Physical Activity Levels and Barriers to Exercise in Individuals with Low Bone Mineral Density

by

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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Science
in
Kinesiology

Waterloo, Ontario, Canada, 2013

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

Background: Fractures are a major health concern for older adults, especially for those with osteoporosis or low bone mineral density (BMD). Physical activity and exercise can be important self-management strategies for older adults with osteoporosis or low BMD to prevent fractures.

Objectives: This study examined the physical activity and exercise levels of older adults with low BMD and determined the proportion of individuals meeting the Canadian Physical Activity Guidelines. As well, this study characterized perceived individuals' barriers to exercise and their willingness to pay for different methods of delivering exercise information. Secondary goals of this study were to investigate correlates of aerobic exercise and factors associated with meeting moderate- to vigorous-intensity aerobic physical activity guidelines.

Methods: Individuals aged 50 years or older with a self-reported diagnosis of low BMD were recruited from the Canadian Osteoporosis Patient Network (COPN) and an osteoporosis public education event. Questionnaires were distributed online and through mail to individuals interested in participating. Participants were asked about the amount of time they spent doing moderate- and vigorous-intensity physical activity (MVPA) and the frequency at which they did strength and balance training per week. Also, participants were asked about potential barriers to exercise that they perceive, the strength at which they perceived those barriers at, and their interest in and willingness to pay (WTP) for different methods of delivering exercise information. Information about different factors affecting exercise behaviour such as risk perception, intention to exercise, and exercise self-efficacy were collected as well.

Results: The total number of participants included in this study was 130 (mean [SD] age 66.32 [8.81] years). The mean (SD) time spent doing MVPA per week reported by participants was 831.35 (1065.43) minutes. The mean (SD) days per week that participants reported doing strength and balance training were 1.90 (1.66) and 1.36 (1.84), respectively. Sixteen individuals (12.3%) did not meet the guideline of engaging in at least 150 minutes of MVPA per week. Forty-one participants (31.5%) did not report doing any strength training and sixty-five individuals (50%) did not report doing any balance training. The most prevalent barriers to exercise that were reported was having no enjoyment for exercise (51.2%) , having no company to exercise with (47.2%), and health-related problems (37.5%). Although a majority of participants expressed interest in all methods of delivering exercise information, the mean WTP for a group exercise class and for training one-on-one with a certified personal trainer was lower than the suggested amounts that they would normally cost. Factors associated with meeting MVPA recommendations were intention to exercise ($p = 0.03$), exercise self-efficacy ($p = 0.03$), and strength of perceived barriers ($p = 0.02$).

Conclusion: Many older adults with low bone mineral density are not meeting established physical activity guidelines. Greater measures need to be taken in promoting strength and balance training among these individuals. Addressing barriers to exercise may be an effective strategy to encourage individuals with low bone mineral density to become more active.

Acknowledgements

As I become closer to finishing my thesis, I am slowly realizing that I am approaching the end to another chapter of my life, the completion of my Masters of Science degree. My experience in graduate school has been a challenging and uncomfortable one, however, it has also been very rewarding and has allowed me to grow in ways that I don’t think I would have otherwise. I would not have been able to reach this point of my life without the love and support of many people around me. Writing has never been my forte and even though I have had many opportunities to work on this skill, I find myself still struggling to put words onto paper and to communicate my thoughts in a clear and eloquent manner. I hope that my words here can adequately convey the amount of gratitude that I have for those who have helped me throughout this journey.

Firstly, I need to thank my graduate supervisor, Dr. Lora Giangregorio. Thank you for providing me the opportunity to pursue post-graduate education and to be a part of your research team. Thank you for teaching me that some of life’s most important lessons are learned under the toughest circumstances and that learning is an uncomfortable but fulfilling process. The growth that I have experienced within the last two years would not have happened had you not challenged me to continually work on my weaknesses and to always put forth my best efforts. As well, from you, I have learned the importance of thinking critically and to communicate messages in a clear and concise manner. Thank you for believing in me and seeing my potential. Much of my achievement and improvement can be credited to you and words cannot truly express how much I appreciate the guidance and support that you have given me over the course of my Master degree. I will be sure to take the lessons that I have learnt here and apply them to whatever I will be doing in the future. Like you, I hope to be able to find a problem that I am passionate about and to build a career around trying to solve that problem. Your mentorship has led me to grow academically and personally and for that, I am truly grateful.

I would also like to thank my committee members, Dr. Paul Stolee and Dr. Bill McIlroy who provided me with useful feedback during my proposal. Your questions and insights have led me to think about my thesis in ways that I did not before and have helped me grasp the significance of my work. As well, I would like to thank Osteoporosis Canada, particularly Christine Cruz, for helping me advertise and distribute my survey to the members of the Canadian Osteoporosis Patient Network. In addition, I would like to show appreciation to all the individuals who participated in my study because if it were not for them, I would have no data or thesis to work with.

Another individual I need to thank is Dr. James Tung who has also played a significant role during my time here at UW. If it were not for your continual support and belief in my abilities, I would not have been able to reach this point in my degree. Thank you for always taking the time to talk with me when I needed advice or for providing me with feedback whenever I asked for it. It has truly been a pleasure to work with you and I am so thankful to have had this opportunity. Thank you so much for helping me get through the tough times of graduate school, your wise words always managed to provide me with a sense of comfort and relief. You have been like a second mentor to me and I am very lucky to have learned so many things from you (including what jungle music is!).

Thank you to all my colleagues and peers at UW. My graduate student experience would have not been as enjoyable without your friendship and support. Thank you for listening to me when I spoke about my troubles or for providing me with feedback on my work when I asked for it. In particular, I would also like to extend a thank you to my past and present lab mates: Symron Bansal, Cameron Moore, Carly Skidmore, and Dr. Cheryl Lynch. Thank you for helping me make my thesis better by providing me with constructive criticism and taking the time to allow me to practice my presentation in front of you. In addition, thank you for your encouragement. I am very grateful to have met and been able to work with all of you.

I would like to thank my parents, Dennis and Rosanna, who have continually supported my choice to pursue my Master degree and have taught me the value of education. Throughout my life, you have shown me what it means to work hard and provided me with the tools to be successful. I hope that the milestones that I have achieved here have made you proud of me and demonstrated to you that I have taken to heart the many lessons that you have taught me. I could not have asked for better parents and the love and care that you have dedicated to me has allowed me to become the person that I am today. I would also like to thank my little sister, Heidi. Thank you for comforting me during my times of stress and hardship. I hope to be able to provide you with guidance and lend you an ear when you have troubles in the future or when you embark on your own journey in university.

Lastly, I would like to thank my friends. There are too many of you to list individually, but each and every one of you played a role in helping me get to where I am. The last couple of months of graduate school were particularly difficult and you picked me up when I couldn't pick myself up. Thank you for listening to me and providing me with comfort when I came to you with my worries. Thank you for giving me the courage to face my challenges and believing that I could always overcome whatever obstacles that came my way. I cannot express enough how much I cherish and appreciate my friendship with each of you.

Everyone that I have mentioned above played an integral part in helping me reach this point of my Masters degree. Through my experience at UW, I have learned to become a better person, student, and researcher. I look forward to being able to take what I have learned here and use it in my future endeavors. And with that, I would like to end with a quote that encapsulates what I have taken away most from this experience: "Be willing to be uncomfortable. Be comfortable being uncomfortable. It may get tough, but it's a small price to pay for living a dream" – Peter McWilliams.

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1.0 Chapter 1: Introduction

1.1 Rationale

Fractures are a major health concern for older adults and pose a growing societal burden. Approximately 75% of vertebral, hip, and wrist fractures occur among individuals the age of 65 years or older (1). As well, fractures are associated with significant increases in mortality, decreases in quality of life and independence, and functional decline (2,3). Fractures place a financial burden on the affected individual, and pose a substantial economic burden on the healthcare system (4). As the older adult population is rapidly growing, fractures and their associated adverse outcomes will become greater problems to the healthcare system (5). Therefore, it is important to seek appropriate approaches to prevent and manage fractures in older adults.

One major risk factor for fractures is osteoporosis. Osteoporosis, or low bone mineral density (BMD), is highly prevalent among older adults and is associated with 80% of fractures in this population (6). While there are pharmacologic interventions, such as antiresorptive and anabolic therapies, available to help manage osteoporosis, the inclusion of other management strategies can help to further minimize the risk of fracture. Important strategies to decrease fracture risk in older adults are physical activity and exercise participation. Physical activity is defined as “bodily movement produced by skeletal muscles which results in energy expenditure” (7). Engaging in physical activity can decrease the risk of fracture by maintaining or increasing bone mineral density and decreasing the risk of falls-- the most common mechanism for fractures (8). Exercise is “planned, structured, and repetitive movement performed to improve or maintain physical fitness” (7). Strength training has been shown to be effective for increasing bone mineral density, and balance training has shown to be effective for reducing falls in older adults (8,9). Furthermore, there are many additional benefits of regular physical activity participation such as improved cardiovascular function, self-perceived health and reduced functional decline (10–12).

Despite the known benefits of engaging in physical activity and exercise, activity levels of older adults, including those with osteoporosis, remain quite low (5,13). In particular, older adults at risk for osteoporosis have exhibited low levels of adherence to exercise programs (14). Thus, finding ways of improving physical activity levels and adherence to exercise and promoting strength and balance exercises, is important for decreasing fracture risk in older adults at risk for or with osteoporosis.

There are a number of health behavior change models used to promote adoption of certain health behaviors, one being the Health Action Process Approach (HAPA) (15). HAPA suggests that external factors such as perceiving barriers will influence an individual's intention and action to initiate and maintain new health behaviours (15). In this case, barriers would consist of factors that may hinder intention and action to engage in physical activity. Examples of barriers include lack of motivation and having health-related complications. Another area that also needs further investigation among older adults with low bone mineral density is their willingness to pay for exercise. Willingness to pay can be a method of quantifying the strength of an individual's preferences or to what degree an individual may view cost as a barrier (16). Identifying provisions of exercise that are associated with a high willingness to pay among older adults with low BMD may help determine their preferences for exercise and different aspects of exercise that they may value. As well, it may provide insight into whether these individuals perceive cost as a barrier to exercise.

The goal of this thesis is to characterize current levels of physical activity among older adults with osteoporosis. This thesis will identify barriers to exercise and determine their willingness to pay for different methods of delivering exercise information. In doing so, this study may provide information for developing effective ways of encouraging these individuals to become more active and to adhere to their exercise programs. Furthermore, it may provide insight into the degree to which these individuals view cost as a barrier and provide an indication of their intention to participate in physical activity, as well as their preferences. The outcomes of this thesis may inform strategies to help older adults incorporate exercise into their strategies for managing osteoporosis.

1.2 Study Aims

The aim of this study is to obtain a deeper understanding of: 1) current levels and types of physical activity that older adults with low bone mineral density engage in and 2) external factors that affect intention and action to participate in exercise for these individuals. The results of this study may help inform potential methods of helping these individuals incorporate exercise into their strategies for managing osteoporosis. Encouraging individuals in this population to integrate exercise into their self-management strategies may help increase levels of exercise adherence and contribute to decreasing their fracture risk.

The primary aim of this study is to characterize current levels and types of physical activity, barriers to exercise, and willingness to pay for different provisions of exercise in older adults with low BMD. Secondary aims are to determine correlates of leisure time physical aerobic activity and factors associated with meeting recommended moderate- to vigorous-intensity physical activity guidelines in these individuals.

2.0 Chapter 2: Background

2.1 Fractures

2.1.1 Epidemiology

There is a high incidence of fractures among older adults. In the year 2000, an estimated 9.0 million fractures were sustained worldwide (17). The most common sites of fracture are at the vertebrae, hip, and wrist (18). The prevalence rates of vertebral fractures are greatly underestimated because many fractures are asymptomatic and are commonly undiagnosed without noticeable pain or height loss (19). Fracture rates greatly increase with age and the prevalence of vertebral fracture is 23.5% and 21.5% in women and men respectively over the age of 50 years (20,21). Roughly 1.6 million hip fractures occur annually worldwide, with approximately 80% of cases being women (22,23). Wrist fractures are the most frequent fragility fractures observed in older adults under the age of 75 and are most commonly found in postmenopausal women (24). Fracture prevalence is expected to increase due to the increasing older adult population. By the year 2051, approximately one in four Canadians is expected to be aged 65 or older, and about 40% of older adults will reach the age of 90 (25). As well, by the year 2050, hip fracture prevalence is expected to increase to 4.5 million (26). Therefore, it is important to understand the negative consequences and risk factors associated with fractures in order to decrease their incidence among older adults.

2.1.2 Adverse Outcomes Associated with Fractures

Fractures sustained at the vertebrae, hip, and wrist have been associated with decreased function, independence, quality of life, or increased mortality. Vertebral fractures are associated with limitations in spine mobility, chronic back pain, and decreased pulmonary function (27–30). These functional impairments can lead to difficulties with activities of daily living. For instance, older adults may have difficulties with rising from a chair, bathing, dressing, cooking, climbing stairs, and walking (31–33). Moreover, their quality of life is further impacted by psychological and social consequences of fractures such as anxiety, depression, loss of social roles, and social isolation (34). Individuals who have sustained vertebral fractures have a fivefold increased risk for future vertebral fractures and a threefold increase in risk for hip fractures (35–37). Moreover, vertebral fractures are linked with an increased risk of mortality, especially in women (38,39).

Similar to vertebral fractures, hip fractures can negatively impact quality of life, independence, and survival. Hip fractures can decrease one's capacity to perform activities of daily living such as ambulation, chair/bed transfers, climbing stairs, use of toilet, bathing and dressing (40). Furthermore, individuals who have sustained a hip fracture can experience depression, cognitive impairment and/or a fear of falling which are also associated with negative functional outcomes (41–43). As well, a loss of independence may occur after sustaining a hip fracture. One study found that merely 40% of surviving individuals reacquire their level of mobility pre-fracture, 25% return to their former functional status, and up to 33% of patients become institutionalized one year after sustaining a hip fracture (44,45). Hip fractures are considered the most serious type of fracture due to their association with a high mortality rate. Individuals that have sustained hip fractures, especially women, are at an increased risk of death during the first year of follow-up and the increased risk persists for at least five years afterwards (46,47).

Unlike vertebral and hip fractures, wrist fractures have little impact on mortality; however, they still adversely affect quality of life and substantially increase the risk for future fractures (46). A progressive functional decline can be initiated by the occurrence of wrist injury and remain apparent for three years (48). Wrist fractures increase the risk for future fractures at other sites. The risk of vertebral fracture can be heightened 5.2- fold in women and 10.7-fold in men following wrist fracture at all ages (49). Likewise, the risk of hip fracture increases 1.4-fold and 2.7-fold in women and men, respectively, after a wrist fracture; however, the excess risk observed in women is only applicable to those who sustained their first wrist fracture at age 70 years or older (49). Previous wrist fractures can act as strong indicators of the three-year risk of future osteoporotic fractures in post-menopausal women (50). It is evident that vertebral, hip, and wrist fractures adversely impact the individuals who sustain them. However, these types of fractures can produce negative economic effects as well.

2.1.3 Economic Burden Associated with Fractures

Vertebral, hip, and wrist fractures have substantial economic implications for the healthcare system. Treatment of fractures can lead to direct medical costs including cost of prescription drugs, physician billings, hospitalizations, nursing home admissions, and home care services (51). These direct medical costs can create a considerable economic burden. In a population-based cost-of-illness analysis, Leslie et al (2011) identified incremental costs between the year before and after fracture associated with the three most common sites of fracture in Canadian older adults over a ten year period. These authors found that among all fracture types, hip fractures were linked with the largest total incremental costs, with median increases of $16,171 and $13,111 for women and men, respectively. Vertebral fractures were associated with the second greatest incremental costs, $8,345 in women and $6,267 in men, and wrist fractures were associated with the lowest costs, $663 and $764 in women and men correspondingly (51).

Overall, direct health care costs due to vertebral, hip, and wrist fractures demonstrated staggering pre- and post-fracture incremental costs in health care utilization; the amounts surpassed $245 million Canadian in women and $108 million Canadian in men over the ten year study period (51). It is evident that there are many adverse outcomes associated with fractures. As well, the economic burden attributed to fracture treatment and management is quite substantial. In order to seek feasible solutions to minimize these adverse outcomes and economic burden, it is imperative to recognize and understand fracture risk factors to develop effective methods of preventing fractures.

2.1.4 Risk Factors for Fractures

Amongst a number of risk factors identified to be associated with an increased risk of fracture, two significant risk factors for fractures are being at an increased risk of falls and decreased bone mineral density. Other common risk factors and their effects on fracture risk researched from a selection of academic literature are shown in Table 1.

Table 1: Common Risk Factors for Fractures and their Effects

Risk Factor	Description
Age	Lifetime risk of fracture increases with age until the age of 70
Sex	Women have a higher risk for fracture than men
Weight	Body mass index (BMI) is an indicator of body density and is determined by the relationship between weight and height. Low BMI has been indicated has a risk factor for future fracture
Height	
Previous Fracture	Presence of prior fractures approximately doubles fracture risk
Parental Hip Fracture	Parental history of fracture indicates greater risk of fracture
Smoking	Smoking is associated with decreases in bone mineral density which increases risk of fracture
Oral Glucocorticoid Use	Glucocorticoids can cause osteoporosis and increase risk of fracture however, the elevated risk is not only reliant on bone loss
Rheumatoid Arthritis	Rheumatoid arthritis increases fracture risk that is independent of bone mineral density and glucocorticoid use
Secondary Osteoporosis	There is an increased rate of bone loss in secondary osteoporosis therefore increasing risk of fracture
Alcohol ≥ 3 Units Daily	Alcohol intake of more than 3 units per day has a dose-dependent relationship with increased risk in fracture
Femoral Neck BMD	Decreased femoral neck bone mineral density is an indicator of fracture risk

(Reference (52–63))

An increased risk of falls can lead to greater risk of fracture. Approximately 30% of community-dwelling older adults experience a fall each year which can potentially lead to decreased mobility and independence and increased mortality (64). Of the older adults that suffer a fall, nearly half experience a minor injury and 5%-25% have a serious injury (64). Fractures are common outcomes of falls. Over 90% of fractures occur following a fall (65). In addition, more than 90% of hip fractures in seniors are caused by falls and wrist fractures are typically sustained through falling with an outstretched hand (66,67). Older adults are at increased risk of falls due to the presence of certain risk factors. For example, aging can lead to frailty which is often accompanied by the onset of gait instability, visual impairment or cognitive impairment, all of which contribute to fall occurrences (68). Furthermore, older adults may have comorbidities (e.g., arthritis) that require medication to be taken (e.g., psychotropins); these medications can induce decreased reaction time, weakness, and poor mental health-- further heightening the possibility of fall occurrence and decreasing the ability to avoid falls (69,70). As well, approximately 30 % of older adults develop fear of falling following a fall ; this psychological trauma can result in the self-restriction of activities (71). While it is evident that falling is a key determinant of fracture risk, fear of falling may be associated with poor bone health, as well. Self-restriction of activity due to fear of falling can lead to physical inactivity which decreases bone density (72).

Low bone mineral density (BMD) can increase the risk of sustaining fractures. Osteoporosis is a disease that is highly prevalent amongst seniors, and is characterized by low BMD and microarchitectural deterioration of bone structure. Osteoporosis is linked with a number of fracture risk factors such as decreased muscle strength, increased fall occurrences, and increased previous fracture occurrences (73). Furthermore, low BMD has the highest predictive value for fracture at the hip (74). It is evident that individuals with osteoporosis have an increased susceptibility to fractures (22). By understanding the magnitude of the problem that osteoporosis poses in terms of adverse outcomes greater insight can be gained into effective ways of decreasing fracture risk in this population.

2.2 Osteoporosis

2.2.1 Epidemiology of Osteoporosis

Osteoporosis is a significant problem worldwide and in Canada. Approximately more than 200 million people have osteoporosis worldwide, and of those, 1.4 million individuals are Canadians (75). Osteoporosis is more prevalent in women than in men, about one in four women compared to one in eight men over the age of 50 have osteoporosis (76). The prevalence of osteoporosis increases with advancing age, ranging from 6% at the age of 50 to over 50% in ages over 80 (77). Roughly 80% of fractures in people over the age of 60 years are related to osteoporosis (78). Furthermore, worldwide, osteoporotic fractures are responsible for 0.83% of the global burden of non-communicable disease (17). The increasing incidence of vertebral, hip, and wrist osteoporotic fracture with increasing age is well illustrated by Cooper and Melton (1992) in the graph below (Figure 1).

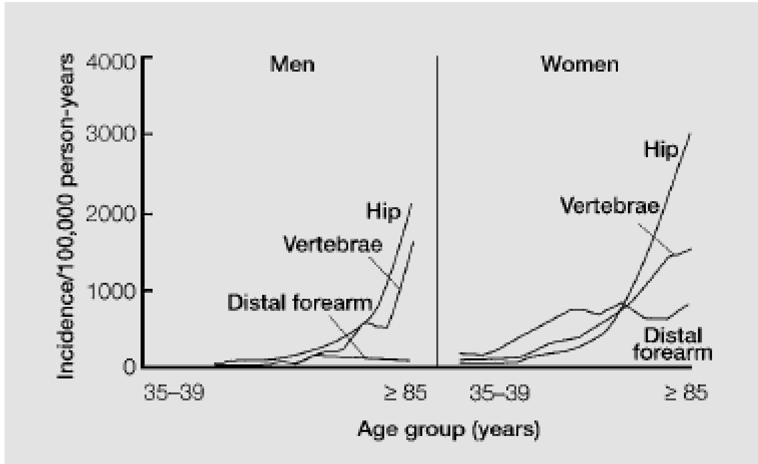

Figure 1: Trends in vertebral, hip, and distal forearm osteoporotic fractures with increasing age in men and women (Source: Cooper and Melton, 1992)

It is apparent that osteoporosis is a prevailing problem in older adults that needs to be addressed. Insight into risk factors for osteoporosis can inform appropriate ways of preventing, treating, and managing this disease.

2.2.2 Risk Factors for Osteoporosis

There are a number of risk factors for osteoporosis, many of which overlap the risk factors for fractures. Risk factors for osteoporosis can give indications to physicians and clinicians that BMD may need to be measured in an individual (79). These are outlined in the clinical practice guidelines for the diagnosis and management of osteoporosis in Canada and can be viewed in Table 2 (79).

Table 2: Risk Factors for Osteoporosis

Older Adults (age ≥50 yr)	Younger Adults (age < 50 yr)
• Age ≥ 65 yr (both women and men) • Clinical risk factors for fracture (menopausal women, men age 50-64yr) • Fragility fracture after age 40 yr • Prolonged use of glucocorticoids • Use of other high-risk medications • Parental hip fracture • Vertebral fracture or osteopenia identified on radiography • Current smoking • High alcohol intake • Low body weight (< 60 kg) or major weight loss (>10% of body weight at age 25 yr)	• Fragility fracture • Prolonged use of glucocorticoids • Use of other high-risk medications • Hypogonadism or premature menopause (age < 45 yr) • Malabsorption syndrome • Primary hyperparathyroidism • Other disorders strongly associated with rapid bone loss and/or fracture

• Rheumatoid arthritis • Other disorders strongly associated with osteoporosis	

(Reference: (79))

An additional risk factor for osteoporosis that is important to note is physical inactivity or sedentary behaviour. Perez et al (2011) found that the most commonly reported osteoporosis risk factor among menopausal women was physical inactivity. Physical inactivity negatively affects bone mineral density (80) . Following bone maturation, approximately 40% of peak bone mass is influenced by environmental factors such as weight-bearing physical activity (81). Regular aerobic and resistance exercise during maturation can contribute to high lifetime peak bone mass (80). Conversely, physical inactivity can lead to a decreased lifetime peak bone mass than would have been achieved with regular physical activity. Furthermore, prolonged disuse of bones and aging can lead to increased bone resorption and decreased bone formation (82,83). During disuse, bone resorption exceeds bone formation which results in increased porosity, decreased bone structural properties, decreased mineralization, and decreased bone strength (82). The effects of prolonged disuse of bones can be seen during periods of extended bedrest (84). Therefore, physical inactivity can contribute to an increased risk of developing osteoporosis.

2.2.3 Assessment for Osteoporosis

Rather than treating low bone mineral density, the focus of the prevention and treatment of osteoporosis has shifted to preventing fragility fractures and their adverse outcomes ; this is reflected in the Clinical Practice Guidelines for the Diagnosis and Management of Osteoporosis (79). Individuals over the age of 50, especially those who have previously sustained a fragility fracture, should be assessed for risk factors for osteoporosis and fracture (79). Risk factors for low bone mineral density and falls and fractures can be captured by a detailed history and individually focused physical examinations (79). Certain indicators such as age greater than 65 years, previous fragility fracture, and prolonged use of glucocorticoids can suggest that an individual is at a higher risk of having osteoporosis and that BMD may need to be measured (79).

Bone mineral density can be measured using dual energy x-ray absorptiometry. An individual with a bone mineral density that is ≤2.5 standard deviations below the peak bone mass for young adults would be diagnosed with osteoporosis (79). In addition, fracture risk assessment tools, such as one developed by the Canadian Association of Radiologists and Osteoporosis Canada (CAROC) and the Fracture Risk Assessment tool (FRAX), are available to clinicians to aid 10-year fracture risk assessment (79).

2.2.3.1 CAROC and Fracture Risk Assessment Tool (FRAX)

The CAROC and FRAX are 10-year fracture risk assessments tools that have been validated in Canadians (85–87). The CAROC uses age, sex, and femoral neck BMD to classify older adults as low, moderate, or high risk for major osteoporotic fracture within 10 years (88). Additional risk factors for fractures, such as previously sustaining a fragility fracture after the age of 40 or prolonged use of glucocorticoids, can increase an individual's risk for osteoporotic fracture to the next risk category (63,89).

The FRAX, similar to CAROC uses age, sex, and femoral neck BMD to assess 10-year fracture risk. In addition, FRAX incorporates other risk factors into its assessment such as body mass index, parental hip fracture, secondary causes of osteoporosis, glucocorticoid use, previous fracture, current smoking, alcohol intake, and secondary causes of osteoporosis (79). The fracture rates predicted by the CAROC and FRAX are in close agreement and there is roughly 90% concordance in risk categorization between both tools (88).

2.2.4 Negative Impact of Osteoporosis

A number of consequences are faced by individuals who have osteoporosis, the most serious outcome being sustaining a fracture. Osteoporotic fractures can lead to severe, adverse outcomes. For example, multiple vertebral compression fractures can cause height loss, thoracic hyperkyphosis, loss of lumbar lordosis, and compression of internal organs (90). As well, hip fractures can lead to great pain and limitations in mobility (91). Overall, individuals who sustain fractures can experience increased mortality and morbidity, decreased quality of life, and functional decline. Individuals with osteoporosis demonstrate a greater number of previous falls compared to individuals without; this may be attributed to decreased lower-limb strength and lower trunk extension muscle strength observed in those with osteoporosis (73). In addition to physical consequences, osteoporosis can lead to adverse psychological consequences. Individuals with osteoporosis commonly experience depression and exhibit signs of low self-esteem due to difficulties in performing activities of daily living (92,93). Even a diagnosis of osteoporosis without known prior fractures can have negative psychological effects such as stress, sadness, anger, and denial on individuals that are affected (94,95). Furthermore, physical consequences of osteoporotic fractures such as thoracic hyperkyphosis can lead to feelings of physical unattractiveness (92,93). Treatment and management for osteoporosis can be very costly. Additional expenses such as inpatient medical services, nursing home care, and rehabilitation can quickly accumulate (4). Following an initial fracture, healthcare resource utilization increases, further increasing costs associated with osteoporosis management. Therefore, greater emphasis should be placed on prevention of fractures and osteoporosis. In addition, when choosing a plan of treatment for individuals with osteoporosis goals such as improving quality of life and minimizing costs should be considered.

2.2.6 Management of Osteoporosis

2.2.6.1 Pharmacologic Intervention for Osteoporosis

There are two main categories of osteoporosis medications: antiresorptive medications and anabolic drugs. Antiresorptive therapies increase bone strength by slowing down bone loss and consist of five classes: bisphosphonates, estrogens, selective estrogen receptor modulators (SERMs), calcitonin, and monoclonal antibodies. These monoclonal antibodies target a protein required for osteoclast formation, function, and survival, known as receptor activator of nuclear factor κB ligand (RANKL) (96,97). On the other hand, anabolic agents, such as teriparatide, are designed to stimulate new bone formation (98).

Following completion of teriparatide therapy, treatment with an antiresorptive agent is important to prevent bone loss that is seen after discontinuation of teriparatide (98).

2.2.6.1.1 Efficacy

2.2.6.1.1.1 Efficacy of Antiresorptive Therapy

Various types of antiresorptive therapy have shown different efficacies in improving bone mineral density and reducing risk of fractures. Bisphosphonates have been found to reduce risk of vertebral fracture in postmenopausal women (99). As well, bisphosphonates that contain nitrogen, such as alendronate, risedronate, and zoledronate, can reduce the risk of hip and nonvertebral fractures (100–102). Previous studies have shown that estrogens, which were once the primary therapy for prevention of osteoporosis in postmenopausal women, can reduce vertebral and hip fractures by 33% and 40% respectively (96,103,104). Furthermore, estrogen treatment may also be effective in reducing nonvertebral fracture risk (96,105). SERMs inhibit bone resorption through the same mechanism as estrogens (96). Previous work has shown that raloxifene, the most widely use SERM, can reduce the risk of vertebral fractures by 35-43% (106,107). The reduction in bone turnover associated with calcitonin treatment is much smaller than that seen with other antiresorptive treatments (96). Use of a nasal spray containing calcitonin has been found to reduce risk of vertebral fractures by 33%. However, the methodological findings likely affected the results and reduced the confidence of this finding (96,108,109). Denosumab, a newer antiresorptive agent that is an antibody that inhibits RANKL, may be able to reduce risk of vertebral, hip, and nonvertebral fractures by 68%, 40%, and 20%, respectively in postmenopausal women (110).

2.2.6.1.1.2 Efficacy of Anabolic Therapy

Currently, teriparatide is the only approved anabolic therapy for osteoporosis in Canada and the United States (98). Previous work has shown that it induces the most significant increases in bone mineral density at the spine (98). For example, the Teriparatide Fracture Prevention Study found that 20mcg/d and

40mcg/d of teriparatide for a period of 18 months led to an increase in bone mineral density by 9.7% and 13.7%, respectively (111). As well, the same study found a decrease in femoral and total hip bone mineral density by 0.7% and 1.0%, respectively, in individuals receiving 20mcg/d (111). In individuals receiving 40mcg/d of teriparatide, a 5.1% and 3.6% increase in bone mineral density was found at the femoral neck and total hip, respectively (111).

In addition, teriparatide has shown to be able to reduce risk of new vertebral fractures by 65% and 69% in postmenopausal women receiving 20mcg/d and 40 mcg/d of treatment, respectively (111). Furthermore, nonvertebral fractures were reduced by 53% and 54% in individuals receiving 20mcg/d and 40mcg/d, respectively (111). The Teriparatide Study was not powered to detect changes in hip fractures.

2.2.6.1.3 Adherence and Cost-Effectiveness of Osteoporosis Medication

Adherence to medications is low and suboptimal in many chronic diseases, including osteoporosis (112). Long term adherence of antiresorptive therapy is poor (113–117). For example, approximately 75% of women who begin bisphosphonate therapy have been shown to be non-adherent within the first year and 50% discontinue therapy by that time (118,119).As well, adherence to calcitonin therapy has been noted as “notoriously low” (120). Similarly, adherence to anabolic therapy is poor. Although adherence to teriparatide appears to be good for the first six months, adherence still declines over time (121).

Poor adherence to medication can adversely impact healthcare costs and cost-effectiveness of these therapies (112). Nonadherence can increase healthcare costs associated with the condition being treated due to reduced clinical effectiveness of the therapy (112). Furthermore, previous studies have shown that poor adherence to therapy can potentially result in a doubling of the cost-effectiveness of osteoporosis medication (112,122). Therefore, it is evident that adherence to osteoporosis medication is low and can negatively impact cost-effectiveness of these therapies as well as potentially increase heathcare costs.

2.2.6.1.4 Side Effects

There are a number of adverse effects that are associated with antiresorptive therapy even though the prevalence of these effects are quite low (96). For instance, long term use of bisphosphonates may increase the risk of atypical stress fractures in the femoral shaft (123,124). As well, other severe adverse events that have been reported to be associated with bisphosphonate use include osteonecrosis of the jaw, atrial fibrillation, esophageal cancer, gastric ulcers, and upper gastrointestinal intolerance (100,125,126). The most widely used SERM, raloxifene therapy, has been associated with increased risk of venous thromboembolism, pulmonary embolism, fatal stroke, hot flashes, and leg cramps (106,127). Previous literature has associated calcitonin use with adverse effects such as nausea, rhinitis, stinging or tingling of the nasal passages, sneezing, nasal mucosal erythema, and minor bleeding (108,109). The most frequently reported side effects associated with denosumab use are infections of the skin and urinary tract and dermatological reactions, such as dermatitis and eczema (110). Again, it is important to note that the prevalence of the side effects of antiresorptive therapy is very low, less than 10% (96). Common adverse effects of teriparatide use at the approved dose of 20mcg are dizziness, leg cramps, hypercalcemia, and hypercalciuria (98).

Therefore, after examining antiresorptive and anabolic therapy efficacy in reduction of fractures, adherence, cost-effectiveness, and side effects, it can be concluded that osteoporosis medications are important to incorporate into the management of osteoporosis. However, there are other interventions such as physical activity and exercise that may also be important for reducing risk of fracture. Physical activity is “any bodily movement produced by skeletal muscles that leads to energy expenditure” (7). Engaging in physical activity may help reduce fracture risk and provide other physiological and psychological benefits (8,10,128). Exercise is “planned, structural, and repetitive body movement performed to improve physical fitness” (7). Specific exercises, such as strength and balance training, may be most effective in improving bone health and reducing fracture risk (8,9). Physical activity and exercise may be a feasible intervention for older adults with osteoporosis to include into their self-management strategy. However, further understanding of physical activity and exercise barriers of these individuals is needed to provide insight into the design of exercise programs that will decrease fracture risk and have high adherence.

2.3 Physical Activity and Exercise

2.3.1 Physical Activity, Exercise, and Fracture Risk Reduction

Participation in physical activity, particularly exercise, may help decrease fracture risk through increasing or maintaining bone mineral density and decreasing fall risk (8). Older adults who engage in an active lifestyle have lower rates of hip fracture compared to their sedentary counterparts (129,130). Physical activity can lead to mechanical loading on bone, exposing skeletal structures to localized tensile and compressive strain (131). This mechanical loading can initiate bone remodeling which reshapes bone to accommodate for mechanical usage. (131). As bone cells are sensitive to strain magnitude, frequency, and rate, mild overloading on bone can lead to increased remodeling that result in greater bone formation than resorption (131). Thus, physical activity can potentially lead to increased BMD. In addition, previous work has shown that although resorption rate for bone occurs at a rate of approximately 1% per year, exercise has the potential to negate these age-related declines (10). For example, exercise may minimize bone loss in postmenopausal women by maintaining cortical and trabecular volumetric BMD (132). Although physical activity participation can benefit bone mineral density, doing certain exercises may be more effective in decreasing risk for fracture.

Strengthening exercises may be one of the most effective types of physical activity for increasing bone mineral density (133,134). Strength training is a type of exercise that uses resistance to induce muscle contractions. When muscles contract or shorten, they create strain, deformation of bone tissue in response to mechanical loading, in bone where the muscle attaches to the bone (135). Strength training performed at a high enough intensity can provide sufficient strain to help maintain or increase bone mineral density. Modifying aspects of strength training such as varying the exercises, using a progressive program, and changing the speed of movement can lead to unusual strain distributions, high peak strain magnitudes, and rapid changes of strain (136–138). Bone is responsive to short periods of loading with unusual strain distributions, high peak strain magnitudes, and rapid changes of strain (136–138). Furthermore, greater strain magnitudes and unusual strain distributions are most effective for stimulating bone formation (138–140). Strength training is a type of exercise that produces these effects because it involves greater magnitudes of stress or mechanical loading on bone than non-weight bearing activities (i.e. bones support body weight or when movement is resisted) (141). Skeletal adaptation is proportional to the strain magnitude of loading events (131). Loading events with greater peak strain levels have larger osteogenic effects compared to loading events with less strain (131). Furthermore, in order to stimulate bone accrual, daily loading cycles of a certain threshold strain magnitude are needed (142). Marques et al (2011) compared the effects of resistance exercise to aerobic exercise on bone mineral density in older women. Marques et al (2011) found that following 32 weeks of resistance exercise, three times a week, there were significant increases in BMD of 2.9% and 1.5% at the trochanter and at the total hip respectively. On the other hand, no significant changes in BMD were observed in participants in the aerobic exercise group (8). As well, a Cochrane review found that the most effective type of exercise intervention on BMD for the neck of the femur was non-weight bearing high force exercise (i.e. progressive resistance strength training for lower limbs) (Mean Difference BMD 1.03 95% CI 0.24-1.82) (141). Meanwhile, the most effective intervention for BMD at the spine were exercise programs that consisted of two or more of the following types of interventions : static weight bearing, dynamic weight bearing exercise low force, dynamic weight bearing exercise high force, non-weight bearing exercise low force, or non-weight bearing exercise high force (Mean Difference BMD 3.22 95% CI 1.80-4.64). Therefore, engaging in strength training may be important for improving bone health.

Engaging in exercise may decrease fall risk and in turn decrease risk for fracture in older adults. Although aerobic exercise did not yield significant changes to bone mineral density in the study conducted by Marques et al (2011), improvement in balance test performance was observed in aerobic exercise participants and participants in the resistance exercise group. Furthermore, a randomized controlled trial by Persche et al (2009) found that lower limb strength training improved fall-related gait patterns in elderly women. As well, Beling & Roller (2009) noted that inclusion of balance training as a core component of physical activity in older adults resulted in significant improvements in functional balance ability and decreased fall risk. A systematic review by Sherrington et al (2011) revealed that exercise as a single intervention can prevent falls (pooled rate ratio 0.84, 95% CI 0.77-0.91). Moreover, the most effective fall reducing exercise programs were those that incorporated balance training, included higher doses of exercise (e.g. 2 hours per week for 6-months), and did not include walking training (9). Multi-component exercise programs that include balance and muscle strength training have been shown to significantly reduce the rate of falls (RaR 0.71 95% CI 0.63-0.82) and risk of falling (RR 0.85 95% CI 0.76-0.96) among older adults (143). Furthermore, tai chi, a form of exercise that challenges balance, has been shown to significantly reduce risk of falling (RR 0.71 95% CI 0.57-0.87) (143). Engaging in physical activity does positively impact fracture risk through maintaining or increasing bone mineral density and decreasing risk of falls. More specifically, strengthening exercises and balance training may be the most effective types of physical activity for decreasing risk for fracture. In addition to reducing fractures, physical activity participation can provide older adults with other physiological and psychological benefits as well.

2.3.2 Other Physiological and Psychological Benefits of Physical Activity

In addition to decreasing fracture risk, physical activity can positively impact three different types of outcomes: 1) health-related 2) functional; and 3) psychobehavioural.

Medical outcomes such as morbidity and mortality are decreased with routine physical activity. Health complications such as worsening cardiovascular status, reductions in aerobic endurance, changes in body composition, skeletal muscle atrophy, and weakness often accompany aging (10). Regular exercise can counteract these changes through improving maximal and submaximal aerobic capacity, augmenting maximal cardiac output, reducing resting blood pressure, as well as producing favorable changes in body and muscle composition (10). Physical activity initiated in late life can yield a decrease in mortality and improve longevity, even when accounting for individual differences such as smoking, hypertension, family history, and weight gain (144).

Furthermore, older adults who engage in physical activity can decrease their probability of functional decline and disability. Progressive resistance training is ideal for improving and maintaining function in community-dwelling and institutionalized seniors (12,145,146). Additionally, performing exercises similar to activities of daily living allow older adults to remain able in everyday life. Numerous studies have shown that functional improvements can be seen following performing exercises similar to bed mobility, transfers, and general mobility (10,147–151).

Physical activity can benefit psychobehavioural outcomes as well. Involvement in physical activity has the potential to prevent the onset of mental health problems or help prevent such problems from intensifying to levels of clinical concern (152). Furthermore, self-perceived health can be improved with the practice of weight bearing exercise (11). As well, a relationship exists between loneliness and reduced physical activity suggesting that increasing physical activity levels may reduce feelings of isolation (128). Overall, there are numerous additional benefits to participating in physical activity other than improving bone health and decreasing fall and fracture risk. Yet, at the same time, there are possible risks to consider before participating in physical activity.

2.3.3 Risks Associated with Physical Activity and Exercise

Although the health benefits that can be gained from engaging in physical activity are likely to outweigh the risks, it is still important to recognize risks associated with physical activity. One way of identifying risks associated with physical activity is through adverse event reporting of studies involving exercise. For example, Liu & Latham (2010) conducted a systematic review that summarized adverse event reporting in randomized controlled trials that applied progressive resistance training in older adults. Their findings revealed that adverse events were more frequently reported in studies that involved participants with certain health conditions, functional limitations, or a sedentary lifestyle (153). Furthermore, among the 43 trials that were analyzed, 27 reported events which were musculoskeletal-related (e.g. muscle strain, bruising, and joint pain) (153). As well, 5 trials reported falls, 5 trials reported cardiovascular reactions (e.g. increased blood pressure, arrhythmia, myocardial infarction), and 4 trials reported illness (e.g. aggravation of existing arthritis) (153). Liu & Latham (2010) suggested that adverse events were more likely to occur among high risk groups. Their results gave rise to an analysis of adverse events in randomized controlled exercise trials involving individuals with osteoporotic hip and vertebral fractures. Among the 22 studies that were analyzed, 8 studies reported death as an adverse event and death was the most commonly reported adverse event. However, reasons for death were either unspecified by these studies or not attributable to the exercise intervention implemented. Furthermore, osteoporotic individuals that have sustained hip and/or vertebral fractures suffer increased mortality and functional declines; therefore, this population may have already been predisposed to a state of fragility. Deaths observed in the studies that were analyzed may be attributed to characteristics of the participants rather than the exercise interventions implemented. Other adverse events reported included soreness and pain; each of these events were reported by two studies. Indeed, participating in physical activity can increase opportunities for older adults with osteoporotic hip and vertebral fractures to experience adverse events. Other types of physical activity, such as walking, can lead to adverse events. Several studies have reported that frequent walking in older adults is associated with increased fracture incidence (154,155). Although there are inherent risks to participating in physical activity, these risks may progressively diminish following prolonged participation. For example, Gill et al (2000) observed that there were minor increases in risk of a cardiac event associated with exercise; however, these increases in risk are diminished, and overtime are reduced, by the advantages of partaking in exercise training. Therefore, despite all the possible health concerns associated with participating in physical activity, the benefits may still outweigh the risks. Thus, older adults with osteoporosis should be encouraged to incorporate physical activity in their daily routine.

2.3.4 Impact of Physical Activity on Healthcare

Provision of physical activity programs to older adults can lead to lower utilization of healthcare services and is cost-effective (156,157). A retrospective cohort study by Nguyen et al (2007) demonstrated that healthcare costs can be lowered by providing individuals with physical activity classes.

In this study, older adults with diabetes were given an opportunity to attend free physical activity classes. Individuals who attended the classes were age- and sex-matched with individuals who were eligible to participate but did not. Nguyen et al (2007) found that the total healthcare costs of individuals who attended the physical activity classes regularly were 41% less than the costs of individuals who did not attend the classes. As well, Sari (2010) examined the impact of increased physical activity on the use of hospital services among older adults in Canada. Sari (2010) was able to conclude that amount of physical activity is negatively associated with use of hospital services and duration of hospital stays. Furthermore, the results obtained by Sari (2010) suggested that a 20-minute daily walk by inactive older adults could lower total hospitals stays by roughly 2% of the total annual inpatient days. Thus, increasing physical activity among older adults can lower utilization of healthcare services and therefore healthcare costs. Providing physical activity programs to older adults can be cost-effective. Munro et al (1997) studied the potential impact of a community-based program of physical activity on hospital admissions and deaths from coronary heart disease, stroke, diabetes, femoral neck fractures, and mental disorders using risk reduction data from previous observational studies. Munro et al (1997) reported that to provide twice-weekly exercise classes for 10 000 older adults would cost approximately £854,700 annually and prevent 76 deaths, as well as, 230 in-patient hospital stays. Also, the provision of exercise classes could potentially save roughly £601,000 in annual health care costs (157). Thus, important health benefits can be achieved at a relatively low cost through a publicly funded exercise program for older adults. Providing additional opportunities for older adults to engage in physical activity is not only important in enhancing the quality of life and functionality, as well as decreasing mortality and morbidity for these individuals, but may also have a positive impact on the healthcare system. However, despite the benefits and cost-effectiveness of providing exercise programs to older adults with osteoporosis, adherence to these programs may still remain an issue. It is important to recognize current adherence to exercise in this population and identify ways to increase adherence.

2.3.5 Increasing Physical Activity Levels in Older Adults with Osteoporosis

Even though the health benefits of physical activity and exercise are well known by older adults, low levels of activity are habitually reported in this group (13). Older adults represent the most inactive group of the adult population: physical activity levels and participation in vigorous activities decrease with age (5). Among older adults, individuals with chronic diseases, such as osteoporosis, are more likely to be physically inactive as well (5). Moreover, older adults have exhibited low levels of adherence to exercise programs (158). For example, it is estimated that roughly half of older adults who begin an exercise program drop out within the first six months (159). Older adults at risk for osteoporosis have demonstrated poor adherence to exercise programs as well. In a study involving a home-based exercise program taught by a physical therapist for older postmenopausal women, the 18-month compliance rate was merely 17.8% (14). Therefore, physical activity programs for older adults with osteoporosis should aim to ensure that these individuals adhere to their programs. The use of theory while designing interventions or research is important because it allows for testing of the theory's proposed causal relationships and can potentially provide a map for future effective interventions (160). A number of theoretical models explain social-cognitive factors that affect health-related behaviors, one of which is the Health Action Process Approach (HAPA) (161). Certain aspects of the HAPA model can provide an overarching framework for different factors that influence adoption, initiation, and maintenance of health behaviors such as physical activity and exercise participation.

2.3.5.1 Health Action Process Approach (HAPA)

Past research has used different theoretical frameworks such as the theory of planned behaviour, social cognitive theory, and the transtheoretical model of change to predict physical activity or exercise adoption and maintenance. However, there are deficiencies in these models which limit their ability to predict behaviour. For example, continuum models, like the theory of planned behaviour and the social cognitive theory, assume that cognitive and behavioural changes occur in a unidirectional manner (162). As a result, these models do not account for qualitative changes such as changing mindsets, phase transitions, or recycling back and forth that may occur throughout the behaviour change process (162). As well, continuum models assume that intention leads to behaviour (162,163). Therefore, these models focus on identifying and adjusting factors that influence intention (163). Previous reviews have supported that intention and behaviour are closely related (164–166). However, many of the conclusions of those studies were drawn from correlational evidence and were not able to determine whether intentions have a causal impact on behaviour (167). A recent meta-analysis examining the intention-behaviour relationship based on studies that used PA behaviour change as an outcome found that changes in intention (d = 0.45) did not lead to corresponding changes in behaviour (d = 0.15) (168). The results of this study reflected what is commonly referred to as the 'intention-behaviour' gap. Hence, even if people hold positive intentions on increasing their physical activity levels, there is a possibility that their intentions will not transform into action. By not elaborating on how intention is translated into action, continuum models are not able to entirely explain behaviour (162,163). Stage models, such as the transtheoretical model of change, also have shortcomings which limit their ability to predict and guide behaviour change. Similar to continuum models, stage models focus on personal motivation as the main determinant for behavior change (169). Therefore, they do not consider external and social factors like age, gender, and socioeconomic status (169). Furthermore, exercise is composed of different behaviours rather than a single behaviour (169). Stage models assume that individuals are in a single, overall, stage for physical activity (169). However, more realistically, individuals may be in a number of different stages of change depending on the activity being considered (169). By reducing PA to a single behaviour and not acknowledging its associated complexities, stage models may not be able to capture all the factors and specificities that are needed to induce a change in PA behaviour (169). Therefore, earlier theoretical frameworks may not be suitable for predicting and guiding PA and exercise behaviour.

The HAPA attempts to compensate for what previous models lacked by incorporating post-intentional mediators of behaviour, thereby addressing the intention-behaviour gap (162,163). This model suggests that the process of adopting, initiating, and maintaining health behaviours is divided into two phases/stages: motivation and volition (15). The motivational phase is where intentions are developed, whereas in volition, intentions are transformed into action (15). The motivation stage contains features of the theory of planned behaviour and the social cognitive theory (163). Intention formation is influenced by risk perceptions, outcome expectancies, and perceived action self-efficacy (15). Few models include a volitional stage, which distinguishes HAPA from other theories (163). This stage can be divided into three phases: planning, initiation, and maintenance (170). Planning involves action planning (developing a plan that details when, where, and how the behaviour will be performed), and coping planning (determining potential barriers that may prevent one from reaching their goal, and devising ways to overcome them) (163,170). Another distinguishing aspect of the HAPA is the differentiation between multiple types of self-efficacy (171). Action self-efficacy, which influences intention formation during the motivational stage, represents an individual's belief in their capability of performing the behaviour, prior to action (163). Maintenance and recovery self-efficacy are both part of the volitional stage. Maintenance self-efficacy refers to an individual's confidence in overcoming barriers that they may encounter while engaging in the behaviour whereas recovery self-efficacy is an individual's belief in their ability to reengage themselves after being set off track (170). External factors, such as barriers and resources, are the only elements that contribute to both the motivational and volitional stages. Barriers and resources can greatly influence intention formation and transformation of intention into action (15). A summary of the HAPA can be viewed in Figure 3.

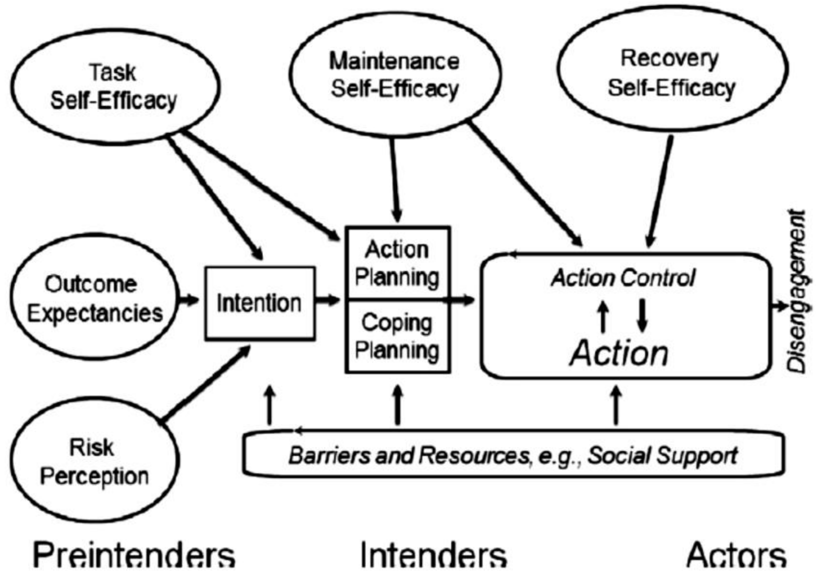

Figure 2: Overview of the Health Action Process Approach (HAPA)

(Reference (170))

The HAPA has been applied to a number of health behaviours. One study that compared the abilities of the health belief model, theory of planned behaviour, and HAPA to predict intentions to resist dieting and perform breast self-examinations found that the HAPA was the best predictor of intentions (172). Another study of breast self-examination behaviour provides further support for HAPA and in particular, the important role of planning as an intermediary of intention and behaviour (173). HAPA has been also shown as a useful model to predict other types of health behaviours such as healthy eating and seat-belt use. More importantly, previous work supports that the HAPA is an appropriate framework for the identification of social cognitive determinants of physical activity involvement among middle-aged and older adults (170,174). The appropriateness of the use of HAPA for describing physical activity behaviour in older adults has been confirmed by a study conducted by Caudroit et al (2011). Therefore, the HAPA may be an appropriate theoretical model to use in describing physical activity behaviour among older adults with low bone mineral density.

2.3.5.2 Outcome Expectancies

Positive outcome expectancies of physical activity and exercise, such as increased bone mineral density, may increase intention to participate in physical activity and in turn contribute to higher levels of participation in individuals with osteoporosis. The stronger an individual's beliefs of positive outcomes are, the more likely they will initiate and persist with a specific behavior (175). In a study among older adults with rheumatoid arthritis, Ehrlich-Jones (2011) found an association between strong beliefs that physical activity can be helpful for managing disease and higher levels of physical activity participation. Likewise, Matthews et al (2010) found that older adults cited positive outcome expectations as an enabler to physical activity. On the other hand, initial outcome expectations were not significantly associated with physical activity participation in a group of older women (176). This result was similar to that of Caudroit et al (2011) and supports the need for adjustment of HAPA according to different age groups and different health conditions. Greater research is needed to determine whether promotion of positive outcome expectancies can increase intentions to engage in physical activity and adherence levels to exercise in older adults with osteoporosis.

2.3.5.3 Risk Perception

It is unclear whether risk perception increases or decreases intention to engage in physical activity because risk communication can lead individuals to act in two different ways (15). A high risk perception of sustaining a fracture can encourage an individual to participate in physical activity (15). On the other hand, a high risk perception can also cause individuals to feel overwhelmed by the threat and in response, act defensively. That is, they would avoid physical activity in fear of increasing opportunity for an injury (15). Risk perception may play a positive role in changing health-related behavior for older adults due to age-related increases in the presence of health-related problems (177). This notion is supported by a study which identified factors associated with exercise among older adults in a continuing care retirement community where negative outcome expectations were found to be positively related to exercise behaviour (178). Further research on how risk perception of sustaining a fracture influences intention to participate in physical activity in older adults with osteoporosis is needed.

2.3.5.4 Barriers and Resources

Barriers and resources influence intention and action of changing health-related behaviors (15). More specifically, barriers are factors that can decrease intention to engage in and maintain physical activity and exercise participation. On the other hand, resources facilitate intention and action to participate in physical activity (15).

2.3.5.4.1 Barriers to Physical Activity

Perceptions of barriers can influence important determinants of physical activity and exercise participation (159,179). According to the HAPA, perceiving barriers may negatively affect intention and action to change or maintain health behaviors (170). Other theories, such as the Health Belief Model, also recognize that perceived barriers can be strong indicators of behavior change (180). Negative attitudes towards health-promoting behaviors may be formed by individuals who identify greater obstacles than benefits (181). Previous studies have identified perceptions of barriers as an important correlate of exercise participation and adherence to exercise programs (182,183). More specifically, there is an inverse relationship between perception of barriers and amount of physical activity or exercise performed (184,185). Therefore, it is important to investigate and identify the barriers that older adults with low BMD perceive. This may inform whether interventions reducing factors that impede these individuals from being active is an effective way of increasing physical activity and exercise levels in this population. Furthermore, identifying particular barriers may allow these individuals to target and focus on improving specific coping self-efficacies.

Approximately 87% of older adults experience at least one barrier to exercise engagement (186). Personal or 'internal' barriers appear to be a greater impediment for this population compared to environmental barriers, those that are beyond an individual's control. Commonly cited factors that hinder older adults from being active include health-related problems (i.e., poor health, pain, dizziness), low self-efficacy or intention, lack of interest or time, lack of knowledge of appropriate exercises and fear of injury or falling (13,175,182,187–189). Environmental barriers such as weather, impediments to program delivery, poor terrain, and not living in close proximity to exercise facilities have been noted as well (175,182,190,191). Although numerous factors that prevent older adults from engaging in physical activity and exercise have been identified, many gaps in the literature still remain.

One potential barrier to exercise that has not received much attention is willingness to pay. Willingness to pay (WTP) is defined as "an individual's choice between not having versus having a particular commodity, and having the commodity but forgoing a certain amount of money" (192). The amount of money an individual is willing to forgo is their WTP. It can also be a method of quantifying the strength of an individual's preferences (16). A person who does not want to spend money on or does not enjoy exercise may be less inclined to take part in programs that involve high costs. A high WTP may indicate aspects, types, and outcomes of exercise that individuals may value. Currently, there are few studies that have investigated WTP for different provisions of exercise in older adults, including in those with low BMD. It is worthwhile to characterize WTP for exercise in these individuals to gain insight on their preferences, as well as provisions of exercise that they may be interested in but which for which they require greater support in order to participate.

Although previous work on barriers to physical activity and exercise in older adults has been done, there is a need for greater understanding of barriers for older adults with low BMD. Factors that pose as challenges to being active may be different for those with chronic diseases compared to those without. Furthermore, barriers may vary depending on the types of illnesses that an individual faces. For example, a past study examining perceived exercise barriers, benefits, and enablers in exercising and non-exercising adults with arthritis found that although there were some factors perceived to influence exercise that were similar to those in general adult samples, there were still factors unique to individuals with chronic disease (176). Moreover, there were barriers to exercise that were only applicable to those with arthritis (176). The same case may be applied to individuals with low BMD in which they may face challenges that are unique to them. Therefore, there is a need to describe barriers to physical activity and exercise in individuals with low bone due to different characteristics of this population. As well, it is important to characterize WTP for various provisions of exercise in these individuals to gauge their preferences and determine areas in which they may require greater support in order to participate. Identifying factors that impede individuals with low BMD from being active can help inform future studies and interventions that attempt to increase activity levels in this population.

2.3.5.4.2 Resources

As mentioned above, resources help facilitate intention and action to engage in physical activity and exercise (15). However, lack of resources can become perceived barriers to exercise. Social support is a good example of how a factor can be a barrier and a resource. Instrumental, emotional, and informational social support can enable the adoption and maintenance of health behaviours (193). At the same time, lack of support can adversely affect intentions and adherence to health promoting behaviours and is commonly cited as a barrier among older adults (13).

2.4 Application of Research

It is hoped that the findings of this study will further current work on integrating physical activity and exercise into the self-management strategies of older adults with low BMD by understanding current physical activity and exercise levels and identifying barriers to exercise. Self-management is composed of the plan of actions that individuals undertake to promote health, manage an illness, and manage life with an illness (194). It is also a way for individuals dealing with chronic illness to bring order into their lives (195). The process of self-management integration is composed of several phases: seeking effective self-management strategies, considering the costs and benefits of self-management strategies, creating routines and plans of action, and negotiating self-management that fits into life (194). Seeking effective self-management strategies occurs after an individual perceives a need for self-management (e.g. adverse changes in health) (194). It is where individuals seek information about self-management, through friends and health care providers, and use trial and error to determine what strategies are suitable for them (194).

Next, individuals compare the effectiveness of self-management against the costs (194). To continue with this process, individuals need a sense that self-management is effective (194). Creating routines and plans of action helps individuals to remember and engage in self-management more easily by simplifying everyday decision-making and minimizing the number of times they reconsider their decisions each time a self-management activity is performed (194). Lastly, in the negotiation phase, individuals attempt to find a balance between life goals and illness control while prioritizing and adapting self-management strategies to suit their unique circumstances (194). As well, a number of variables such as illness experience, life situations, and personal beliefs and values, influence the context of self-management integration (194).

Our study aims to determine the degree in which older adults with low BMD incorporate physical activity and exercise into their strategies to manage osteoporosis. Furthermore, another objective is to identify factors or barriers that these individuals perceive that make it difficult for them to maintain a balance between their life goals and engaging in sufficient amount of physical activity to maintain good health and prevent falls and fractures. Determining external factors, specifically willingness to pay, in these individuals' life situations that affect their ability to engage in exercise is another goal of this study. Gaining knowledge of WTP will provide insight into methods of furthering the ability of older adults with low BMD to integrate physical activity into their self-management strategies.

2.5 Summary of Background

Fractures are common and serious health concerns that are associated with increased mortality, functional decline, and reduced quality of life in older adults. Furthermore, they can cause substantial financial burden to affected individuals, as well as economic burden to the healthcare system. As the proportion of older adults significantly increases in the coming years, fractures and their associated consequences will become a greater problem. One major risk factor for fractures is osteoporosis or low BMD. Osteoporosis is associated with a majority of fracture that occurs in older adults (6). In addition to pharmacologic interventions to manage osteoporosis, physical activity can decrease fracture risk as well.

More specifically, strength training exercises can help increase or maintain bone mineral density and balance training can decrease risk of falls. Despite efficacy of physical activity to reduce fracture risk in older adults, many individuals still demonstrate low levels of habitual physical activity and low adherence to exercise programs. A number of behavior models can explain factors that influence changes in health-related behaviors, one being the HAPA. According to HAPA, external factors, such as perceiving barriers can influence intention and action to engage in physical activity and exercise. Although there is research available pertaining to barriers to exercise for older adults, there is a need for greater characterization of these factors specifically in older adults with low BMD. The aim of this study is to describe current physical activity levels and types of physical activities and characterize barriers to exercise in older adults with osteoporosis. By gaining such knowledge, different approaches to increasing physical activity levels and adherence in older adults with osteoporosis can be generated, thereby contributing to the ultimate goal of decreasing fracture risk in this population.

3.0 Chapter 3: Research Methodology

3.1 Research Questions

3.1.1 Primary Research Questions and Sub Questions

1. <u>Current Action</u>

   What are the current physical activity levels of individuals with low bone mineral density?

   - How many minutes do individuals spend doing moderate- to vigorous-intensity physical activity per week?
   - How many times do individuals do muscle strengthening exercises per week?
   - How many times do individuals do balance training each week?
   - What proportion of people are doing at least 150 minutes of moderate- to vigorous-intensity physical activity each week?
   - What proportion of people is doing strengthening exercises two or more times each week?
   - What proportion of people is doing balance exercises at least two or more times each week?

2. <u>Correlates of Physical Activity</u>

   What are correlates of physical activity for individuals with low bone mineral density?

3. <u>Barriers</u>

   What are barriers to exercise that individuals with low bone mineral density perceive?

   - Do these individuals perceive barriers to exercise?
   - What barriers to exercise do these individuals perceive?

4. <u>Barriers – Willingness to Pay</u>

   What is the willingness to pay for an exercise program amongst individuals with low BMD?

   - What is the willingness to pay for different methods of delivering exercise information?

3.2 Research Hypotheses

1. Current Action

   It is hypothesized that approximately 40-60% of older adults with low BMD are not doing at least 150 minutes of MVPA per week and more than 20% of older adults with low BMD are not doing strength and balance training exercises at least twice each week.

2. Barriers

   It is hypothesized that the most commonly perceived barrier to exercise among individuals with low BMD is lack of motivation and that the barrier that these individuals perceive as preventing them from being able to exercise regularly the most is health-related complications.

3.3 Design and Sample Size

This study was a descriptive, cross-sectional study conducted by distributing questionnaires online and through mail to individuals that are part of the Canadian Osteoporosis Patient Network (COPN) and to individuals recruited from an osteoporosis public education event. At the time of the study, COPN consisted of 5002 members. This study was conducted in collaboration with Osteoporosis Canada. This study was approved by the Research Ethics Board of the University of Waterloo.

3.4 Participants

People recruited for this study were individuals aged of 50 years or older that had a self-reported diagnosis of low BMD, osteoporosis or osteopenia.

Table 3: Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• ≥ age 50 • Previously diagnosed with low bone mineral density (Osteoporosis or Osteopenia)	• < age 40 • Inability to understand or communicate in English • Previously diagnosed with cognitive impairment by a physician

Individuals younger than the age of 40 years were excluded from this study in order to exclude people who have secondary osteoporosis. Secondary osteoporosis occurs as a result of other medical conditions or diseases or the treatment of other conditions or diseases (78).

There were 5002 members in COPN at the time of the survey, 94% of which were females, 5% are males, and 1% of which their gender is unknown to Osteoporosis Canada. Furthermore, out of 5002 COPN members, 3793 individuals were 50 years of age or older and 181 individuals were between the ages of 41 to 50 years old. Additionally, 77% of 4840 members were living with osteoporosis. According to the inclusion criteria of being the age of 50 years or older, 3793 members of COPN were eligible to participate in the study. According to the inclusion criteria of having a self-reported diagnosis of low bone mineral density, 3726 members were eligible to participate. There were members of COPN living in all provinces and territories of Canada, except for Nunavut. Provinces with the highest membership were Ontario, Nova Scotia and British Columbia, with 2193, 1057, and 943 members respectively.

3.5 Participant Recruitment and Consent

Individuals were recruited from the Canadian Osteoporosis Patient Network (COPN) and an osteoporosis public education event. COPN is an online network associated with Osteoporosis Canada and is composed of individuals who are living with or affected by osteoporosis. A brief announcement of the study was included in the monthly COPN newsletter, COPING. It described the objective of the study and how members could participate. Individuals who received the COPING newsletter online were provided a link to the study's survey while members who received COPING via mail were provided with a telephone number to contact Osteoporosis Canada to have a print copy of the survey mailed to them. In addition, individuals who had attended an osteoporosis public education event, hosted by Osteoporosis Canada were asked to provide their e-mail address if they were interested in participating in future research. These individuals were sent an e-mail that briefly described the study aims and what would be required of participants, as well, a link to the survey was included (Appendix A). Before beginning the survey, participants were provided with a description of different components of the survey. Participant agreement to proceed to the survey was considered as implied consent. Similarly, consent was implied when participants returned completed print surveys to Osteoporosis Canada.

3.6 Outcome Assessments

3.6.1 Health History Questionnaire

Demographic and medical information was collected in the form of a health history questionnaire to gain an understanding of our participants. Demographic information including gender, date of birth, education level, province of residence, and level of household income was collected from participants. Medical information such as diagnosis of low bone mineral density, previous fracture history, possible risk factors for falls and fractures, use of supplements and walking aids, and presence of comorbidities were included in the questionnaire as well. Some of these variables, such as presence of comorbidities and history of falls in the past six months, were used to help determine what may have been correlates of aerobic exercise among older adults with low BMD. A detailed summary of information asked of participants from the health history questionnaire is summarized in Table 4.

Table 4: Detailed Summary of Information Asked in Health History Questionnaire

Demographic Information	Medical Information
• Gender • Current age • Education level • Level of household income • Province of residence • Approximate population of city of residence • Caregiver status	• Previous diagnosis of low bone mineral density (osteoporosis or osteopenia), diabetes and cancer • Presence of vision problems and/or neurologic conditions • History of falls in the past 6 months • History of fractures after age 40 years • Previous hip or joint replacements • Use of supplements and bone medication • • Presence of comorbidities • Previous use of glucocorticoids • Diagnosis of cognitive impairment • Use of walking aid • Presence of chest pain not controlled by medication • Self-perceived health

All personal and medical history related information was stored on a password-protected computer file and the password was saved in another secure file. Health history information was accessible only to the primary investigator and research assistants involved in the study. Data collected was removed of information that can link participants to their data to further ensure confidentiality.

3.6.3 Physical Activity Levels Questionnaire

Current physical activity levels were assessed using a modified version of the long-form International Physical Activity Questionnaire (IPAQ) (http://www.ipaq.ki.se/ipaq.htm). The IPAQ is a self-reported measure of physical activity designed to provide information about time spent walking and doing vigorous- and moderate-intensity activities in job-related, transportation, domestic, and leisure-related domains during the past seven days. The IPAQ assesses different domains of physical activity that are relevant to older adults and there is sufficient evidence from previous work that supports the validity of the IPAQ to measure physical activity levels.

Validity of the IPAQ for measuring physical activity in various ways has been inconsistently reported in previous literature. One study comparing the measurement of total energy expenditure by the IPAQ to the doubly labeled water (DLW) technique found that although there was good approximation by the IPAQ at low levels of physical activity (~187-376 daily MET/min), it underestimated energy expenditure by 27% (196). However, the IPAQ was not specifically designed to measure activity-related energy expenditure which may help explain its inaccuracies in energy expenditure measurement (196). IPAQ validity has also been tested against the Computer Science and Applications, Inc. (CSA) accelerometers (197). The agreement between total physical activities reported by accelerometers and the IPAQ over a seven day period was merely 0.33 (95% CI 0.26-0.39) (197). In another study, time spent doing vigorous-intensity physical activity and total amount of physical activity reported by the IPAQ demonstrated a 0.71 and 0.55 correlation, respectively, to the times measured by accelerometers (198). The same study also found a correlation of only 0.21 between time spent in moderate intensity physical activity reported by the IPAQ and time spent in moderate level measured by the accelerometer (198). In a validation study involving older adults, correlations of 0.42 and 0.49 were found between total physical activity measured by an accelerometer and total IPAQ score for men and women, respectively, aged 65 to 74 (199). Furthermore, correlations of 0.53 and 0.49 were found for men and women aged 75 to 89, respectively (199). Previous work has tried to adapt the IPAQ to be more relevant to older adults by changing activity examples to be more age-relevant activities, by reversing the question order (i.e. instead of vigorous to light, asking from light to vigorous intensity), and increasing font size of the questionnaire (200). All self-reported activity domains were positively associated with the corresponding variable that was objectively measured by an accelerometer, ρ ranged from 0.277 to 0.471. Past studies have shown that the IPAQ is able to provide sufficient estimates of levels of moderate- to vigorous-intensity aerobic physical activity among older adults as compared to objective measures of physical activity, such as accelerometers.

In addition to sufficient psychometric properties, it is important to ensure that the IPAQ is understandable and is able to be completed properly by older adults. Previous work has suggested that older adults may experience difficulties in using this questionnaire (201). For example, one study found that the most difficulties arose while understanding and performing the primary task such as comprehending what information was needed and retrieving information that was relevant to the question being asked (201). More specifically, these individuals made errors such as recalling physical activity in a "usual" week rather than the previous seven days, including activities that lasted less than 10 minutes each session, and reporting the same activity more than once (201). Furthermore, individuals were unsure of what activities were applicable to the question being asked and used a variety of strategies to determine frequency and duration of their activities (201). To avoid similar errors being made by our participants, recommendations made by Heesch et al (2010) (Table 5) for improving the IPAQ for use in older adults were incorporated into this study.

Table 5: Heesch et al (2010) Recommendations for improving IPAQ for older adults

1. List in the instructions at the beginning the activities that will be asked for in the questionnaire (i.e. vigorous physical activity, moderate physical activity, walking, sitting). 2. State in the instructions at the beginning and for each activity domain that activities already reported for one domain should not be reported again for another. 3. State in the instructions at the beginning and for the duration questions that only activities lasting at least 10 minutes during the previous 7 days should be included. 4. For vigorous and moderate physical activity, state in the instructions to include only the amount of time spent at the specified intensity. 5. For vigorous and moderate physical activity, state in the instructions that the examples given are only indicators of activities which might be done at the specified intensity and that the examples are not to be used as choice-limiting checklists. 6. Add examples of activities relevant to older adults and clarify activities mentioned as examples in the questionnaire. 7. Provide instructions for the walking activities to report. 8. Offer strategies for determining the frequency and duration of activities. 9. For duration questions, clarify or revise the phrase *usually spent on one of those days*.

The long form of the IPAQ was chosen because it addressed different domains of physical activity that are relevant to older adults and it had sufficient psychometric properties based on previous literature. In addition, modifications to IPAQ instructions, suggested by Heesch et al (2010), were made to improve its readability and understandability among older adults.

To determine how much time participants spent doing moderate- to vigorous-intensity physical activities per week, time reported in the IPAQ doing activities with those intensities in job-related, transportation, domestic, and leisure-related domains were summed. Time spent walking or bicycling was included into time spent doing MVPA as well. The proportion of participants not meeting the MVPA recommendation was calculated by determining the number of individuals who reported less than150 minutes of MVPA divided by the total number of participants. Strength and balance training levels were assessed by incorporating additional questions that asked participants the number of days per week that they engaged in those activities. The proportion of individuals not meeting strength and balance training recommendations was calculated by determining the number of individuals who reported doing these activities less than twice per week and dividing those figures by the total number of participants.

3.6.2 Perceived Barriers to Exercise Questionnaire

Perceived barriers to exercise and factors that influence intention and action to participate in physical activity were examined using a questionnaire. Participants were asked to what degree certain barriers made it difficult for them to exercise on a regular basis and were asked to check a number that best reflected their answer on a four-point Likert scale. One represented not true at all, that the barrier being asked did not pose any difficulties to participants to exercise on a regular basis, whereas four represented exactly true, that the barrier did make it difficult for them to exercise regularly. Barriers that were included in the questionnaire were based on barriers that were commonly reported in other populations of older adults. In addition, participants were provided with an open text box to express additional barriers to exercise that they perceived and were not already addressed in previous questions. These responses were grouped into themes. Strength of perceiving barriers overall was assessed using a five-point Likert scale. Participants were asked to consider all of the barriers that they faced on some or all days and how difficult those barriers made it for them to do at least 150 minutes of MVPA, exercises to increase muscle strength of major muscle groups at least twice per week, and exercises that challenged their balance at least twice per week. Participants were asked to choose a number on a scale of one to five that best reflected the degree of difficulty that their perceived barriers posed, one being not difficult at all and five being extremely difficult (Appendix B).

Factors that influence intention and action to engage in physical activity and exercise, such as risk perception, intention, and self-efficacy were assessed using a Likert scale. Participants were asked how likely they thought they would break a bone sometime in the future and answered by choosing a number on a seven-point Likert scale that best reflected their risk perception. One represented very unlikely, meaning that individuals thought it was highly unlikely for them to sustain a fracture in the future, whereas seven represented very likely to sustain a fracture. Similarly, intention was assessed using a seven-point Likert scale. Individuals were asked about their intentions to participate in exercise in the coming weeks and months and chose a number on the Likert scale that best represented their intentions. One represented that they did not intend to exercise at all, whereas seven represented that they strongly intended to exercise regularly. Intentions to exercise regularly, to do at least 150 minutes of MVPA per week, to do strength training two times each week, and to do balance training at least twice per week were assessed. Self-efficacy was assessed using a four-point Likert scale. Participants were presented with a statement such as "I am sure that I can be physically active" and were asked to check a number that best reflected their answer. One represented not true at all whereas four represented exactly true. Self-efficacy to be physically active, to achieve a goal of doing at least 150 minutes of MVPA each week, to do strength training two times per week, to do balance training twice per week, and to become physically active again following a period of not exercising was assessed. The wording and format of the questions that assessed perceived barriers, risk perception, intention, and self-efficacy was derived from assessments tools that were based on the Health Action Process Approach (202). A summary of the perceived barriers to exercise and factors that influence intention and action to engage in physical activity that were explored in the current study are summarized in Table 6.

Table 6: Summary of perceived barriers and factors that influence exercise intention and behaviour assessed in questionnaire

Perceived Barriers to Exercise	Factors that Affect Exercise Intention and/or Action
• Lack of motivation or interest • Lack of time • Cost • Poor health or health-related complications • Lack of transportation • Fear of injury • No available equipment to exercise with • No facilities available or close by • No enjoyment for exercise • No persistence to exercise on a regular basis • Perceives self as too old to exercise • Need to rest and relax in spare time rather than exercise • No company to exercise with • Lack of knowledge of appropriate exercises	• Risk perception • Intention to exercise • Exercise self-efficacy • Strength of perceived barriers

Willingness to pay for different methods of delivering exercise was assessed. Participants were asked if they were interested in receiving exercise information through an exercise DVD designed for individuals with osteoporosis, participating in a group exercise class, and working one-on-one with a certified personal trainer. If participants responded yes to being interested in receiving any of the above methods of delivering exercise, they were asked to provide their highest WTP for that method of delivery. Example costs for each method of delivery were provided to participants to give them an idea of how much each method may cost in real life. Cost of the exercise DVD were estimated to range from $15-$30, group exercise classes $50-$60, and working one-on-one with a personal trainer $360-$420. The prices of these methods of delivering exercise information were determined by investigating prices of these types of products or programs online. The complete questionnaire can be found by referring to Appendix B: Complete Online and Print Questionnaire.

3.7 Statistical Analyses

Medical and demographic information collected from the health history questionnaire was reported using descriptive statistics, including mean and standard deviation (SD) and count (%). Count (%) was used to characterize risk perception, intentions, exercise self-efficacy, perceived barriers, and strength of perceived barriers, or other categorical variables. Mean (SD) was used to describe minutes per week spent doing vigorous- and moderate-intensity physical activity, walking, and strength and balance training, and any other continuous variables. In addition, mean (SD) was used to describe the highest amount of money participants reported they were willing to pay for different methods of delivering exercise information. To identify correlates of aerobic physical activity, associations between certain variables (Table 7) and time spent doing aerobic physical activity during leisure time were determined using Pearson product-moment correlation coefficient or Spearman's rank correlation coefficient. Time spent doing aerobic physical activity during leisure time was measured by summing minutes spent walking and doing moderate- and vigorous-intensity physical activities during leisure time. Pearson product-moment correlation coefficient describes a linear relationship and was used with continuous variables whereas Spearman's rank correlation coefficient describes a non-linear relationship and was used with dichotomous variables; both measure the strength of association between two variables. Variables chosen were ones that have been identified as correlates of physical activity in other populations of older adults or are part of the HAPA model (193,203–205). A normal probability plot revealed that data collected on time spent doing leisure aerobic physical activity was not normally distributed, therefore, a logistic regression to determine variables that influenced whether an individual met the recommended guidelines for time spent participating in moderate- to vigorous-intensity aerobic physical activity was performed instead. Univariate logistic regression analyses were performed to determine which variables were significantly associated with meeting MVPA recommendations and those that were significant were included in the multivariable logistic regression. A list of all of the variables that were assessed for a correlation with aerobic physical activity and included in the logistic regression analyses can be found in Table 7. Cronbach's alpha was used to determine internal consistency between responses to questions that addressed intention and self-efficacy to meet the Canadian Physical Activity Guidelines for older adults. As well, Cronbach's alpha was used to determine how closely related responses to questions that asked about the strength at which participants perceived barriers were. An alpha above 0.7 was considered as sufficient evidence that the responses had internal consistency and could be combined together. Responses were combined together by summing the scores from each question. Responses for intention, self-efficacy, and perceived strength of barriers had an alpha of 0.82, 0.88, and 0.80 respectively. Intention, self-efficacy, and perceived strength of barriers were each represented by one score in the univariate and multivariable logistic regression analyses. All statistical analysis was conducted using Statistical Analysis Software (SAS) and the statistical significance level was set at alpha 0.05.

Table 7: Variables that were examined as potential correlates of physical activity for individuals with low bone mineral density

Potential correlates of physical activity
• Age • Gender • Whether assistance was required for certain activities of daily living • Exercise self-efficacy • Intention • Strength of perceived barriers • History of falls in the past 6 months • History of fractures after age 40 • Previous hip or joint replacements • Presence of comorbidities • Self-perceived health • Education level

4.0 Chapter 4: Results

4.1 Study Flow and Recruitment

A total of 135 individuals completed the study's questionnaires. Of those, two individuals were excluded having reported that they had difficulties with memory, problem solving, or reasoning. As well, three individuals were excluded because they reported that they had not been diagnosed with low bone mineral density. The final number of participants in this study was 130 (Figure 3). Participants were from various provinces and territories in Canada including Ontario (57%), British Columbia (25%), Alberta (5%), Nova Scotia (6%), Quebec (2%), Manitoba (2%), Saskatchewan (1%), Yukon (1%), and New Brunswick (1%).

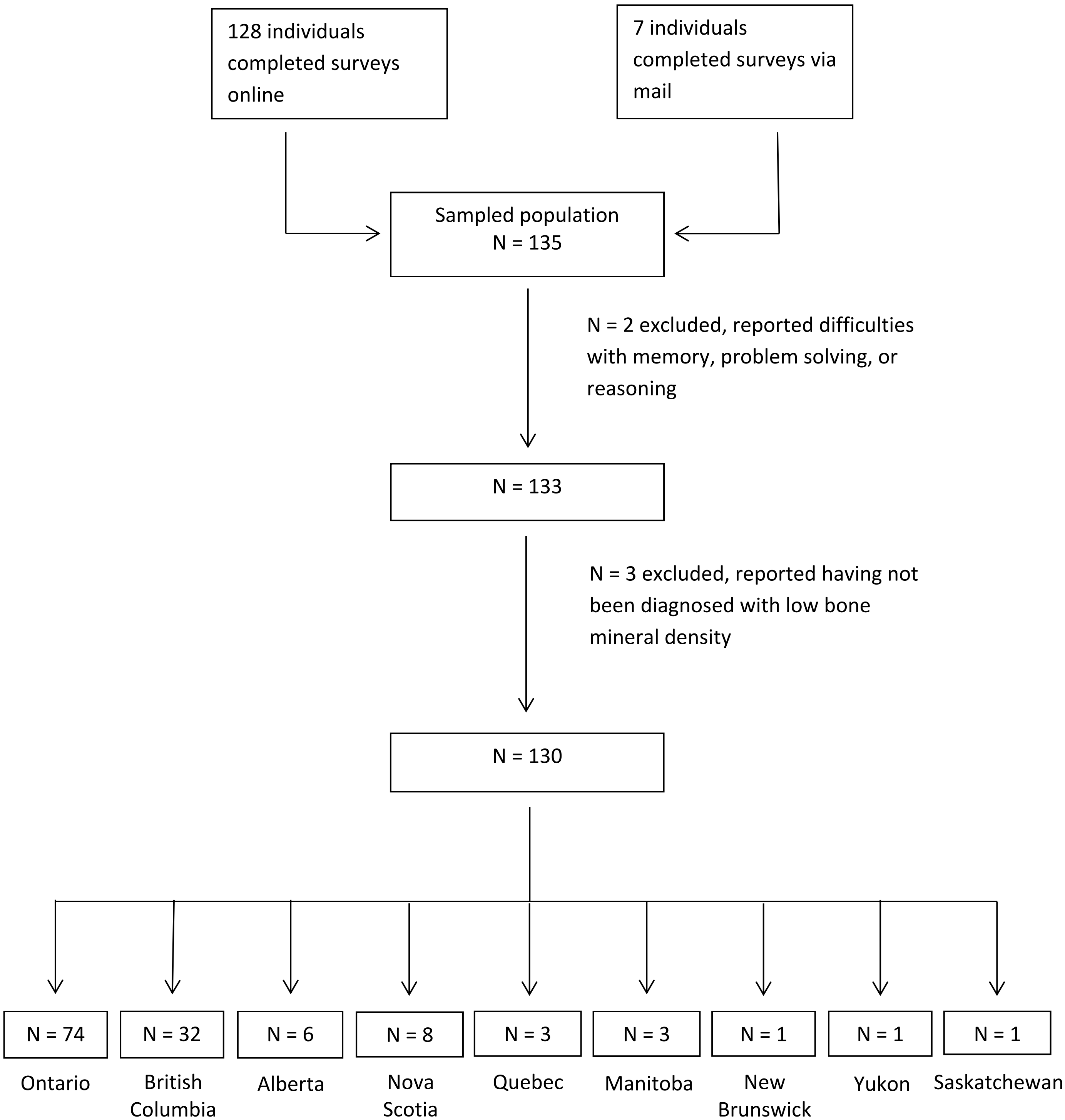

Figure 3: Flow diagram of participation

4.2 Participant Demographics

One hundred and thirty individuals (96.1% female) with mean (SD) age 66.32 (8.81) years participated in the study. Seventy-six percent (76%) of the sample reported having osteoporosis, 20% reported having osteopenia, and 2% reported being diagnosed with low BMD but were unsure whether they had osteopenia or osteoporosis (Table 8). Sixty-three participants (49%) reported sustaining a fracture after the age of 40 years; there were 5 hip/femur fractures, 17 wrist fractures, 6 fractures at the upper arm, 17 rib fractures, 18 fractures of the spine, with 30 fractures reported at other sites. Seventeen individuals (13%) reported requiring additional assistance in activities such as caring for themselves, housekeeping, eating, meal preparation, and shopping. Seventy-seven individuals (59%) reported having one or more comorbidities and the most commonly reported condition was arthritis (37%) (Table 8 and 9). Twenty-three participants (18%) had fallen at least once within the past six months of completing the survey. Ninety-three individuals (73%) reported taking medication to prevent bone loss or fractures. The most frequently reported types of medication for bone health were Actonel (risedronate) and Prolia (denosumab), reported by 20 participants (16%) and 15 participants (12%), respectively. All participants (100%) reported vitamin D supplementation. Twenty-eight participants (23%) rated their current health as excellent, 61 (47%) as very good, 33 (25%) as good, and 8 (7%) as fair. Most participants reported their highest level of education achieved as either post-secondary (42%) or greater than post-secondary (38%). The minimum level of education achieved by all participants was high-school.

Table 8: Summary of Participant Characteristics

Total number of participants	130
Age in years: mean (SD)	66.32 (8.8)
Number of females: n (%)	125 (96.1)
Self-reported diagnosis of low bone mineral density: n (%)	
Osteoporosis: n (%)	99 (76)
Osteopenia: n (%)	26 (20)
Diagnosed with low BMD but unsure whether its osteopenia or osteoporosis: n (%)	3 (2)
Did not know or was unsure of diagnosis n (%): n (%)	1 (1)
Did not answer question	1 (1)
Previous fracture after age 40 years: n (%)	63 (49)
At least one fall within the past 6 months: n (%)	22 (17)
Use of walking aid (cane, walker): n (%)	15 (12)
Use of medication for low BMD: n (%)	97 (75)
Vitamin D supplementation (IU): mean (SD)	2327.3 (6550.5)
Receive additional assistance in activities of daily living: n (%)	17 (13)
Previous use of oral glucocorticoids: n (%)	10 (8)
Number of comorbidities: n (%)	
None: n (%)	52 (40)
One: n (%)	44 (34)
Two: n (%)	19 (15)
Three: n (%)	11 (9)
Four: n (%)	3 (2)

Education Level: n (%)	
Elementary School: n (%)	0 (0)
High School: n (%)	26 (20)
Post-Secondary: n (%)	54 (42)
> Post-Secondary: n (%)	49 (38)
Level of Household Income: n (%)	
< $ 20, 000: n (%)	11 (9)
$ 20, 000 – 40, 000: n (%)	23 (18)
$ 40, 000 – 60, 000: n (%)	20 (16)
$ 60, 000- 80, 000: n (%)	31 (24)
> $100, 000: n (%)	17 (13)
Did not know or preferred not to answer: n (%)	27 (21)
Self-Perceived Health: n (%)	
Poor: n (%)	0 (0)
Fair: n (%)	8 (6)
Good: n (%)	33 (25)
Very good: n (%)	61 (47)
Excellent: n (%)	28 (22)

Table 9: Comorbidities and health-related complications reported by participants

Comorbidity/health-related complication	Number of participants reporting comorbidity/health-related complication
Stroke	0
Parkinson's disease	0
Multiple Sclerosis	0
Chest pain during activity or at rest	4
Difficulties with vision	13
Previous joint replacement	6
Arthritis	49
Past or current cancer	16
Diabetes	1
Other comorbidities or health-related complications listed by participant that was not specifically asked	37

4.3 Self-reported Physical Activity

The mean (SD) time spent doing MVPA per week by the entire sample was 831.35(1065.43) minutes. This figure reflects the amount of time that participants reported doing moderate- and vigorous-intensity activities while at work, doing housework or house maintenance, caring for their family, and engaging in recreation, sport, and leisure-time aerobic physical activities. The mean (SD) minutes spent doing MVPA in different PA domains are listed in Table 10. The mean (SD) minutes that participants spent walking for recreation, sport, or leisure was 129.46 (169.39) minutes. The mean (SD) days per week that participants reported doing strength and balance training were 1.90 (1.66) and 1.36 (1.84), respectively. As well, on average participants reported spending 361.68 (392.84) minutes walking in total per week. Sixteen individuals (12.3%) did not meet the physical activity guideline of engaging in a minimum of 150 minutes of MVPA during the week of activity reported. Forty-one participants (31.5%) did not report doing strength training at all and fifty-five participants (42.3%) reported doing strength training less than twice per week. Sixty-five individuals (50%) did not report doing balance training exercises and eight-two participants (63%) reported doing balance training less than two times during the week of recalled activity.

Table 10: Time spent engaged in MVPA in different domains of activity

PA Domain	Mean Minutes spent doing MVPA/week (S.D.)
Job-Related	50.76±196.00
House work, House Maintenance, Caring for Family	289.96±839.79
Recreation, sport, leisure-time PA	258.17 ±393.05

4.3.1 Correlates of time spent doing aerobic exercise

Univariate analyses revealed that four variables were significantly correlated with minutes spent doing aerobic exercise. Self-perceived health was positively associated with minutes spent doing aerobic leisure time physical activity ($r = 0.22$, $p = 0.01$). Similarly, perceived strength of barriers to exercise and intention to exercise score, both had a positive association with the outcome. The correlation between perceived strength of barriers to exercise and time spent doing aerobic exercise during leisure time was $r = 0.28$, $p = 0.001$. Self-efficacy had a correlation of $r = 0.19$, $p = 0.03$ with the minutes spent doing aerobic exercise. As well, intention to exercise was positively correlated with minutes spent doing aerobic exercise ($r = 0.22$, $p = 0.01$). The associations between participant characteristics and minutes spent doing aerobic leisure physical activities are summarized in table 11.

Table 11: Correlations between participant characteristics and minutes spent doing leisure physical activity

Variable	r-value	p-value
Age	-0.15	0.10
Gender	-0.08	0.38
Education level	-0.01	0.93
Self-perceived health	0.22	0.01
History of falls in the past 6 months	0.04	0.68
History of fractures after age 40 years	-0.01	0.88
Number of comorbidities	-0.16	0.06
Perceived strength of barriers to exercise	0.28	0.001
Exercise self-efficacy	0.19	0.03
Use of additional assistance	0.06	0.48
Intention to exercise score	0.22	0.01
Risk perception of sustaining a fracture	-0.13	0.16

4.3.2 Correlates of meeting MVPA guidelines – logistic regression analysis

Univariate logistic regression analyses revealed that three variables, intention to exercise, exercise self-efficacy, and perceived strength of barriers were significantly related to whether an individual was able to engage in at least 150 minutes of moderate- to vigorous-intensity aerobic physical activity (Table 12). The odds of meeting MVPA guidelines were increased with higher intentions to engage in exercise (OR 1.17 95% CI [1.01; 1.36], p = 0.03) and higher exercise self-efficacy (OR 1.10 95% CI [1.01; 1.21], p = 0.03). A higher strength of perceived barriers was also associated with increased odds of meeting MVPA recommendations (OR 1.21 95% CI [1.04; 1.42], p = 0.02). In a multivariable logistic regression involving intention to exercise, exercise self-efficacy, and strength of perceived barriers, none of the variables remained significant (Table 13).

Table 12: Univariate logistic regression analyses for variables associated with meeting MVPA recommendations

Variable (reference)	OR (95% CI)	p-value
Age (per year)	0.98 (0.92; 1.05)	0.65
Education Level (High school)	1.00	
Post-Secondary	1.04 (0.24; 4.55)	0.95
> Post-Secondary	2.00 (0.37; 10.70)	0.42
Self-Perceived Health (Fair)	1.000	
Good	1.04 (0.10; 10.77)	0.97
Very Good	1.60 (0.16; 15.74)	0.69
Excellent	1.86 (0.15; 23.58)	0.63
Intention to Exercise Score (per point)	1.17 (1.01; 1.36)	0.03
Self-Efficacy Score (per point)	1.10 (1.01; 1.21)	0.03
Perceived barriers to exercise (per point)	1.21 (1.04; 1.42)	0.02
Use of additional assistance (requires additional assistance for certain activities)	1.33 (0.27; 6.69)	0.73
Number of comorbidities (≤ 1 additional comorbidity)	0.68 (0.19; 2.43)	0.55
History of fractures after age 40 years (Have fractured after age 40 years)	1.05 (0.32; 3.45)	0.93
History of falls in the past 6 months (Have fallen in the past 6 months)	0.97 (0.20; 4.77)	0.97
Risk perception	1.13 (0.76; 1.68)	0.54

Table 13: Multivariable logistic regression analyses for variables associated with meeting MVPA recommendations

Variable (reference)	OR (95% C.I.)	p-value
Intention to exercise score (per point)	2.58 (0.68; 9.79)	0.16
Exercise self-efficacy score (per point)	0.41 (0.12; 1.34)	0.14
Perceived barriers to exercise (per point)	2.25 (0.95; 5.36)	0.07

4.4 Barriers to exercise and strength of perceived barriers

The most commonly perceived barrier to exercise was no enjoyment for exercise and it was reported by 66 participants (51%) (Table 14). As well, sixteen individuals (13.0%) reported that having no company to exercise with was the barrier that they perceived as preventing them from being able to exercise regularly the most. Twenty-five participants (20%) reported health-related problems (i.e., pain, previous injuries) as an additional barrier to exercise. Other additional barriers that were reported by participants included having to care for others (i.e., children, spouse, family members), not having facilities or exercise programs in close proximity, seasonal- or weather-related restrictions (i.e., concern of black ice), not having knowledge of appropriate exercises, not being interested in exercise, having other obligations or responsibilities (i.e., volunteer work), fear of injury or fall, and lack of motivation (Table 15). Twenty-seven (21.3%) participants reported that their perceived barriers to exercise made it difficult or extremely difficult for them to do at least 150 minutes of MVPA per week. Thirteen (10.2%) individuals reported that barriers to exercise made it difficult for them do strength training two times each week. Eleven (8.7%) participants reported that barriers made it difficult for them to meet balance training guidelines (Table 16).

Table 14: Perceived barriers reported by participants

Barrier to Exercise	Number of participant responses (%)
	Barrier does make it difficult for them to exercise regularly
Lack of time	39 (30.9%)
Lack of motivation	63 (49.5%)
Fear of injury	60 (47.2%)
No equipment	40 (32.2%)
No company	58 (47.2%)
Poor health/health-related complications	48 (37.5%)
No facilities	34 (26.5%)
No enjoyment	66 (51.2%)
No transportation	14 (10.9%)
No persistence	55 (42.6%)
Not affordable	45 (34.8%)
Too old	9 (7.03%)
Need more time to rest/relax rather than exercise	29 (23.3%)
Lack of knowledge of appropriate exercises	50 (39.1%)

Table 15: Response distribution of additional barriers to exercise reported by participants

Reported barrier	Number of participants that reported barrier (%)
Health-related complications	25 (19.3%)
Having to care for others	8 (6.15%)
Not having exercise facilities or programs in close proximity	4 (3.08%)
Seasonal- or weather-related restrictions	11 (8.46%)
Lack of knowledge of appropriate exercises	3 (2.31%)
No interest in exercise	1 (0.77%)
Having other obligations or responsibilities	1 (0.77%)
Fear of injury or fall	3 (2.31%)
Lack of motivation	4 (3.08%)

Table 16: Response distribution of ratings of difficulty to achieve physical activity guidelines considering barriers to exercise

Degree of difficulty to meet PA guideline given barriers	Number of participant responses (%)		
	Do ≥150 min MVPA aerobic exercise each week	Do exercises to increase muscle strength ≥2 times each week	Do exercises that challenge balance ≥2 times each week
Not difficult	76 (59.8%)	90 (70.3%)	94 (74.0%)
Neutral	24 (18.9%)	25 (19.5%)	22 (17.3%)
Difficult	27 (21.3%)	13 (10.2%)	11 (8.7%)

4.4.1 Willingness-to-pay for different methods of exercise provision

Seventy-eight percent (78%) of the sample responded that they would be interested in using an exercise DVD that is designed for individuals with osteoporosis. The mean (SD) WTP for this type of provision of exercise was $16.99 (8.44) and WTP ranged from $0 to $30. Ninety-five individuals (74%) expressed interest in participating in a group exercise class that would involve doing aerobics and muscle strengthening exercises for one hour per week for 12 weeks. The mean (SD) WTP for the group exercise class was $44.75 (21.53) and ranged from $0 to $100. Eighty-one participants (64%) reported that they would be interested in working one-on-one with a certified personal trainer for one hour a week for six weeks. The mean (SD) and range WTP for this type of provision of exercise was $179.29 (167.36) and $0 to $300, respectively. Mean WTP for a group exercise class and working one-on-one with a personal trainer was less the suggested amount of money that these methods of delivery would normally cost. Self-reported household income was significantly associated with WTP for a group exercise class (r = 0.29, p = 0.001) and WTP for working one-on-one with a personal trainer (r = 0.26, p = 0.002). The associations between household income and WTPs for different methods of delivering exercise information are summarized in table 17.

Table 17: Correlations between income and WTP for different methods of delivering exercise information

Method of delivering exercise information	r-value	p-value
Exercise DVD	0.03	0.70
Group exercise class	0.29	0.001
Working one-on-one with a personal trainer	0.26	0.002

4.5 Other factors that affect exercise behavior

4.5.1 Perceived risk of sustaining a fracture

Forty (31.0%) participants reported that they did not perceive a risk of sustaining a fracture sometime in the future. Fifty-two (40.3%) individuals reported their risk perception of breaking a bone in the future as neutral. Thirty-seven (28.7%) participants did perceive a risk of sustaining a fracture.

4.5.2 Participants' intentions for exercise

One hundred and nine (84.5%) individuals expressed a high intention to exercise regularly. As well, 79 (61.7%) participants, 89 (69.5%) individuals, and 85 (66.4%) participants reported a high level of intention to meet MVPA, strength training, and balance training guidelines, respectively. The number of individuals who responded to each level of intention for each exercise criteria is summarized in Table 18.

Table 18: Response distribution of levels of intention for exercise

	Number of participant responses (%)			
Level of Intention	To exercise regularly	To do ≥150 min aerobic MVPA/week	To do exercises that increase muscle strength 2x/week	To do exercises that challenge balance 2x/week
Low intention	7 (5.44%)	37 (28.5%)	22 (17.2%)	24 (18.7%)
Neutral	13 (10.1%)	14 (10.8%)	16 (12.5%)	19 (14.8%)
High intention	109 (84.5%)	79 (61.7%)	89 (69.5%)	85 (66.4%)

4.5.3 Participants' self-efficacy for exercise

Eighty-seven percent of the sample reported that they were sure of themselves that they could be physically active. Eighty-five (65.9%) participants, 104 (81.3%) individuals, and 100 (78.7%) participants reported high levels of self-efficacy to meet MVPA, strength training, and balance training recommendations, respectively. Furthermore, 106 (82.2%) participants reported that they felt sure that even if they stopped exercising for some time, that they could become physically active again. The number of individuals that responded to each level of self-efficacy for each exercise criteria can be found in Table 19.

Table 19: Response distribution of levels of self-efficacy for exercise

	Number of participant responses (%)				
Level of Self-Efficacy	"I am sure that I can be physically active"	"I am sure that I can do ≥150 min aerobic exercise each week"	"I am sure that I can do exercises to increase muscle strength 2x/week	I am sure that I can do exercises that challenge my balance 2x/week	"I am sure that even if I stop exercising for some time, I can become physically active again"
Low	21 (16.2%)	44 (34.1%)	24 (18.8%)	27 (21.3%)	23 (17.9%)
High	109 (87.0%)	85 (65.9%)	104 (81.3%)	100 (78.7%)	106 (82.2%)

4.6 Associations between HAPA model constructs

Intention to meet the Canadian Physical Activity guidelines for older adults was found to be significantly associated with measures of self-efficacy ($r = 0.98$, $p = < 0.0001$) and strength of perceived barriers ($r = 0.88$, $p = < 0.0001$). On the other hand, risk perception was not significantly associated with intention ($r = -0.12$, $p = 0.16$). Time spent doing moderate- to vigorous-intensity aerobic physical activity was significantly associated with measures of self-efficacy ($r = 0.21$, $p = 0.01$), strength of perceived barriers ($r = 0.22$, $p = 0.01$), and intention ($r = 0.21$, $p = 0.02$).

5.0 Chapter 5 Discussion

The key findings of the study were: 1) among individuals who are likely engaged in self-management, a majority met MVPA recommendations but many did not meet strength and balance training guidelines, and 2) predominant barriers to exercise reported by these individuals were: having no enjoyment for exercise, having no company to exercise with, and health-related problems or complications. The initial hypothesis that a majority of older adults with low BMD are not meeting physical activity guidelines for older adults was partially supported. One hundred and fourteen (87.7%) participants reported doing at least 150 minutes of MVPA per week and seventy-five (57.7%) participants reported doing strength training at least twice each week but only forty-eight (36.9%) participants reported doing balance training exercises at least twice per week. Contrary to our initial hypothesis that approximately half our respondents would not report at least 150 minutes of MVPA per week, we found that only sixteen participants (12.3%) did not meet MVPA recommendations. On the other hand, consistent with our hypothesis, the majority of respondents were not doing strength and balance training at least twice per week. The most commonly perceived barrier to exercise among individuals with low BMD was not lack of motivation, but was having no enjoyment for exercise. Furthermore, the barrier that these individuals perceived as preventing them from being able to exercise regularly the most was not health-related complications but was having no company to exercise with. More than half of the sample expressed interest in receiving an exercise DVD that is designed for individuals with osteoporosis, participating in a group exercise class that would involve doing aerobics and muscle strengthening exercises, and working one-on-one with a certified personal trainer. However, mean willingness to pay for a group exercise class and working one-on-one with a personal trainer was less than the suggested amount of money that these modes of delivery would normally cost. Given that physical activity and exercise participation may be important strategies in preventing fractures, our findings suggest that one way to increase participation in MVPA and strength and balance training among individuals with low BMD is to address barriers to exercise reported by these individuals e.g. by finding effective ways of increasing levels of enjoyment, promoting a sense of community within exercise settings, or educating people on strategies to minimize the influence of health-related problems on their exercise routines. As well, the results of this study suggest that individuals with low BMD may view cost as a barrier to participating in exercise activities.

5.1 Physical Activity Levels of Individuals with Low Bone Mineral Density

5.1.1 MVPA Levels

MVPA levels reported by individuals in our study were higher compared to levels found in previous work in older adults and only 12.3% of the sample was still not achieving at least 150 minutes of MVPA per week (206–209). Previous studies have found that many older adults do not meet MVPA recommendations. The Canadian Health Measures Survey reported that among 901 older adults that participated in their study, only 13.1% (95% CI 9.0-17.3) had met the criteria of accumulating more than 150 minutes of MVPA per week (207). Similarly, a study that used accelerometry to measure time spent doing MVPA found that less than 10% of their participants met the recommended level (206). Considering that our participants were members of the Canadian Osteoporosis Patient Network or people that attended an osteoporosis public education event, these individuals were likely somewhat engaged in self-management and aware of their risk of fracture. In comparison to individuals who are less engaged and have lower risk perceptions, it is more likely that our participants would meet MVPA guidelines (210). In comparison to past studies, a greater proportion of our participants met the guidelines for MVPA. Although a considerable number of individuals in our study were engaging in enough moderate- and vigorous-intensity aerobic activities, it is likely that individuals who are less engaged and have lower risk perceptions are doing less MVPA. Therefore, older adults with low BMD may still require greater encouragement to increase their activity levels.

Self-perceived health, self-efficacy, intention to exercise, and strength of perceived barriers were variables that were significantly correlated with time spent doing aerobic exercise or with odds of meeting MVPA recommendations. Examining how these variables influence physical activity and exercise behaviour and finding ways of improving them may be conducive to increasing aerobic exercise levels in older adults. Self-perceived health has been found to be associated with a number of health behaviors and is considered a reliable predictor of physical activity in older adults (211,212).Previous studies have found that having very good or excellent self-perceived health has been associated with a greater likelihood to meet physical activity recommendations (213). In contrast, poor self-perceived health has been associated with lower levels of physical activity, including in those with chronic diseases (212,214,215). Past studies have noted that one's efforts to achieve health-related goals, such as being more active, may regulate individuals' self-perceived health (216). Older adults' perceptions of their health are dependent on their ability to adjust to the demands of their everyday life in the context of their resources and capabilities (217). Chronic diseases, such as osteoporosis, can create struggles for older adults trying to make the adjustments that are required to cope with the demands of daily living, thus negatively influencing their perception of their health and quality of life (218–220). For older adults to improve their perception of health, they may need to adjust their expectations regarding life situations over time (217). As well, others can help older adults with chronic diseases by supporting them in their efforts to deal with demands of daily living (217).

Previous work has found self-efficacy to be a correlate of leisure time physical activity and exercise in different groups of older adults (178,203,221). In particular, action self-efficacy and coping self-efficacy have been identified as major predictors of physical activity intentions and physical activity behaviour in this population, respectively (177). Self-efficacy has been hypothesized to influence physical activity and exercise initiation, planning, and behaviour. For example, it may operate as a moderator between planning and behaviour and may be a necessary precondition for initiation and maintenance of physical activity (222). As well, self-efficacy may serve as a mediator between self-regulatory processes, such as executive function, and adherence to exercise in older adults (223). In our study, measures of self-efficacy were found to be significantly associated with intention to meet the Canadian Physical Activity guidelines for older adults and with time spent doing moderate- to vigorous-intensity aerobic physical activity. These findings were consistent with the HAPA model which states that task self-efficacy contributes to intention formation (170) Therefore, it is evident that self-efficacy is essential to initiating and maintaining physical activity and exercise behaviour and raising self-efficacy has been a common goal of educational interventions for persons with chronic illnesses (224). Factors such as perceiving social support, having a greater understanding of the illness, and not being greatly affected by consequences from illness have been found to be directly related to higher self-efficacy among individuals with chronic diseases (225). Social support may be provided in the form of reminders of personal accomplishments, verbal encouragement, or learning from others' experiences (226). Significant others can also encourage individuals with low BMD to try new ways of managing osteoporosis-related problems or add to the understanding of his or her illness (225). Understanding of one's illness can be viewed as precondition for knowing what to do to cope with the situation, whereas experiencing many and severe consequences from illness can lead to feelings of hopelessness which can take away from coping beliefs (225). Self-efficacy can be strengthened through experiencing success in performing actions as planned, such as being able to engage in physical activity and exercise on a regular basis (227). Suffering from many and severe consequences from illness can also hinder individuals from being able to master performing physical activity regularly and from gaining positive emotional arousal from doing it (225,227–229). Therefore, perceiving social support and having a greater understanding of illness can help strengthen self-efficacy. As well, minimizing the effect of consequences from illness can reduce negative affective responses associated with exercise which can help improve self-efficacy in older adults with low BMD.

Similar to the results found in this study, others have reported an association between intention to exercise and exercise behaviour (230). Intentions can provoke individuals to engage in action planning, which in turn influences the behaviour-change process (231). High intentions strengthen the efficacy of if-then plans, decisions made in advance as to when and where to take specific actions to reach a goal (232). As well, intention strength influences the degree of specification of if-then plans which is predictive of the likelihood of behavior enactment (232). Therefore, intentions mediate the relationship between planning and behaviour, and the degree of mediation is dependent on intention level (233).

Forming intentions to engage in physical activity or exercise is an essential step to becoming more active even though strong intentions do not necessarily lead to behaviour change (234). Communicating risk perceptions of sustaining a fracture has been identified as an effective way of strengthening intention to exercise among older adults with low BMD (177). However, in our study, risk perceptions were not significantly associated with measures of intention. This is contrary to the HAPA model which considers risk perception to have a significant influence on intention formation (170) Our participants expressed high levels of intention to engage in exercise regularly and measures of intention were significantly associated with self-efficacy and strength of perceived barriers. According to the HAPA model, formation of intentions are linked to self-efficacy and perception of barriers, thus these findings are consistent with the model (170).Therefore, other ways of strengthening intentions that may be more effective among older adults with low BMD are improving action self-efficacy or ensuring that individuals have strategies to overcome barriers to exercise. Other factors that were not examined in this study, such as affective and health-related outcome expectancies, may greatly influence intentions to exercise regularly in this group as well. Previous work has found that there is a direct effect from affective, but not health-related outcome expectancies, on physical activity intentions among older adults (235). In contrast, other studies have found that health-related outcome expectancies are significantly associated with intentions for physical activity among older adults with chronic illnesses (236). For that reason, the association between intentions and affective and health-related outcome expectancies among individuals with low BMD should be investigated in future work.

Surprisingly, strength of perceived barriers to exercise was positively associated with intention to meet the physical activity guidelines and time spent doing aerobic exercise during leisure time. This finding is contrary to the HAPA model because the HAPA considers barriers to be a factor that contributes to health-compromising behaviours, such as physical inactivity (170). Furthermore, other studies have found perception of barriers and physical activity levels to be inversely related (184,185). Considering that the participants of our study were, to some extent, engaged in self-management, it may be that they were aware of the potential barriers that they may encounter and had made plans ahead of time to overcome them. Previous work has found that although physically inactive and active older adults share some barriers to exercise, physically active individuals were able to develop strategies to overcome them (237). In addition, individuals in our study may have a high recovery self-efficacy and a strong belief that they are able to get back on track after experiencing a lapse in behaviour (163). Many of our participants reported a high level of self-efficacy to exercise after a period of inactivity. Therefore, this may help explain the unexpected positive association found between strength of perceived barriers and leisure time aerobic exercise. However, the relationship found between strength of perceived barriers, intention to meet physical activity guidelines, and time spent doing aerobic exercise during leisure time may not be the same among individuals with lower levels of self-efficacy. Finding strategies such as actively engaging in coping planning and enhancing self-belief in their ability to recover from backslides may be effective for older adults with low bone mineral density to manage barriers.

Our study suggests that self-perceived health, self-efficacy, intention to exercise, and strength of perceived barriers are modifiable factors that influence leisure time aerobic exercise and MVPA in older adults with low BMD and that improving these factors may help increase activity levels in these individuals. Other results of our study suggest that there may be a need to assess alternative factors that influence aerobic exercise and MVPA. A majority of individuals reported their health as being positive and more than half of our participants reported a high self-efficacy to engage in 150 minutes of MVPA per week. As well, more than half of the sample expressed high intentions to exercise regularly and to meet MVPA guidelines and few individuals reported barriers to exercise as making it difficult for them to engage in MVPA. Rather than focusing on variables that are already strong among older adults with low BMD, it may be more important to explore other factors that could account for why many individuals are still not doing enough MVPA, such as outcome expectancies of physical activity or translating intentions into action. Regular aerobic physical activity and exercise are associated with reduced mortality, better health outcomes, and improved functional performance (238–241). Improving factors such as self-perceived health, self-efficacy, intention to exercise, and reducing strength of perceived barriers may help contribute to reaching this goal. In addition, it may be important to investigate other factors that influence engagement in aerobic activity.

5.1.2 Strength Training Levels

Almost half of our participants did not report partaking in strength training at all, even though it is one of several recommendations in Canada's Physical Activity guidelines and may be a good way to maintain bone density. This finding is surprising considering more than half of our participants reported a high level of intention and self-efficacy to do exercises that increase muscle strength twice per week. Moreover, not many individuals reported their perceived barriers as making it difficult to meet strength training recommendations. These results suggest that low levels of intention and self-efficacy, and perceiving barriers may not contribute to the low levels of strength training found among older adults with low BMD and that other variables, such as outcome expectancies, may need to be investigated. These results may also suggest that levels of intention, self-efficacy, and perception of barriers may not have been accurately captured. Although the findings of our study cannot provide a reason as to why many older adults with low BMD are not engaging in strength training, other studies may provide insight into barriers and correlates associated with participation in this type of exercise. For example, older adults have expressed lack of enjoyment associated with strength training and inaccessibility of exercise facilities (242). Previous work also suggests that there are misconceptions about strength exercise among older adults, such as a lack of understanding that strength training increases muscle mass or that increasing number of repetitions is more important than increasing weight for building strength (243). Furthermore, the same study found that 37% of its sample considered walking to be more effective than lifting weights for building muscle strength (243). These misconceptions were found even among individuals who already participated in a strength training program (243). Likewise, individuals in our study may hold the same misconceptions and approximately 40% of our participants reported lack of knowledge of appropriate exercises as a barrier to exercise. Therefore, older adults with low BMD may require further education on the benefits and recommendations of strength exercise (243). Other studies also provide support for the importance of highlighting benefits of strength training to older adults. Intention to undertake strength training is more closely related to coping appraisal than to threat appraisal (244). That is, older adults' intention to participate in strength training is more strongly associated to their beliefs in the potential benefits, such as improvement in general health or reduction in fall risk, compared to their perceived threat or fear of sustaining a fracture (244). Thus, ensuring that older adults with low BMD are aware of and understand the benefits of strength training may be an effective strategy to increase their participation. As well, subjective norm, which is the perceived pressure to perform a behavior that comes from observing what important others say or do, has been shown to be a strong determinant of strength-training behavior (245,246). Self-perceived health has also been identified as a correlate of participation and adherence to strength training programs (247,248). This correlate was also found in our study when we examined variables associated with meeting MVPA recommendations and time spent doing aerobic exercise. Therefore, strategies used to encourage older adults to increase MVPA levels may be applicable to strength exercises as well. There may also be a need to target individuals with lower levels of formal education (247). Lower education levels have been associated with a decreased likelihood to participate in strength training and decreased knowledge of strength exercise recommendations (243,247). It may be imperative to place additional emphasis on increasing awareness of the benefits of strength training, as well as improving their knowledge of strength training principles among those individuals. While the scope of our study cannot determine why older adults with low BMD are not engaging in strength training, our study does reveal that these individuals are likely not meeting the recommended levels of strength training. Since strength training is an important self-management strategy for preventing fractures, it is necessary to find ways to minimize barriers that are specific to strength training and to find approaches to promote this type of exercise for this population.

5.1.3 Balance Training Levels

More than half of the individuals in this study reported that the number of times they did balance exercises each week was less than what is recommended by the physical activity guidelines. Similar to strength training, more than half of our participants reported a high level of intention and self-efficacy to do exercises that challenge their balance and few individuals reported barriers to exercise as making it difficult for them to do balance training. Therefore, other factors may account for the low levels of balance training observed in individuals with low BMD. Intention to engage in balance training is more closely related to the perceived potential benefits than threats to health (244,249). However, many of our participants reported strong intentions to engage in balance training, thus outcome expectancies may be an important factor contributing to why these individuals are not doing this type of exercise.

Other studies have found that low levels of balance training may be attributed to older adults' refusal to accept that they are potential fallers even though they are aware of their likelihood of falling (250). Denial of personal risk represents a determination to maintain an active, self-sufficient, and independent lifestyle and identity (249). Older adults may be more receptive to balance training if they were convinced that their goal of independent living is entirely compatible with undertaking this type of exercise (249). Emphasizing multiple immediate benefits of balance training may be viewed as promoting independent activity and may be a more effective way to encourage participation (250). As well, focusing on benefits of balance training may be more likely to motivate individuals who thought of falls as not being preventable (251–253). Support from other important individuals such as family, friends, and health care providers is also associated with greater intention to carry out balance training and participation in fall prevention programs (244,251). Among older adults with low BMD, people of older ages may need greater encouragement to engage in balance training because they may be less inclined to leave home and join programs in the community (251). Although the results of this study were unable to determine why older adults with low BMD are not meeting recommended levels of balance training, it is clear that these individuals need greater encouragement and support to incorporate this type of exercise into their lifestyle. The current Canadian Physical Activity Guidelines specify that those with poor mobility should engage in balance training. Older adults with low BMD may not perceive themselves as having poor mobility or may be unaware of recommendations for balance training. There is not enough research specifically examining balance training participation in older adults. More work investigating determinants, correlates, perceptions, knowledge, and barriers associated with this type of exercise among older adults and those with chronic illnesses is needed to inform the development of approaches to increase balance training in this population.

It is likely that many older adults with low BMD are not meeting recommended levels of physical activity, particularly in doing strength and balance training. Our participants were recruited from the Canadian Osteoporosis Patient Network who receive educational materials on exercise or attended an osteoporosis public education event. Therefore, these individuals were engaged in self-management and physical activity levels reported by them are likely higher than those reported by individuals with lower risk perceptions and not as actively engaged in seeking information to decrease their risk of fracture (210). Despite this, a majority of participants in our study did not meet one or more criteria of the physical activity guidelines. Thus, there is a need to continue encouraging individuals with low BMD to do moderate- to vigorous-intensity aerobic exercise and exercises that are effective in improving bone health and reducing fall risk more frequently.

5.2 Perceived Barriers to Exercise

Predominant perceived barriers to exercise among our participants were having no enjoyment for exercise, no company to exercise with, and health-related complications. To our knowledge, this is one of the few studies to specifically examine barriers to exercise for older adults with low BMD. The barriers reported by our participants have been found in other studies of older adults as well (187,204,254). According to the HAPA, the perception of barriers can negatively influence intention to engage in physical activity and exercise and behaviour (170). A majority of older adults have at least one barrier which prohibits them from participating in exercise and individuals with chronic diseases are likely to face more perceived barriers than the general population (186,255). Most of our participants in our study reported that their perceived barriers to exercise did not make it difficult for them to meet physical activity guidelines. There may be a disconnect between the degree to which these individuals perceive barriers and the actual degree to which barriers influence their physical activity levels. Another explanation may be that our participants have learned to overcome their barriers in their everyday life and therefore do not perceive them as adversely affecting their ability to meet physical activity guidelines. In any case, underlying health conditions has been found to be a major contributor to lack of participation among older adults (256). Exercise programming should target the specific needs and health conditions of older adults (256). Identifying perceived barriers may help determine what obstacles that older adults with low BMD face while exercising, better understand the needs of this group, and inform future interventions to encourage these individuals to increase their engagement in exercise.

Having no enjoyment for or lack of interest in exercise is a frequently cited barrier to exercise among older adults (204,254,257). Intrinsic motivations, such has enjoyment for an activity, represent the highest level of self-determinism and are important for progression and maintenance of that activity (258–261). In older adults, enjoyment has been found to contribute most to differentiating between inactive, active, and sustained maintainers of physical activity and its influence is greater at higher levels of activity (259). Furthermore, enjoyment of physical activity has been found to be associated with self-efficacy in different groups of people (262,263). As noted before, self-efficacy greatly influences intentional and volitional phases of adoption of health behaviours and is an important determinant of exercise behaviour (175,193). Therefore, while enjoyment can represent a resource, lack of it can be a major barrier to adopt or maintain exercise engagement (193). To our knowledge, there are few studies that investigate methods of directly increasing enjoyment as an emotion that accompanies the experience of physical activity. However, there are potential ways of meeting this goal through related variables. For example, one method of increasing enjoyment for exercise proximally is through enjoyment of social affiliation or receiving support from others who also exercise (264). Having others as a motivator to exercise has been noted as a positive influence to engage in physical activity (264). Older adults find that having social support can assist them in overcoming their perceived barriers (265,266). Furthermore, social support specific to the behaviour has been shown to be a better predictor of future behaviour in comparison to general social support, that is, exercise class attendees have more of an influence than family members (264,267). Indeed, lack of company is a frequently reported barrier to exercise among older adults as well (204,254). Therefore, encouraging older adults with low BMD to participate in a structured, group program would allow them to perceive positive social influences from those around them and increase their enjoyment for physical activity and exercise (268). Self-efficacy has been shown to have an important influence on physical activity enjoyment, therefore, improving self-efficacy may be a way of increasing enjoyment (263). Our participants reported a high level of exercise self-efficacy, therefore, it may be that their reported level of self-efficacy does not reflect their actual level or that improving self-efficacy may not be the most effective way to increase enjoyment to exercise and to encourage individuals with low BMD to be more active. It is no surprise that having no enjoyment or lack of interest in exercise was the most commonly reported barrier for individuals in our study. Enjoyment as a positive affective response can influence participation in physical activity and has been found to differentiate adherers and non-adherers of exercise (267). Thus, it may be worthwhile to find effective ways of increasing enjoyment among older adults with low BMD to encourage them in becoming more active.

Lack of company was another predominant barrier to exercise reported by participants of our study and has been noted by other groups of older adults as well (189,204,254). Many exercise programs or interventions are conducted in group settings which allow for opportunities for social interaction and development of important social support networks (269). Social support is a commonly cited resource in adopting and maintaining health behaviours, and similar to enjoyment for exercise, lack of it can be a barrier (193). Identifying with others who are active and receiving encouragement by significant others are important motivators for older adults and can contribute to enjoyment of exercise (268,270–273). Past research has indicated that social support greatly influences adherence to physical activity among older adults (269). As well, it is indirectly related to exercise behaviour through its effect on self-efficacy (274).

As previously mentioned, one method of addressing lack of company is to encourage older adults with low BMD to join organized, group activities (268). Exercise groups are composed of their own social structure and the interactions, friendships, and alliances that are formed are unique to the exercise group (269). Social support gained from an exercise setting is a better predictor of future exercise behaviour compared to general social support (267). Positive social influences, such as identifying with others in exercise classes and expectations of others in regards to behaviour and attendance, can be perceived through structured classes (268). As well, previous literature has demonstrated that reductions in loneliness can result from joining exercise programs or interventions (269). The physical activity environment can provide social resources to combat loneliness, a common problem encountered by older adults (269,275). Older adults may perceive negative social situations such as feeling embarrassed while participating in a group exercise class (264). However, these pressures may be resolved and regular attendance may be encouraged if individuals are able to recognize that others felt the same (264). Educating not only older adults, but significant others around them, that physical activity and exercise is important for maintaining health may be another strategy to address older adults' perception of lack of company while exercising (268). Important others may invite older adults to exercise with them after being more aware of the positive impact of physical activity on health (268). Not having others to exercise with or a lack of company can discourage older adults from engaging in physical activity. Therefore, addressing this perceived barrier is instrumental to increasing activity level among older adults with low BMD.

Many participants in our study reported health-related complications as an additional barrier to exercise that they perceived. Health-related complications, health problems, or poor health is a frequently reported barrier to exercise among other populations of older adults as well (189,204,276,277). Comorbid health conditions are common in older adults and can negatively affect their ability to engage in physical activity and exercise (278). In addition, a number of comorbidities, such as heart disease and Parkinson's disease, have been shown to be associated with fracture (279). On the other hand, health concerns have also been considered as motivators to participation (280). A majority of our participants reported a positive rating of self-perceived health which may be contrary to our finding that health-related complications are a predominant barrier to exercise for these individuals. However, previous studies have found a potential disconnect between self-perceived health and actual health status among older adults (256). Therefore, health-related problems may indeed contribute to nonparticipation. To help older adults with low BMD increase their physical activity levels, there may be a need to take into consideration individual physical conditions while planning exercise programs and choosing suitable types of activities (281). This may be best promoted by having health care providers offer advice on activities that are appropriate according to each individual's health status (281). Another method to address health-related problems as a barrier for these individuals is to improve exercise self-efficacy (282). As noted above, self-efficacy has been shown to be a positive predictor of physical activity intention and behaviour among older adults (177). However, participants in our study already reported high levels of exercise self-efficacy. It may have been that the level of self-efficacy these individuals reported did not truly reflect their actual level of self-efficacy. Another possible explanation is that our participants do indeed have high levels of exercise self-efficacy but may not have the same level of self-efficacy in overcoming health-related problems. Although it is unclear from this study whether improving self-efficacy is an effective way to encourage individuals with low BMD, self-efficacy may still be a contributor to the low levels of physical activity found among this group. People fear and avoid situations that they believe exceed their coping skills (282,283). One way of improving self-efficacy may be to introduce mild forms of physical activities that can be well tolerated to increase one's confidence in their capabilities of engaging in exercise (281). As well, goal setting and making ongoing modifications to goals that were met and unmet may be another method of promoting self-efficacy (284). Goal setting can assist individuals to form beliefs about what they are able to do and guide their actions towards achieving their goals (227,284). This process can help facilitate an individual's motivation and self-efficacy (284). Furthermore, by achieving their goals, individuals are able to evaluate their progress which provides further motivation to continue exercising (284). Our study reveals that among our participants, the strength of perceived barriers is associated with leisure time aerobic activity levels although a majority of individuals reported that perceiving barriers do not make it difficult for them to exercise regularly. Identifying barriers for older adults with low BMD may help inform future interventions that encourage these individuals in becoming more active.

5.2.1 Willingness to Pay for Different Provisions of Exercise

Most participants expressed interest in receiving exercise instruction via different modes of provision such as using an exercise DVD designed for individuals with osteoporosis, participating in a group exercise class, and working one-on-one with a certified personal trainer. Considering that our participants are engaged in self-management, it not surprising to see that many of these individuals were interested in receiving exercise instruction. The mean willingness to pay reported by participants for the exercise DVD was within the suggested amount that it would normally cost. On the other hand, for the group exercise class and working one-on-one with a personal trainer, mean willingness to pay was less than the suggested amounts. Furthermore, our study found that self-reported household income was significantly associated with willingness to pay for a group exercise class and with willingness to pay for working one-on-one with a personal trainer. Previous work has also found willingness to pay for health improvements of exercise to be influenced by income (16). Cost or the ability to pay may be a barrier for older adults with low BMD to participate in provisions of exercise that are more costly but may have higher levels of adherence. Taking part in group exercise classes may be more enjoyable and provide social support for these individuals and working one-on-one with a personal trainer may provide opportunities for individualized planning of exercise programs. Cost has been cited as a barrier to exercise among other populations of older adults (285,286). As well, one study found that offering low- or no-cost classes was among the features of physical activity programs that older adults had suggested to enhance participation (277). Considering that older adults have reported lack of knowledge about exercise as a barrier and that they can benefit from social aspects of group exercise, it may be worthwhile to consider finding ways of offering exercise instruction to these individuals at lower costs to encourage greater participation (268,276).

To our knowledge, this is the first study examining willingness to pay for different provisions of exercise among individuals with low BMD. Willingness to pay can be a method of quantifying the strength of an individual's preferences(16). Since physical activity and exercise may be important strategies for older adults with low BMD to decrease their fracture risk, it may be important to conduct further research on willingness to pay for exercise among these individuals. Research that has been done in other populations of older adults may provide insight into our population of interest. Previous work has shown that individuals with higher education and income levels report a higher willingness to pay for the health effects of physical activity (16). Furthermore, individuals may value short-term health improvements gained from exercise more than long-term improvements (16). In a study examining patient preferences for falls prevention in hospitals, the intervention that was most highly valued was the multifactorial intervention program (287). The participants of this study may have preferred this intervention most due to its availability of multiple options for preventing falls and the tailoring of these approaches to their individual needs (287). Furthermore, in the same study, the booklet and video education intervention was not valued very highly suggesting that these individuals value opportunities for social interaction, the ability to ask questions directly of a health professional or that they feel it may be easier to learn information if there is someone there to explain it (287). Our findings revealed that older adults with low BMD may require greater encouragement and support for exercise programs that require greater costs to participate. Further research examining willingness to pay for different provisions of exercise among these individuals is needed. Future work may help elicit valuable information about the physical activity and exercise preferences of this population.

5.3 Use of the IPAQ to Measure Time Spent doing MVPA

There were a number of strengths and limitations to using the IPAQ to measure time spent doing MVPA per week among our participants. The long form of the IPAQ addresses different domains of physical activity (i.e. job-related, housework/house maintenance) that are relevant to older adults and that may not have been salient to our participants if they were not asked about those activities specifically. However, this attribute of the IPAQ may also have led to overestimation of time spent doing MVPA. It is possible that participants may have reported time spent doing the same activity in two different categories of the IPAQ which would lead to over reporting of MVPA. This concern was raised by Heesch et al (2010) and was addressed by including reminders in the questionnaire to only report activities once. Another instance in which participants may have overestimated their time spent doing MVPA was while they reported the amount of time they spent doing activities at certain intensities. For example, participants may have believed that they were performing an activity at a higher intensity than in actuality. This concern was addressed by providing examples of what it may feel like while doing activities at a vigorous- or moderate-intensity. Our participants may also have reported activities that were performed for less than 10 minutes which would also overestimate time spent doing MVPA. Prompts were provided within IPAQ questions to remind participants to only include physical activities that they did for at least 10 minutes at a time. In addition to being able to address different domains of physical activities, one other strength of the IPAQ is that it has demonstrated sufficient validity to measure time spent doing MVPA among older adults against objective measures, such as accelerometry, in past studies (198,199). However, accelerometers have been noted to underestimate physical activity levels (288). Many previous studies asked their participants to wear their accelerometers at the waist (198,199,288). One major limitation of a waist-mounted accelerometer is that it is likely to underestimate upper body movement such as strength training and carrying heavy loads (288). Furthermore, activities such as swimming or cycling cannot be captured or are underestimated by an accelerometer (288). It is unknown how an accelerometer's limitations influence the findings of studies that used accelerometers to investigate the validity of the

IPAQ to measure time spent doing MVPA. Therefore, the findings of the IPAQ-accelerometer validation studies may have misled our decision to use the IPAQ for this study.

5.4 Study Limitations

The current study has a few limitations that need to be acknowledged. Individuals of our study were recruited from the Canadian Osteoporosis Patient Network and from an osteoporosis public education event. Therefore, our participants were likely engaged in self-management and it was expected that the results would differ from those who are not. For example, we would expect lower levels of reported physical activity in individuals less engaged. As well, individuals who are less engaged in physical activity or in self-management may report different barriers to exercise, lower risk perceptions of future fractures, lower intentions to engage in regular exercise, lower exercise self-efficacy, and higher strength of perceived barriers. Furthermore, all data, including physical activity levels and frequency of participating in strength and balance training, was collected via self-report questionnaires and susceptible to social desirability bias. This may mean that participant physical activity was overestimated. As well, the results of our study were also subject to recall bias. This is particularly concerning when studying older adults as their responses may be influenced by health status and mood, depression, anxiety, or cognitive ability (289). To minimize the length of our survey, outcome expectancies were not assessed. This decision was made based on previous literature that found outcome expectations to not be significantly associated with physical activity intentions or participation among older adults (177,276). However, based on the findings of our study that risk perception was not significantly associated to measures of intention to exercise regularly, outcome expectancies may have been a variable that needed to be included into our questionnaire. Our study did not have enough participants to properly perform a logistic regression model to determine factors that were associated with meeting MVPA guidelines. It is suggested that there be at least 10 events per variable needed to maintain the validity of the model (290). In this case, our study needed at least 220 participants for a valid model. This significantly limits the strength of the study findings and the predictive ability of the model. Therefore, our study was underpowered and exploratory. The collection of our data was carried out over the fall and winter months. It is well documented that older adults' levels of physical activity vary with seasonality and that poor or extreme weather is a frequently reported barrier to exercise among these individuals (291,292). It is likely that participants reported lower levels of physical activity compared to if they completed the questionnaire during months with warmer temperatures, longer hours of daylight, and less extreme weather.

5.5 Future Directions

Our study reveals that greater efforts need to be put forth in encouraging older adults with low BMD to engage in sufficient amounts of physical activity, particularly in strength and balance training which may be most effective for preventing falls and fractures. Future studies should examine whether modifying variables such as self-perceived health, intention to exercise, exercise self-efficacy, and strength of perceived barriers would help these individuals increase their time spent doing aerobic exercise and investigate other potential variables that can influence aerobic exercise engagement such as outcome expectancies, action planning, and coping planning. Moreover, interventions that are designed to overcome lack of enjoyment for exercise, lack of company, and health-related complications need to be conducted in order to determine whether these barriers are major contributors to the low levels of activity observed. There is also a need to investigate whether there are barriers that are specifically related to strength and balance training. Greater work examining willingness to pay for various provisions of exercise is needed. It is important to determine why older adults with low BMD feel less inclined to pay for exercise programs that they may be more likely to adhere to but require greater costs and to find ways to address or overcome their low WTP. Furthermore, there is a need to identify aspects of exercise programs that these individuals value. This study was able to inform potential approaches to encourage greater engagement in physical activity and exercise levels among older adults with low BMD.

5.6 Conclusions

The findings of this study reveal that even among individuals with low BMD who are actively participating in self-management, a majority still do not meet all of the established physical activity guidelines for older adults. Although there is evidence to support that strength and balance training may be the most effective types of exercise for preventing falls and fractures, greater measures need to be taken in the promotion of these activities. Future work should be aimed at implementing educational or behaviour change strategies around strength and balance training for these individuals. Furthermore, perceived barriers to exercise and willingness to pay for different provisions of exercise were identified for older adults with low BMD. Different approaches to overcome having no enjoyment and no company to exercise with and health-related complications may be important for increasing physical activity levels in this population.

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Appendix A – Recruitment Materials

Recruitment Announcement in Online Newsletter for members of Canadian Osteoporosis Patient Network

Are you too fit to fracture?

Exercise is an important strategy in the management of osteoporosis. We are looking to improve our educational tools and programs on exercise and we would like input from you. The researchers at the University of Waterloo want to find out how active you are and to determine what things help or hinder you from being active. Your input will be used to develop future educational tools and inform future research. You may recall from the November 23 COPING issue, you were invited to fill out an online survey about osteoporosis and exercise that should take about 30-40 minutes to complete. Your contribution will make a positive impact on the lives of individuals living with osteoporosis! If you haven't already completed, please click the link below to fill out the survey.

http://fluidsurveys.com/surveys/uwaterloobonelab/osteoporosis-exercise/

We really appreciate your help!

Recruitment Announcement in Print Newsletter for members of Canadian Osteoporosis Patient Network

Are you too fit to fracture?

Exercise is an important strategy in the management of osteoporosis. We are looking to improve our educational tools and programs on exercise and we would like input from you. We want to find out how active you are and to determine what things help or hinder you from being active. Your input will be used to develop future educational tools and inform future research. We would like to invite you to fill out a survey about osteoporosis and exercise that should take about 30-40 minutes to complete. Your contribution will make a positive impact on the lives of individuals living with osteoporosis!

To participate, please contact Osteoporosis Canada by calling 1-800-462-6842. You will be mailed a print copy of the survey and a pre-paid envelope that you can use to mail your answers back to us. We really appreciate your help!

Informational E-mail for members of Canadian Osteoporosis Patient Network

Hi,

You are being invited to participate in a research study conducted by researchers at the University of Waterloo. This study is titled '**Physical Activity Levels and Barriers to Exercise in Individuals with Low Bone Mass**'.

An important strategy for individuals with low bone mass (osteoporosis/osteopenia) to decrease fracture risk and manage osteoporosis is physical activity and exercise participation. The aim of our study is to gain a better understanding of current physical activity and exercise levels of individuals with low bone mass, and to learn about different factors that make it difficult for these individuals to exercise.

If you choose to participate in our study, you will be asked to complete three questionnaires which should take approximately 30-40 minutes to complete in total. These questionnaires will ask you questions about your health, your current physical activity, and factors that make it difficult for you to exercise.

The results of our study will be summarized and reported in a future COPN newsletter. Your input is greatly appreciated and can help inform future education strategies and future research studies about exercise promotion among individuals with osteoporosis. Your contribution is important and will positively impact the lives of others living with osteoporosis.

Your personal information and data collected from the survey is anonymous and will be stored in a secure area at the University of Waterloo. This study has been reviewed by, and received ethics clearance, through the Office of Research Ethics at the University of Waterloo.

Please contact Osteoporosis Canada by calling 1-800-463-6842 if you would like to participate in this study. You will be mailed a print copy of the survey and a pre-paid envelope that you can use to mail your answers back to us.

Thank you for your time.

Sincerely,

Larry Funnell
(Chair of COPN)

Christine Cruz
(Osteoporosis Canada)

Lora Giangregorio
(University of Waterloo)

Informational E-mail for Individuals recruited from Osteoporosis Public Education Event

Hi,

Thank you for expressing your interest in our research at the Osteoporosis Public Education Forum. We would like to invite you to participate in a research study that we are currently conducting titled '**Physical Activity Levels and Barriers to Exercise in Individuals with Low Bone Mass**'.

An important strategy for individuals with low bone mass (osteoporosis/osteopenia) to decrease fracture risk and manage osteoporosis is physical activity and exercise participation. The aim of our study is to gain a better understanding of current physical activity and exercise levels of individuals with low bone mass, and to learn about different factors that make it difficult for these individuals to exercise.

If you choose to participate in our study, you will be asked to complete three online questionnaires which should take approximately 30-40 minutes to complete in total. These questionnaires will ask you questions about your health, your current physical activity, and factors that make it difficult for you to exercise.

Should you choose to participate in our study, you will be provided a summary of the results of our study. If you have already completed this questionnaire, please do not complete it again. Below, please find the link to our study's questionnaire.

[Invite Link]

If you have any questions, please contact Helen Ng through e-mail (hhlng@uwaterloo.ca) or telephone (519-888-4567 ext. 38779).

This study has been reviewed by, and received ethics clearance through the Office of Research Ethics (ORE) at the University of Waterloo. If you have any comments or concerns resulting from your participation in this study, you may contact the ORE at 519-888-4567 ext. 36005.

Thank you for your time and interest,

Helen Ng, MSc Candidate
Student Investigator
University of Waterloo
Department of Kinesiology
Faculty of Applied Health Sciences
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Appendix B – Complete online and print questionnaire

Physical Activity Levels and Exercise Preferences in Individuals with Low Bone Mass

Part 1: Health History Questionnaire

All of your responses will remain confidential and will only be accessible by the researchers of this study.

<u>Demographics</u>:

1. Please select your gender: □ Male □ Female

2. What is your current age?

3. Which province or territory do you currently live in?
   □ Alberta □ Nunavut □ British Columbia
   □ Ontario □ Manitoba □ Prince Edward Island
   □ New Brunswick □ Quebec
   □ Newfoundland and Labrador □ Saskatchewan □ Northwest Territories
   □ Yukon □ Nova Scotia

4. What is the approximate population in the city you live in? Please select one.
   □ < 15, 000 □ 100, 000 – 499, 999 □ 15, 000 – 30, 000
   □ ≥ 500, 000 □ 30, 000- 99, 999 □ I do not know

5. What is your highest level of education achieved?
   □ Elementary School □ Post-Secondary □ High School □ > Post-Secondary

6. Do you need assistance from another person with any of the following activities? Check all that apply.
   □ Caring for yourself □ Housekeeping □ Eating
   □ Meal Preparation □ Shopping
   □ I do not need assistance with any of the above activities

7. The next question is about your household income. We need to ask this question because your income can determine whether you can afford things like physiotherapy

or medications that are not covered. Your response will be kept confidential. Which of the following categories best describes the total income, before taxes and deductions, from all household members and from all income sources, in the last 12 months?

□ < $20, 000 □ $60, 001- 80, 000 □ $20, 000-40, 000
□ > 100, 000 □ $40, 000- 60,000
□ I do not know or prefer not to answer this question

Health History Section:

1. Have you been diagnosed with osteoporosis or osteopenia by a physician? Check one.
   □ Yes, I have been diagnosed with osteoporosis
   □ Yes, I have been diagnosed with osteopenia
   □ I have been diagnosed with low bone mineral density, but I am not sure whether I have osteoporosis or osteopenia
   □ I don’t know or am not sure
   □ I have not been diagnosed with low bone mass

2. Has a physician ever told you that you have difficulties with memory, problem solving, or reasoning?
   □ Yes □ No □ I do not know

3. A) Do you have any of the following conditions? Check all that apply.
   □ Stroke □ Parkinson’s disease
   □ Multiple Sclerosis □ Chest pain during activity or at rest
   □ Difficulties with vision □ Joint replacement
   □ Arthritis □ Past or current cancer
   □ Diabetes □ Other: ___________________________
   □ I do not have any of these medical conditions.

4. Have you experienced a fall within the past 6 months?
   □ No □ Yes, I have fallen 1-2 times
   □ Yes, I have fallen more than 2 times □ I don’t know

5. Do you use any of the following:
   □ Walker □ Cane
   □ Other
   - If other, please specify: ______________________________
   □ I do not use a walking aid

6. Have you ever broken any of the following bones after the age of 40? Select all that apply.
   - □ Hip
   - □ Wrist
   - □ Humerus (upper arm bone)
   - □ Rib
   - □ Spine
   - □ Other, please specify: ________________________
   - □ I have not broken any bones since the age of 40 years
   - □ I do not know

7. Have you ever used oral glucocorticoids (e.g., prednisone) for a period of 3 months or longer? We are not interested in inhaled glucocorticoids, just ones taken as pills.
   - □ Yes
   - □ No
   - □ I do not know or am not sure

8. Are you taking any of the following medications to prevent bone loss or fractures? Check all that apply.
   - □ Fosamax (Alendronate)
   - □ Didrocal (Etidronate)
   - □ Actonel (Risedronate)
   - □ Aredia (Zoledronate)
   - □ Prolia (Denosumab)
   - □ Miacalcin (Calcitonin)
   - □ Evista (Raloxifene)
   - □ Forteo (Tetraparatide)
   - □ I am not taking any of these
   - □ Other
     - ▪ Please specify: _________________________
   - □ I am not taking any medications to prevent bone loss or fractures

9. Do you take any vitamin D supplements?
   - □ Yes
     - ▪ If yes, what dose of vitamin D do you take daily (in IU)?

       _______________________ IU
   - □ No

10. Overall, how would you rate your current health? Select one.
    - □ Excellent
    - □ Very good
    - □ Good
    - □ Fair
    - □ Poor

Part 2: International Physical Activity Questionnaire

The next section of our survey is a physical activity questionnaire that we will use to understand how much time you spent doing various activities in the last 7 days. Please answer each question even if you do not consider yourself an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Here are a few instructions:

1. a) We will first ask you **how many days** you did a particular activity during the **last 7 days** and you will fill out a box like this:

   ____ days per week

   For example, if you did yard work 1 day during the past 7 days, you would answer like this:

   __1__ day per week

   b) We will then ask you **how much time** you usually spent in each activity. It will look like this

   ____ hours per day

   ____ minutes per day

   For example, if you walked for 1 hour and 20 minutes, you will the question like this:

   __1__ hour per day

   __20__ minutes per day

   If you rode a bike for 20 minutes, you would fill it out like this:

   __0__ hours per day

   20 minutes per day

2. **Each activity you did in the last 7 days should only be reported or "counted" once.**
   - Example: if you report doing 20 min of biking as a means of transportation, don't count it again when you are asked about moderate or vigorous physical activity. .

3. **If there is an activity that you did but it does not fit in any of the categories, put it where it fits best.**

4. **Please report only activities that you did for at least 10 minutes.**
    - Example: If you walk to your mailbox to collect your mail once a week and it only takes you 5 minutes to do so, do not report walking to collect your mail in the questionnaire.

5. **Only report the amount of time spent at the specified intensity.**
    - Example: if you went out dancing, and did vigorous dancing for 10 minutes, rested for 10 minutes and then danced again for 10 minutes, report only 20 minutes of vigorous activity.

<u>PART 1: JOB-RELATED PHYSICAL ACTIVITY</u>

We want to know about any physical activity done during work outside home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked about later.

1. Do you currently have a job or do any unpaid work outside your home?

□ Yes

□ No → **Skip to PART 2: Transportation**

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include travelling to and from work.

2. During the last 7 days, on how many days did you do **<u>vigorous</u>**-intensity physical activities like heavy lifting, digging, climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

Note: Vigorous-intensity physical activities refer to activities that:

- Make your heart rate increase a lot
- You can’t talk or your talking is broken up by large breaths while doing it

____ **days per week**

□ No vigorous-intensity job-related physical activity → **Skip to question 4**

3. How much time did you usually spend on one of those days doing **vigorous**-intensity physical activities as part of your work?

____ **hours per day**

____ **minutes per day**

4. During the last 7 days, on how many days did you do **moderate**-intensity physical activities like carrying light loads **as part of your work**? Please do not include walking. Again, think about only those physical activities that you did for at least 10 minutes at a time.

Note: Moderate-intensity physical activities refer to activities that:

- Make your heart beat faster than normal
- You can talk but not sing while doing

____ **days per week**

□ No moderate-intensity job-related physical activity → **Skip to question 6**

5. How much time did you usually spend on one of those days doing **moderate** –intensity physical activities as part of your work?

___ **hours per day**

___ **minutes per day**

6. During the last 7 days, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

____**days per week**

□ No job-related walking → **Skip to PART 2: TRANSPORTATION**

7. How much time did you usually spend on one of those days **walking** as part of your work?

___ **hours per day**

___ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

Think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

8. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go from **place to place**?

___ **days per week**

□ No bicycling from place to place → **Skip to question 10**

9. How much time did you usually spend on one of those days to **bicycle** from place to place?

___ **hours per day**

___ **minutes per day**

10. During the last 7 days, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

____ **days per week**

□ No walking from place to place → **Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE AND CARING FOR FAMILY**

11. How much time did you usually spend on one of those days **walking** from place to place?

___ **hours per day**

___ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family. Think about activities that you did for at least 10 minutes at a time.

12. During the last 7 days, on how many days did you do **vigorous**-intensity physical activities like heavy lifting, chopping wood, shoveling snow, or digging?

Note: Vigorous-intensity physical activities refer to activities that

- Make your heart rate increase a lot
- You can't talk or your talking is broken up by large breaths while doing it

___ **days per week**

□ No vigorous activity in garden or yard → **Skip to question 14**

13. How much time did you usually spend on one of those days doing **vigorous**-intensity physical activities in the garden or yard?

___ **hours per day**

___ **minutes per day**

14. During the last 7 days, on how many days did you do **moderate**-intensity as part of **outdoor** house maintenance such as sweeping, washing cars, and raking leaves? Again, think about only those physical activities that you did for at least 10 minutes at a time.

Note: Moderate-intensity physical activities refer to activities that:

- Make your heart beat faster than normal
- You can talk but not sing while doing

___ **days per week**

□ No moderate activity in garden or yard → **Skip to question 16**

15. How much time did you usually spend on one of those days doing **moderate**-intensity physical activities in the garden or yard?

___ **hours per day**

___ **minutes per day**

16. During the **last 7 days**, on how many days did you do **<u>moderate</u>**-intensity activities like carrying grandchildren, washing floors, vacuuming and sweeping **<u>inside</u> your home**? Once again, think about those physical activities that you did for at least 10 minutes at a time.

Note: Moderate-intensity physical activities refer to activities that:

- Make your heart beat faster than normal
- You can talk but not sing while doing

___ **days per week**

□ No moderate activity inside home → **Skip to PART 4: RECREATION, SPORT AND LEISURE TIME PHYSICAL ACTIVITY**

17. How much time did you <u>usually</u> spend on <u>one</u> of those days doing **<u>moderate</u>**-intensity physical activities inside your home?

___ **hours per day**

___ **minutes per day**

<u>PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY</u>

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

18. Not counting any walking you have already mentioned, during the last 7 days, on how many days did you **<u>walk</u>** for at least 10 minutes at a time **in your leisure time?**

___ **days per week**

□ No walking in leisure time → **Skip to question 20**

19. How much time did you <u>usually</u> spend on <u>one</u> of those days **<u>walking</u>** in your leisure time?

___ **hours per day**

___ **minutes per day**

20. During the last 7 days, on how many days did you do **<u>strength training</u>** exercises such as lifting weights, or using rubber bands or machines for resistance for at least 10 minutes at a time?

You can include strength training you did on your own, or as part of a fitness class.

___ **days per week**

□ No strength training exercises in leisure time → **Skip to question 22**

21. What types of strength training exercises did you do? Please list below.

22. During the last 7 days, on how many days did you do activities like yoga and tai chi, or other exercises to specifically **<u>challenge your balance</u>** for at least 10 minutes at a time?

___ **days per week**

□ No balance training in leisure time → **Skip to question 24**

23. What types of exercises did you do to challenge your balance? Please list below.

24. During the last 7 days, on how many days did you do **<u>vigorous</u>**-intensity **<u>aerobic</u>** physical activities like jogging, fast bicycling, or energetic dancing in your leisure time?

Include only those activities that you did for at least 10 minutes at a time.

Note: vigorous-intensity physical activities refer to activities that

- Make your heart rate increase a lot
- You can't talk or your talking is broken up by large breaths while doing this

___ **days per week**

□ No vigorous activity in leisure time → **Skip to question 26**

25. How much time did you usually spend on one of those days doing **vigorous**-intensity **aerobic** physical activities in your leisure time?

___ **hours per day**

___ **minutes per day**

26. During the last 7 days, on how many days did you do **moderate**-intensity **aerobic** physical activities like bicycling at an easy pace, ballroom and line dancing, aqua aerobics, or doubles tennis in your leisure time?

Again, think about only those physical activities that you did for at least 10 minutes at a time.

Note: Moderate-intensity physical activities refer to activities that:

- Make your heart beat faster than normal
- You can talk but not sing while doing

___ **days per week**

□ No moderate activity in leisure time → **Skip to next part of survey**

23. How much time did you usually spend on one of those days doing **moderate**-intensity **aerobic** physical activities in your leisure time?

___ **hours per day**

___ **minutes per day**

Part 3: Factors that Affect Exercise

We would like to learn about different factors that influence your physical activity and exercise participation. The next part of this survey will ask you questions about factors that may help or make it difficult for you to exercise.

There are a few questions that might appear to be asking the same thing. Sometimes we ask questions in slightly different ways for a reason, so please be patient with us.

1. How likely do you think it is that you will break a bone sometime in the future? Please check the number that best reflects your answer.

O	O	O	O	O	O	O
1 (very unlikely)	2	3	4 (neutral)	5	6	7 (very likely)

2. We want to know about your intentions to participate in exercise in the coming weeks and months. Which intentions do you have for the next weeks and months? Please check the number that best reflects your answer.

   a) I intend to exercise regularly.

O	O	O	O	O	O	O
1 (I don't intend to at all)	2	3	4 (neutral)	5	6	7 (I strongly intend to)

   b) I intend to do at least 150 minutes of moderate- to vigorous-intensity aerobic exercise every week (e.g., doing 30 minutes, 5 times a week, or 60 minutes, 2.5 times a week).

   Note: aerobic exercise includes things like walking, swimming, biking.

O	O	O	O	O	O	O
1 (I don't intend to at all)	2	3	4 (neutral)	5	6	7 (I strongly intend to)

   c) At least 2 days a week, I intend to do exercises to increase the muscle strength of major muscle groups (e.g., lifting weights, working with resistance bands).

O	O	O	O	O	O	O
1 (I don't intend to	2	3	4 (neutral)	5	6	7 (I strongly intend to)

at all)

d) At least 2 days a week, I intend to do exercises that challenge my balance.

O	O	O	O	O	O	O
1 (I don't intend to at all)	2	3	4 (neutral)	5	6	7 (I strongly intend to)

3. Certain barriers make it hard to exercise regularly. How sure are you that you can exercise regularly? Please check the number that best reflects your answer.

a) I am sure that I can be physically active.

O	O	O	O
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

b) I am sure that I can achieve the goal of doing at least 150 minutes of aerobic exercise each week.

O	O	O	O
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

c) I am sure that I can do exercises to increase the muscle strength of major muscle groups 2 or more times each week.

O	O	O	O
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

d) I am sure that I can do exercises that challenge your balance at least 2 times each week.

○	○	○	○
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

e) I am sure that, even if I stop exercising for some time, that I can become physically active again.

○	○	○	○
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

4. Many people experience barriers that make it difficult for them to exercise on a regular basis. How about you? Please check a number that best reflects your answer.

   It is difficult for me to exercise because…

   a) I do not have enough time to get enough exercise.

○	○	○	○
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

   b) I do not have the motivation to exercise.

○	○	○	○
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

   c) I am afraid that I will hurt myself while exercising.

○	○	○	○
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

d) There is no available equipment for me to exercise with.

O	O	O	O
1	2	3	4
(not true at all)	(barely true)	(mostly true)	(exactly true)

e) I have no other people to exercise with or keep me company.

O	O	O	O
1	2	3	4
(not true at all)	(barely true)	(mostly true)	(exactly true)

f) I have poor health or health-related complications that keep me from exercising.

O	O	O	O
1	2	3	4
(not true at all)	(barely true)	(mostly true)	(exactly true)

g) There are no facilities available or close to me to exercise in.

O	O	O	O
1	2	3	4
(not true at all)	(barely true)	(mostly true)	(exactly true)

h) I do not enjoy exercising.

O	O	O	O
1	2	3	4
(not true at all)	(barely true)	(mostly true)	(exactly true)

i) I do not have a way of transporting myself to a place that I can exercise.

O	O	O	O
1	2	3	4
(not true at all)	(barely true)	(mostly true)	(exactly true)

j) I do not have the persistence to exercise on a regular basis.

O	O	O	O
1	2	3	4
(not true at all)	(barely true)	(mostly true)	(exactly true)

k) I cannot afford to attend exercise programs or to exercise at a facility that requires me to pay for a membership.

O	O	O	O
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

l) I am too old to exercise.

O	O	O	O
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

m) I need to rest and relax in my spare time rather than exercise.

O	O	O	O
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

n) I do not know which exercises are appropriate for me or how to perform exercises properly.

O	O	O	O
1 (not true at all)	2 (barely true)	3 (mostly true)	4 (exactly true)

5. Are there any other things that make it hard for you to exercise that were not mentioned? If so, please describe in the space below.

6. a) Considering all the potential barriers to exercise you face on some or all days, how difficult do those barriers make it for you to do at least 150 minutes of moderate- to vigorous-intensity aerobic exercise each week? Please check the number that best reflects your answer.

O	O	O	O	O
1 (not difficult at all)	2	3	4	5 (extremely difficult)

b) How difficult do barriers make it for you to do exercises to increase the muscle strength of major muscle groups at least 2 times per week?

O	O	O	O	O
1 (not difficult at all)	2	3	4	5 (extremely difficult)

c) How difficult do barriers make it for you to do exercises that challenge my balance at least 2 times per week?

O	O	O	O	O
1 (not difficult at all)	2	3	4	5 (extremely difficult)

7. We want to know how you would prefer to access exercise information. We also want to know if cost is a barrier to getting access to exercise information.

a) Would you use an exercise DVD that is designed for individuals with osteoporosis? This DVD would include warm up, aerobic, and muscle strengthening exercises. Circle yes or no.

Yes

No → If no, skip to question c)

b) What is the highest amount of money you would be willing to pay for an exercise DVD that is designed for individuals with osteoporosis?

(Cost for this ranges $15-30)

Please write-in a dollar amount below. Entering $0 would mean that you are only interested in receiving exercise information via an exercise DVD if it is free.

____

c) Would you participate in a group exercise class that would involve doing aerobics and muscle strengthening exercise? Each class would be 1 hour per week for 12 weeks. Circle yes or no.

Yes

No → If no, skip to e)

d) What is the highest amount of money you would be willing to pay for a group exercise class that would involve doing aerobics and muscle strengthening exercises? Each class would be 1 hour per week for 12 weeks.

A group exercise class that is 1 hour a week for 12 weeks typically costs $50-60.

Please write-in a dollar amount below. Entering $0 would mean that you are only interested in receiving exercise information via a group exercise class if it was free.

____

e) Would you be interested working one-on-one with a certified personal trainer for 1 hour a week for 6 weeks? Circle yes or no.

Yes

No → If no, skip to end of survey

f) What is the highest amount of money you would be willing to pay to work with a certified personal trainer one-on-one for 1 hour each week for 6 weeks?

Working one-on-one with a personal trainer for 1 hour a week for 6 weeks can cost approximately $360-420.

Please write-in a dollar amount below. Entering $0 would mean that you are only interested in receiving exercise information via a group exercise class if it was free.

____

If you have any further comments about your exercise needs and preferences, or about our survey or anything else, please write them below.

Thank you for participating in our survey. We are using your input to inform the design of future education strategies and future research. We will report the results in a future COPING newsletter.

If you have any further questions, please contact Helen Ng by sending an e-mail to hhlng@uwaterloo.ca or phone 519-888-4567 ext. 38770.