TUG speed (0.5 ± 0.2 s) (Table 5.1.). This is the first study to report a small but significant effect of FO supplementation and TUG speed in older adults independent of a physical training protocol. Previous research in older women ($n=45$, 64 ± 1.4 yrs) has reported that FO supplementation (2 g/d), in addition to a 90 d strength training protocol, resulted in significant increases in functional capacity (sit to stand test but not walking speed),

muscular strength, and neural activation (as measured by electromyography) which were greater than values achieved by strength training alone (Rodacki et al., 2011). Although the mechanisms to explain the increase in physical function are currently unknown, it is speculated that O3FAs may improve muscular function by increasing both the fluidity of the membrane and acetylcholine sensitivity (Patten et al., 2002). At the neuromuscular junction, acetylcholine assists in muscle contraction by facilitating fast synaptic transmission, resulting in an increased speed of muscle contraction (Patten et al., 2002). O3FA lipid changes of neural membranes may affect endocytosis, exocytosis, membrane fusion, and neurotransmitter uptake and release (Farooqui & Horrocks, 2006). A recent study in rodents has demonstrated that O3FA supplementation resulted in an increase in peripheral nerve function after injury (Gladman et al., 2012). Therefore, neuronal function declines with age and O3FA supplementation may provide a strategy to ameliorate some of this decline, although more research into this area is needed. Potential reasons for why we did not observe any changes over the supplementation period in physical function (males alone) and grip strength may be because the majority of the participants had healthy values. Also, it may be that a physical stimulus is required to illicit these effects and O3FAs may only be of benefit in addition to physical activity. Further, it may be more advantageous to measure lower body strength (quadriceps) than handgrip strength, since 1) strength declines with age occur to a greater extent in the muscles of the lower body (Janssen et al., 1999), and; 2) osteoarthritis in the hands may also confound the measure.

5.5.3. *Influence of Supplementation on Blood Measures*

Plasma triglycerides were the only blood measure that changed significantly with supplementation, where the FO males had a 32% decrease (0.37 ± 0.09 mmol/L) and the FO females had a 23% decrease (0.29 ± 0.08 mmol/L), while no significant differences occurred in

the PL groups. The effects of fish oil supplementation on TGs are well documented, and our results are similar to changes reported by numerous other studies, with an average decrease of approximately 30% (Harris et al., 2008). Other metabolic effects of fish oils on lipid profile have been reported and include a small increase of LDL and HDL cholesterol (Balk et al., 2006). Although the FO females followed these blood trends, and the FO males had an increase HDL-C but not LDL-C, no significant changes were apparent. Similarly, no significant changes in insulin and glucose levels were found. This finding is consistent with the majority of data reporting that omega-3 fatty acids do not have a role on glucose homeostasis (Balk et al., 2006).

Improvements in cardiovascular measures were evident with FO supplementation. The significant changes in resting heart rate were noticeable after 6 wks of FO supplementation, where the males experienced a 3% decrease (2 bpm), and females a 5% (3 bpm). Similar results were found during exercise where a decrease of 3% (3 bpm) and 2% (2 bpm) occurred for the males and the females. The influence of FO on heart rate variability is well documented, with the greatest decreases occurring in older adults and in those with high resting HR (Mozaffarian et al., 2005). Our cohort had decreases in resting HR that were similar to other studies in healthy older adults (Deslypere, 1992; Vandongen et al., 1993). Diastolic blood pressure, but not systolic blood pressure, was significantly reduced by 8% in the FO males (6 mmHg). No significant difference for BP from baseline measures was found in the females. With respect the BP, a recent study in normotensive younger adults (n=20, 70% female; 35 ± 2.1 yrs) reported a reduction in SBP by 6.8 mmHg and no change in DBP when supplemented with 4 g/d FO (1.6 EPA, 0.8 DHA) for 6 wks (Noreen, 2012). Other research in normotensive middle-aged adults (n=39, 49% female, 40-65 yrs) reported a reduction in DBP by 3.3 mmHg by supplementation of 0.7 g/d of DHA for a 3 month period (Theobald et al., 2007). Meta-analyses of randomized,

controlled trials have reported that intakes in the range of 2-3 g/d of FO results in a decrease in both SBP and DBP, especially in adults older than 45 yrs (Geleijnse et al., 2002).

The cardiovascular benefits of O3FAs are speculated to be due to a number of widespread mechanisms surrounding their preferential incorporation into cell membranes. Potent antiathrogenic and antiarrhythmic properties of these fatty acids act to reduce platelet aggregation by decreasing the metabolism of adhesion molecules, inflammatory processes, and vasoconstriction (Abe et al., 1998; Eritsland et al., 1996; Uauy et al., 1999). In addition, antiarrhythmic effects of O3FAs, particularly DHA, are thought to be related to their ability to inhibit myocardial Ca^{2+} overload (Leaf et al., 1999), ischemic acidosis and K^+ loss (Pepe & McLennan, 1993).

5.5.4. *Limitations and Future Directions*

The majority of O3FA research in older adults is often investigated on populations with disease, and little is known about the effects of supplementation on physical and metabolic markers in healthy individuals. The physical measures (body composition, cardiovascular, and blood) of our cohort appear to be somewhat similar to Canadian population data of adults matched for age and sex (Bryan et al., 2010; Riediger & Clara, 2011; Shields et al., 2010; Statistics Canada, 2010a). Therefore, the research in this paper has the potential to be transferred to the ‘average’ Canadian older adult, especially for the females since the FO and PL supplement groups were well matched for baseline values.

Much remains unknown regarding the potential benefits of O3FAs, especially in community-dwelling older adults. Future research should aim to divide the male participants into supplement groups with similar baseline metabolic measures since there were significant differences between the male FO and PL groups for the resting and exercise HR, RMR, and

resting Fat Ox, with the FO group having lower values than the PL group. The increase in RMR and Fat Ox as observed in the FO males may have been due to initial lower values. Future research should also aim to test a greater number of participants and include a longer period of supplementation (ie. 1 yr) to determine whether the increase in metabolic rate results in changes in body composition. In addition, the consumption of 5 g/d of total FO is difficult to maintain for many older adults, due to increased digestive issues (gastrointestinal discomfort) and the size of the capsules. Determining the optimal dose of FO required to illicit the metabolic and physical benefits is needed.

5.6. SUMMARY

We have demonstrated FO supplementation (2 g/d EPA, 1 g/d DHA) for 12 wks in healthy older adults resulted in 4 novel findings: 1) increased metabolic rate and fat oxidation at rest and during exercise; 2) decreased resting and exercise heart rate; 3) increased lean mass for the females, and; 4) decreased diastolic blood pressure for the males.

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CHAPTER 6

INTEGRATIVE DISCUSSION

6.1. Summary of Results

The proportion of older adults in the population continues to increase and is the world's fastest growing segment of society. Healthy aging is a focus of health care policy and in support of this initiative, a shift from treatment and acute care towards health promotion and prevention has been advocated (PHAC, 2006). Supporting the health of Canadian seniors currently residing in the community is important, since the transition from independent living in the community to residential living occurs primarily due to poor health and disability in older age, and is largely a consequence of chronic disease (Gilmour & Park, 2006, PHAC, 2006). The majority of chronic diseases and disabilities are due to a combination of non-modifiable (i.e., age and heredity) and modifiable (i.e., physical activity and diet) risk factors (Harvey et al., 2002). Physical activity and nutrition are two modifiable factors in older Canadian populations. However, these factors are poorly understood with regard to healthy aging. There are multiple factors (e.g., cognitive, social, physical activity, nutrition) in older adult populations that may improve health. It is currently unknown how powerful these factors may be if the majority of the population were to meet the physical activity and nutrition guideline requirements proposed by experts in this field of study. To address these lifestyle factors and their impact on the health of older adults, this thesis set out to conduct three research studies, two observational and one interventional, in community-dwelling older adults.

The first study determined whether relationships existed between the PASE questionnaire scores and health-related measurements, including body composition, cardiovascular and blood, strength, flexibility, and nutrition (SCREEN questionnaire) in meal-delivery volunteers. Since nutritional data was missing from the first study, and since the majority of the participants recruited for aging research at the university come from high socioeconomic status than the

average Canadian population, the second study examined nutrient intake from food alone, the use of supplements, and the relation between nutrient intake and physical measures of LM and FM, and strength in adults with a high SES. This study also acknowledged the low intake of O3FAs, a family of fatty acids of current interest in research due to the potentially beneficial influence of intake on metabolic and physical measures. The third and final study examined the effects of O3FA intake in the form of fish oil at 5 g/d on metabolic and physical health parameters in healthy older adults who consumed very little O3FA.

Collectively, novel contributions of this thesis include:

- 1) Study 1 (Chapter 3): The PASE questionnaire cannot be used to accurately predict clinically healthy physical measures of body composition, cardiovascular and blood parameters, and flexibility and strength measures. Body composition measures and PASE score demonstrated the most promise in the development of PASE score cut-points. The only PASE score cut-points that could be approximated was WC for both the males and the females. A minimum PASE score of ~140 predicted a favourable WC for males and ~120 a favorable WC for females. This relationship could be used to encourage older adults to become more physically active. Finally, the SCREEN questionnaire indicated that many of the community-dwelling older adults were at nutritional risk.
- 2) Study 2 (Chapter 4): The need for dietary supplement use or the selection of micronutrient dense foods is important in older adult populations, as even populations of higher SES (who do or do not take supplements) still experience a similar risk for inadequate intake of many nutrients. Consuming a daily MVMM resulted in attaining

adequate intake of most nutrients. Finally, vit D intake may be an important nutrient predictor in the maintenance of lean muscle mass.

- 3) Study 3 (Chapter 5): Increased intake of omega-3 fatty acid in the form of fish oils may be a strategic means of combating age-associated metabolic and physical changes, including increasing metabolic rate and fat oxidation at rest and during exercise, and; decreasing HR, BP, and blood TG levels. FO intake has the potential to also increase LM and physical function in females.

6.2. *The Costs Associated with Insufficient Physical Activity and Poor Nutrition*

Healthy aging initiatives are important to the QOL of Canadian seniors, as well as to the economics of the health care system. Physical inactivity and poor nutrition represent a critical cost burden. Approximately \$5.3 billion, or 2.6% of total health care costs in Canada were directly associated with physical inactivity, and \$3.7 billion were indirectly attributable to physical inactivity (Rotermann, 2006). Older adults with injuries and chronic illnesses are the greatest users of health care (Rotermann, 2006). Increasing physical activity would substantially decrease health care spending, and it has been speculated that a 10% decrease in the proportion of individuals who are physical inactive may reduce the annual direct health care costs by \$150 million (Janssen et al., 2012; Katzmarzyk et al., 2000). Initiatives aimed at encouraging and supporting older adults to engage in physical activity and proper nutrition may be the most effective way of preventing and lowering these high health care costs. Research has noted that the most powerful indicators of risk of poor health are body composition measures. In fact, cost associated with obesity in Canada was estimated at \$4.3 billion, or 2.2% of total health care costs (Janssen et al., 2012). Research is accumulating to suggest that WC may be a better estimation

of risk of chronic disease and disability than BMI (Janssen et al., 2004a). Interestingly, the first study demonstrated (Chapter 3) that a PASE score of >140 for males and >120 for females was related to favorable WC. In addition, our data indicated that a PASE score of ~156 and greater was associated with the absence of self-reported chronic disease. With this information a physical activity coordinator at a retirement center could obtain individual PASE scores when necessary, and advise older adults to increase their daily physical activity in a measurable and directed manner to a higher PASE score, a score associated with desirable health parameters. However, this research is in its infancy, and future intervention studies are required to determine the validity and reliability of this approach. A large intervention study would be optimal to first quantify the amount of physical activity performed over a 7 day period and then relate this amount to the participant's PASE score and health parameters. We would further test this relationship by increasing an individual's PASE score by increasing physical activity over a period of time (~12 mo) and measuring the influence on the health parameters. Optimistically, this would provide us with data to suggest that increasing a person's PASE score (activity level) by a certain amount, for a certain period of time, will result in a mean change in various measures of health. This would provide more convincing evidence as to the use of a questionnaire, such as the PASE, to measure and encourage physical activity among older adults.

In comparison to the costs associated with physical inactivity, less research is available on the health care burden of poor nutrition. Health Canada researchers have estimated that poor nutrition accounts for ~\$1.3 billion to direct health costs and \$5.3 billion are attributable to indirect costs (Health Canada, 2003b). We have reported in our first study (Chapter 3) that the majority of community-dwelling older adults who engage in meal-delivery volunteering, are ironically at risk of malnutrition according to the SCREEN II (abbreviated) questionnaire. The

prevalence of risk may be overestimated by using this questionnaire, since only 8 questions are used to determine risk, and the designation is based solely on behaviours surrounding meals (such as eating alone, cooking meals, etc.). These behaviours are associated with increased risk but this does not necessarily translate into future malnutrition. However, in the second study (Chapter 4) we determined that inadequate nutrient intake is common even in the most unlikely older adult populations, such as those with a high socioeconomic status. In addition, vit D appears to be an important nutrient in the prediction of an individual's LM. Since the majority of older adults in Canada, regardless of SES, do not consume a sufficient amount of vit D, this may contribute to a decreased quality and quantity of muscle mass. Research has demonstrated that the skeletal muscle tissue of vit D deficient individuals shows a predominant atrophy of type II muscle fibers (fast twitch) (Boland, 1986) and an increase in intramuscular fat and fibrosis (Yoshikawa et al., 1979). This results in a decrease in the cross-sectional area available to produce force and an increase in the risk of falls, since type II fibers are the strongest fibers recruited in this event (Yoshikawa et al., 1979). Increasing vit D intake (via supplementation) to levels slightly higher than the RDA (20 mcg) for older adults (25 mcg) for a 2 yr period in vit D-deficient stroke patients resulted in an increase in the total percentage of muscle fibres and in type II muscle fiber diameter (Sato et al., 2005). Whether these changes occur in a population that is not deficient but consumes inadequate intake, such as the population we studied, warrants research. Finally, this is just one example where attaining the RDA for a nutrient has physiological benefits that contribute to an increased QOL. In fact, many nutrient intakes from food alone were not sufficient to meet the EAR, let alone the RDA, which is ~20-50% greater. Although nutrition experts in Canada (the Dietitians of Canada) recommend older adults achieve their nutrient requirements through selecting micronutrient-dense foods, with the exception of vit

D, B-12, and calcium where supplement use is suggested, this may not be realistic for the majority of the older adult population. This recommendation predominantly hails from concern that older adults may surpass the tolerable upper limit values for micronutrients and this may lead to negative health consequences if consuming a MVMM in addition to a healthy diet. Our research demonstrated that even those from a privileged background were still unable to achieve the required intakes from food alone, somewhat similar to the percentages denoted by the overall Canadian population data (Health Canada, 2005; 2012). In addition, when supplement intake was added to the intake from food, only a few nutrients that surpassed the UL (i.e., niacin, folate, magnesium); however, this did not appear to be of concern to the majority of the group. Although there exists controversy regarding supplement intake in the form of a MVMM we would suggest, based on our data, that in addition to eating well, adults should attain the EAR by consuming a MVMM. However, the generation of MVMM that provides just the EAR values rather than RDA amounts, with the exception of vit D, B-12, and calcium where RDA amounts may be needed, would be optimal for this population. This would: (1) ensure that nutrient intake does not accumulate above the UL, and (2) encourage older adults to intake a variety of micronutrient-dense foods since they would still need to consume the remaining amounts not provided in the MVMM.

In our final study (Chapter 5), it demonstrated that ~6 wks of fish oil intake (2g/d EPA and 1g/d DHA) increased RMR by 24% for the males and 16% for the females. This translates into an increase in mean daily energy expenditure of ~331 kcal for the males and ~187 kcal for the females. If caloric intake remains constant, over a month this would theoretically translate into a body mass loss of 1.3 kg for males and 0.7 kg for females. It is well known that with increasing age most adults experience a decrease in metabolic rate and skeletal muscle mass, and

an increase in central adiposity. Research has documented an increase in intramuscular fat deposits and the greatest loss of skeletal muscle with age to occur in the lower appendicular muscles. Evidence also suggests that abdominal adiposity may be a more important risk factor for cardiovascular and metabolic disease than is general adiposity (Janssen et al., 2004a). A future study should aim to determine: (1) whether the increase in RMR is temporary or whether it will remain elevated for an indefinite period, (2) whether the increase in RMR results in a decrease in BM or a shift in composition (increase in muscle mass, decrease in FM), and; (3) where the body composition changes (FM and muscle mass) are occurring. Once this information has been determined, it would be beneficial to note the lowest dose of FO needed to illicit these beneficial effects.

The majority of the population does not achieve the recommendations for physical activity, vit D, and DHA and EPA intake. A large intervention study combining these three lifestyle factors and evaluating their effects on RMR, body composition, strength and physical function would be of interest. For example, we would aim to recruit ~100 older adults (50% male) who are sedentary (<60 min/wk of exercise) and intake low amounts of vit D and O3FAs, and randomly divide them among 4 groups: (1) exercise, (2) exercise and vit D, (3) exercise and FO, and (4) exercise, vit D, and FO. We would formulate an exercise regime that meets the physical activity requirements and supplement the respective groups with 800 IU (25 mcg) of vit D and 5 g/d (2 g EPA and 1 g DHA). We would collect measures of PASE score, RMR, body composition, strength, and physical function every 3 months for a year. In addition to these measures we could take muscle biopsies on the FO people and see what mitochondrial and muscle changes have occurred to explain the increased RMR. We hypothesize that the combination of exercise, vit D, and O3FA intake would act synergistically to increase RMR,

muscle mass, strength and physical function. This research would also allow us to evaluate the use of PASE to measure changes in physical health.

6.3. *A Framework For Action*

The research in this thesis supports the Framework for Action, developed by the Public Health Agency of Canada to support healthy aging initiatives (PHAC, 2005). Maintaining independent living in the aging population requires research into increasing physical activity, the promotion of healthy eating, controlling tobacco use to reduce and prevent the incidence of chronic disease and risk of falls, as well as promoting social connectedness (PHAC, 2005). These areas of focus create mechanisms of action, which include supportive environments (age-friendly communities), mutual aid (support for one another), and self-care, that can be used to achieve the healthy aging vision for older adults. Of particular focus within this thesis was self-care, which has been defined as the choices and actions individuals take in the interest of their own health (PHAC, 2005). Best facilitating the self-care choices and actions of older adults is accomplished through providing accessible and reliable information and helping teach learning skills for healthy aging.

6.4. *Limitations & Conclusions*

The main limitations of this thesis include: (1) the low variability of the cohort since most of the participants had clinically healthy values (Chapter 3); (2) the small number of participants (Chapters 4 and 5); (3) the need for a more precise measure of body composition, and; (4) the selection of a suitable placebo (Chapter 5). Moving forward, future research evaluating the use of PASE to predict health should attempt to recruit a more variable (i.e., healthy and unhealthy) population since the majority of the participants had healthy physical values. Body composition

measures with greater precision, such as dual x-ray absorptiometry, will provide more information than BIA, such as the distribution and quality of muscle (intramuscular fat deposits, etc.) and adipose tissue. Finally, the selection of a suitable placebo for fish oil is of debate. We selected olive oil as our placebo, although the effects of olive oil are not completely understood and research has suggested olive oil may induce similar effects to cell membranes and may influence gene expression similar to FO (Periago et al., 1990; Rodríguez et al., 2002). For these reasons, we only provided the participants with 3 g/d of olive oil while the FO group was supplied with 5 g/d. Although we did not observe any significant metabolic and physical changes in the placebo group, it appears that olive oil was a suitable choice in this research. However, a true placebo such as a fat that has no effects is needed.

In addition to the study results provided in the summary, this thesis has given in-depth descriptive characteristics (body composition, cardiovascular and blood, strength and physical function, nutrition and physical activity) of the individuals studied. Due to the great heterogeneity among older adults, descriptive characteristics are essential to compare and contrast the results of one study to another. At this time, very few studies have provided sufficient detail regarding the health of the cohort under examination, making the development of healthy aging guidelines for older adults difficult to interpret and translate to the general Canadian populous (PHAC, 2005).

Physical activity and nutrition are modifiable lifestyle factors that have significant impacts on healthy aging (Harvey et al., 2002). Unfortunately, the majority of older adults in Canada are unaware and/or don't participate in either attaining adequate nutrient intake or physical activity (PHAC, 2005). The optimal amount of these two lifestyle factors required to maintain healthy ranges of descriptive characteristics in healthy cohorts continues to evolve.

Although the Canadian Society for Exercise Science has developed Canadian guidelines for structured exercise (Tremblay et al., 2011), most older adults engage in everyday physical activities of independent living (EAL) (i.e., cleaning the house, yard work, shopping for groceries, etc.) and do not wish to engage in structured exercise (Canadian Fitness and Lifestyle Research Institute, 2006). Therefore, more research needs to accrue as to the quantity and significance of EAL and their contributions to health. Although HR is not a direct measure of physical activity, the volume (i.e., frequency, intensity, and duration) of physical activity can be easily estimated from continuous monitoring of the HR. Therefore, a possible method of investigating the contribution of EAL to daily physical activity would involve monitoring the HR and recording the various activities participants engage in over the course of a week. From this we could determine how much time and for how long the participant engaged in moderate-intensity activity. It would also be of interest to know what exact activities the participant was involved in to illicit this increase (e.g., sweeping, climbing stairs, etc.). To execute this study, we would recruit a large sample (~300) of older adults and divide them into groups based on their self-reported activity and exercise. We would hypothesize that those who engage in a high level of basic daily activities and not much exercise would have similar amount of time their HR is elevated to a moderate-intensity level throughout the day to those that participate in moderate exercise and very little EAL. The next step of this research would involve instructing the participants who engage in EAL but only at low-intensity levels to increase their HR to a certain range indicative of moderate-intensity for ~20 min/d, so rather than engaging formal exercise, engaging in EAL while ensuring their HR is in the moderate-intensity zone. By increasing the intensity of EAL an older adult who does not want to engage in formal exercise will be able to increase their HR for ~150 min/wk as recommended by physical activity guidelines. However,

muscle strengthening activities would need to be performed to fully achieve the guidelines, and this, unfortunately for adults who do not like to engage in formal exercise, may require this approach. In conclusion, monitoring physical activity and the amount needed for positive health parameters is essential to guide and prescribe exercise for this population. The use of a monitoring questionnaire for physical activity may be of benefit to provide goals for each person, and to provide the counselling necessary to reach those goals. This approach fits into the Framework of Action, developed by the Public Health Agency of Canada, by encouraging self-care, mutual aid, and supportive environments for older adults in the community (PHAC, 2005).

Nutritional analysis indicated that even populations with high SES still experienced nutrient inadequacies which may increase their risk of chronic disease, disability, and amount of time remaining independent in the community (Chapter 4). Monitoring and educational resources are essential to encourage and support older adults in the consumption of micronutrient dense foods, and if this is not possible, to take a dietary supplement to attain amounts outlined by Health Canada (Health Canada, 2013a). The potential benefits of O3FAs may be an important dietary strategy in older populations to increase RMR, which may allow the older adult to consume more calories, and thus intake more micronutrients. By increasing metabolic rate decreases in FM may occur (Chapter 5). Finally, the potential for O3FAs to stimulate muscle protein synthesis may translate into an increase in LM (Smith et al, 2011). However, research into O3FAs and the metabolic and physical effects in healthy older adult populations is in its infancy and further research is needed to validate results reported in this thesis.

Healthy aging research is not only essential to the well-being of older adults but also to the economic health of our population, by reducing health care cost in Canada (Health Canada, 2003b; Janssen et al., 2012; Katzmarzyk et al., 2000). For these reasons, additional research on

optimal physical activity and nutrition for healthy aging, and research into monitoring and educating older adult populations of the health benefits associated with optimal physical activity and nutrition is essential and timely.

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6.6. APPENDIX A

The Physical Activity Scale for the Elderly (PASE) Questionnaire

Instructions

****For participant to complete.*** Please read each question carefully and check the box that best represents your response.

LEISURE TIME ACTIVITIES

1. Over the past 7 days, how often did you participate in sitting activities such as reading, watching TV or doing handcrafts?

- Never → Go to Question 2
 - Seldom (1-2 days)
 - Sometimes (3-4 days)
 - Often (5-7 days)
- } Fill out parts 1a. and 1b.

<p>1a. What were these activities? _____</p> <p>1b. On average, how many hours per day did you engage in these activities <u>on these days</u>?</p> <p><input type="checkbox"/> Less than 1 hour <input type="checkbox"/> Between 1-2 hours</p> <p><input type="checkbox"/> 2-4 hours <input type="checkbox"/> More than 4 hours</p>
--

2. Over the past 7 days, how often did you take a walk outside your home or yard for any reason? For example for fun or exercise, walking to work, walking the dog, etc.

- Never → Go to Question 3
 - Seldom (1-2 days)
 - Sometimes (3-4 days)
 - Often (5-7 days)
- } Fill out part 2a.

<p>2b. On average, how many hours per day do you engage in this activity or these activities <u>on these days</u>?</p> <p><input type="checkbox"/> Less than 1 hour <input type="checkbox"/> Between 1-2 hours</p> <p><input type="checkbox"/> 2-4 hours <input type="checkbox"/> More than 4 hours</p>
--

3. Over the past 7 days, how often did you engage in light sport or recreational activities such as ‘light’ cycling on an exercise bike, lawn bowling, bowling, water aerobics, golf with a cart, yoga, tai chi, fishing or other similar activities?

- Never → Go to Question 5
 - Seldom (1-2 days)
 - Sometimes (3-4 days)
 - Often (5-7 days)
- } Fill out parts 4a. and 4b.

<p>3a. What were these activities? _____</p> <p>3b. On average, how many hours per day did you engage in these activities <u>on these days</u>?</p> <p><input type="checkbox"/> Less than 1 hour <input type="checkbox"/> Between 1-2 hours</p> <p><input type="checkbox"/> 2-4 hours <input type="checkbox"/> More than 4 hours</p>
--

4. Over the past 7 days, how often did you engage in moderate sport or recreational activities such as doubles tennis, ballroom dancing, golf without a cart, softball or other similar activities?

- Never → Go to Question 6
 - Seldom (1-2 days)
 - Sometimes (3-4 days)
 - Often (5-7 days)
- } Fill out parts 5a. and 5b.

<p>4a. What were these activities? _____</p> <p>4b. On average, how many hours per day did you engage in these activities <u>on these days</u>?</p> <p><input type="checkbox"/> Less than 1 hour <input type="checkbox"/> Between 1-2 hours</p> <p><input type="checkbox"/> 2-4 hours <input type="checkbox"/> More than 4 hours</p>
--

5. Over the past 7 days, how often did you engage in strenuous sport and recreational activities such as jogging, swimming, cycling, singles tennis, aerobic dance or other similar activities?

- Never → Go to Question 7
 - Seldom (1-2 days)
 - Sometimes (3-4 days)
 - Often (5-7 days)
- } Fill out parts 6a. and 6b.

5a. What were these activities? _____

5b. On average, how many hours per day did you engage in these activities on these days?

Less than 1 hour Between 1-2 hours

2-4 hours More than 4 hours

6. Over the past 7 days, how often did you exercise specifically to increase muscle strength and endurance such as lifting weights or push-ups, etc?

- Never → Go to Question 8
- Seldom (1-2 days)
- Sometimes (3-4 days)
- Often (5-7 days)
- } Fill out parts 7a. and 7b.

6a. What were these activities? _____

6b. On average, how many hours per day did you engage in these activities on these days?

Less than 1 hour Between 1-2 hours

2-4 hours More than 4 hours

HOUSEHOLD ACTIVITIES

7. During the past 7 days, have you done any light housework such as dusting or washing dishes?

No Yes

8. During the past 7 days, have you done any heavy housework or chores such as vacuuming, scrubbing floors, washing windows or carrying wood?

No Yes

9. During the past 7 days, did you engage in any of the following activities:

- a.** Home repairs like painting, wallpapering, electrical, etc. No Yes
- b.** Lawn work or yard care including snow or leaf removal, etc. No Yes
- c.** Outdoor gardening No Yes
- d.** Caring for another person such as a dependent child, spouse or another adult No Yes

WORK-RELATED ACTIVITIES

10. During the past 7 days, did you work for pay or as a volunteer?

No → Go to Question 12

Yes → Fill out parts 11a and 11b.

10a. How many hours per day did you work/volunteer? _____ hours

10b. Which of the following categories best describes the amount of physical activity required on your job/volunteer work?

- Mainly sitting with light arm movements
- Sitting or standing with some walking
- Walking with material handling less than 50 pounds
- Walking with heavy material handling weighing more than 50 pounds

6.7. APPENDIX B

The Rand Short Form 36 Questionnaire

Instructions

**For participant to complete.* Please answer every question by carefully reading and checking the box that best represents your response. Some of the questions may look like others, but each one is different.

1. In general, would you say your health is:

1. Excellent
2. Very Good
3. Good
4. Fair
5. Poor

2. Compared to one year ago, how would you rate your health in general now?

1. Much better now than one year ago
2. Somewhat better now than one year ago
3. About the same as one year ago
4. Somewhat worse now than one year ago
5. Much worse than one year ago

The following items are about activities you might do during a typical day. Does your health limit you in these activities? If so, how much?

3. **Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports.

1. Yes, limited a lot
2. Yes, limited a little
3. No, not limited at all

4. **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling or playing golf.

1. Yes, limited a lot
2. Yes, limited a little
3. No, not limited at all

5. Lifting or carrying groceries.

1. Yes, limited a lot
2. Yes, limited a little
3. No, not limited at all

6. Climbing several flights of stairs.
1. Yes, limited a lot
 2. Yes, limited a little
 3. No, not limited at all

7. Climbing one flight of stairs.
1. Yes, limited a lot
 2. Yes, limited a little
 3. No, not limited at all

8. Bending, kneeling, or stooping.
1. Yes, limited a lot
 2. Yes, limited a little
 3. No, not limited at all

9. Walking more than a mile.
1. Yes, limited a lot
 2. Yes, limited a little
 3. No, not limited at all

10. Walking several blocks.
1. Yes, limited a lot
 2. Yes, limited a little
 3. No, not limited at all

11. Walking one block.
1. Yes, limited a lot
 2. Yes, limited a little
 3. No, not limited at all

12. Bathing or dressing yourself.
1. Yes, limited a lot
 2. Yes, limited a little
 3. No, not limited at all

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your PHYSICAL HEALTH?

13. Cut down the amount of time you spent on work or other activities.
1. Yes
 2. No

14. Accomplished less than you would like.

1. Yes
2. No

15. Were limited in the kind of work or other activities.

1. Yes
2. No

16. Had difficulty performing the work or other activities (for example, it took extra effort).

1. Yes
2. No

During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any EMOTIONAL PROBLEMS (such as feeling depressed or anxious)?

17. Cut down the amount of time you spent on work or other activities.

1. Yes
2. No

18. Accomplished less than you would like.

1. Yes
2. No

19. Didn't do work or other activities as carefully as usual.

1. Yes
2. No

20. During the past 4 weeks, to what extent has your physical health OR emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

1. Not at all
2. Slightly
3. Moderately
4. Quite a bit
5. Extremely

21. How much bodily pain have you had during the past 4 weeks?

1. None
2. Very mild
3. Mild
4. Moderate
5. Severe
6. Very severe

22. During the past 4 weeks how much did pain interfere with your normal work (including both work outside the home and housework)?

1. Not at all
2. A little bit
3. Moderately
4. Quite a bit
5. Extremely

These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling.

23. How much of the time during the past 4 weeks: Did you feel full of pep?

1. All of the time
2. Most of the time
3. A good bit of the time
4. Some of the time
5. A little of the time
6. None of the time

24. Have you been a very nervous person?

1. All of the time
2. Most of the time
3. A good bit of the time
4. Some of the time
5. A little of the time
6. None of the time

25. Have you felt so down in the dumps that nothing could cheer you up?

1. All of the time
2. Most of the time
3. A good bit of the time
4. Some of the time
5. A little of the time
6. None of the time

26. Have you felt calm and peaceful?

1. All of the time
2. Most of the time
3. A good bit of the time
4. Some of the time
5. A little of the time
6. None of the time

27. Did you have a lot of energy?

1. All of the time
2. Most of the time
3. A good bit of the time
4. Some of the time
5. A little of the time
6. None of the time

28. Have you felt downhearted and blue?

1. All of the time
2. Most of the time
3. A good bit of the time
4. Some of the time
5. A little of the time
6. None of the time

29. Did you feel worn out?

1. All of the time
2. Most of the time
3. A good bit of the time
4. Some of the time
5. A little of the time
6. None of the time

30. Have you been a happy person?
1. All of the time
 2. Most of the time
 3. A good bit of the time
 4. Some of the time
 5. A little of the time
 6. None of the time

31. Did you feel tired?
1. All of the time
 2. Most of the time
 3. A good bit of the time
 4. Some of the time
 5. A little of the time
 6. None of the time

32. During the past 4 weeks has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?
1. All of the time
 2. Most of the time
 3. Some of the time
 4. A little of the time
 5. None of the time

33. How true or false is the following statement? I seem to get sick a little easier than other people.
1. Definitely true
 2. Mostly true
 3. Don't know
 4. Mostly false
 5. Definitely false

34. How true or false is the following statement? I am as healthy as anybody I know.
1. Definitely true
 2. Mostly true
 3. Don't know
 4. Mostly false
 5. Definitely false

35. How true or false is the following statement? I expect my health to get worse.

1. Definitely true
2. Mostly true
3. Don't know
4. Mostly false
5. Definitely false

36. How true or false is the following statement? My health is excellent.

1. Definitely true
2. Mostly true
3. Don't know
4. Mostly false
5. Definitely false

6.8. APPENDIX C

The Seniors in the Community Risk Evaluation for Eating and Nutrition II Abbreviated Questionnaire (SCREEN II AB)

Rate your eating habits. For each question, check only one box that describes you best. Your response should reflect your typical eating habits. Feel free to write comments beside any question.

1. Has your weight changed in the past 6 months?

8 No, my weight stayed within a few pounds.

0 I don't know how much I weigh or if my weight has changed.

Yes, *I gained ...*

0 more than 10 pounds *Comments?*

2 6 to 10 pounds

4 about 5 pounds

Yes, *I lost ...*

0 more than 10 pounds

2 6 to 10 pounds

4 about 5 pounds

2. Do you skip meals?

8 Never or rarely

4 Sometimes

2 Often

0 Almost every day

3. How would you describe your appetite?

8 Very good

6 Good

4 Fair

0 Poor

4. Do you cough, choke or have pain when swallowing food OR fluids?

8 Never

6 Rarely

2 Sometimes

0 Often or always

5. How many pieces or servings of fruit and vegetables do you eat in a day?

Fruit and vegetables can be canned, fresh, frozen, or juice.

4 Five or more

3 Four

2 Three

1 Two

0 Less than two

6. How much fluid do you drink in a day?

Examples are water, tea, coffee, herbal drinks, juice, and soft drinks, but not alcohol.

- 4 Eight or more cups
- 3 Five to seven cups
- 2 Three to four cups
- 1 About two cups
- 0 Less than two cups

7. Do you eat one or more meals a day with someone?

- 0 Never or rarely
- 2 Sometimes
- 3 Often
- 4 Almost always

8. Which statement best describes meal preparation for you?

- 4 I enjoy cooking most of my meals.
- 2 I *sometimes* find cooking a chore.
- 0 I *usually* find cooking a chore.
- 4 I'm *satisfied* with the quality of food prepared by others.
- 0 I'm *not satisfied* with the quality of food prepared by others.

Thank you for telling us about your eating habits.