The Effects of a Supervised Walking Program on the Cognitive Function, Gait, Fitness, and Behaviour of Inactive Older Adults

by

Kristina Kowalski
BSc, University of Waterloo, 2005
MSc, University of Victoria, 2008

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in Interdisciplinary Studies

Supervisory Committee

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Abstract

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Background & Objectives: Participation in cognitive, social and physical activity (PA) may play a role in prevention of cognitive decline in older adults. Literature supporting the benefits of healthy lifestyle behaviours, especially PA, on cognition continues to accumulate. Moreover, a strong association between gait and cognitive health is increasingly being recognized. Yet, a firm understanding of the individual differences and between-person effects of PA on cognition and gait of older adults is lacking. Thus, the primary objective of the main study was to distinguish the within- and between-person sources of variation in PA on cognition in a group of inactive older adults. Study 2 examined the within- and between-person effects of a) PA on gait and b) gait on cognition. Study 3 examined the social cognitive predictors of walking.

Methods: The between- and within-person of PA on cognition were examined in a single-group longitudinal design. Participants (n=159) were enrolled in a four-month supervised walking program and provided with materials and coaching to promote the adoption of behaviours to enhance and maintain their cognitive health. Group participants walked *at least 3* times per week at a brisk intensity and were encouraged to get 150 minutes of moderate-to-vigorous PA per week. At baseline, participants completed measures of social cognitive predictors of walking. Assessments of cognition, diet, fitness, gait, PA and other health behaviours occurred at baseline, and at 6, 9, 12, and 16 weeks follow-up.

Results and Discussion*:* Multilevel models revealed significant: 1) within-person effects of PA on select measures of executive functioning and 2) consistent between-group

effects of cognitive activity, but not other lifestyle behaviours, on cognition. Study 2 revealed consistent significant 1) within-person effects of PA on gait velocity and stride time variability during dual task walking, 2) between-person effects of PA on gait velocity during both dual task and normal walking, and 3) between-person effects of gait velocity and stride time variability on cognition during both normal and dual task walking. Significant within-person effects of gait on cognition were limited. In study 3, self-monitoring emerged as a significant predictor of change in walking.

Conclusion: Distinct patterns of within- and between-person effects on the PA, cognition and gait were observed. Further work will need to continue to clearly elucidate the within- and between-person sources of variation in relations between PA, gait and cognition using well-designed longitudinal and experimental designs.

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Dedication

This dissertation is dedicated to my mother, Linda Kowalski, who was my biggest supporter and greatest fan. No matter what my dreams were she was always behind me to give me that little extra push I needed to reach my goals. Her positivity, beautiful smile and belief in me have played an enormous role in my academic pursuits.

If she were here today, she would be beaming with pride.

Chapter 1: General Introduction

Background

Due to the rapid aging of our population and the increased prevalence of age-related cognitive diseases (e.g., Alzheimer's disease and related dementias) with advancing age (Desai, Grossberg, & Chibnall, 2010; Lindsay, Sykes, McDowell, Verreault, & Laurin, 2004), strategies aimed at preventing cognitive decline and promoting healthy cognitive aging are important public health priorities (Desai et al., 2010; Hertzog, Kramer, Wilson, & Lindenberger, 2008; Lustig, Shah, Seidler, & Reuter-Lorenz, 2009). Healthy cognitive aging includes language, thought, memory, executive function, judgment, attention, perception, remembered skills, and the ability to live a purposeful life (Centers for Disease Control and Prevention and the Alzheimer's Association; 2007). It is not synonymous with absence of disease, but rather "the development and preservation of [a] multidimensional cognitive structure that allows the older adult to maintain social connectedness, and ongoing sense of purpose, and the abilities to function independently, to recover functionally from illness or injury, and to cope with residual deficits" (Desai et al., 2010, p. 3).

Dementia and related cognitive disorders have serious consequences not only to the individual and his or her friends and family (e.g., cognitive impairments, poorer quality of life, caregiver burden), but also to society in general (e.g., increased institutionalization, and mortality, health care costs; Larson et al., 2006). With improvements in health care in industrialized nations, individuals are living longer (Statistics Canada, 2010; Health Canada, 2002). As such, it is important to ensure that while prolonging the lifespan of older adults, we are also maximizing their quality of life

and years of independent functioning (Hertzog et al., 2008). Although major causes of death are on the decline (i.e., heart disease, stroke, prostate cancers), deaths from Alzheimer's disease continue to climb, especially in adults aged 65 years of age and over (Alzheimer's Association, 2014).

Theories of cognitive enrichment, including the "use it or lose it" hypothesis, suggest that that leading an engaged lifestyle, including participating in intellectual, social, and physical activities, has a positive impact on cognitive performance throughout the lifespan (Hertzog et al., 2008) and may prevent cognitive decline by "exercising" cognitive abilities (Bielak, 2010). Likewise, theories of cognitive or brain reserve suggest that engagement in intellectual, social and physical activities enhances the cognitive reserve needed to cope with dementia-related pathology. In support of cognitive reserve, a *lack* of association between degree of pathology and clinical manifestations of dementia has consistently been found (Briones, 2006; Daffner, 2010; Fratiglioni, Paillard-Borg, & Winblad, 2004; Fratiglioni & Wang, 2007; Nithianantharajah & Hannan, 2009; Scarmeas, 2007).

Within their cognitive enrichment hypothesis, Hertzog and colleagues view cognitive development within a lifespan perspective, where cognitive performances are seen as malleable and can be enhanced throughout the lifespan (Hertzog et al., 2008). According to their hypothesis, an individual operates at a suboptimal level within a range of cognitive functioning that is constrained by both genetics and biological aging. With advancing age, biological aging puts greater constraints on an older adult's functioning, yet it is not fixed. Instead, they suggest that upward or downward movement in cognitive performance can occur within these set boundaries as the result of various biological,

environmental and behavioural factors. Engaging in physical activity (PA) and other healthy lifestyle behaviours (e.g., eating healthy, staying socially engaged, participating in intellectually stimulating activities) are behavioural factors that can move an individual within their predetermined range of functioning.

In line with these theories, in recent years, there has been a paradigm shift in cognitive health research and programming whereby scientists and public health experts have focused their efforts on maintenance of cognitive health and prevention of decline, rather than on the treatment of cognitive dysfunction in aging (Albert et al., 2007). This paradigm shift has come in response not only to the rapid aging of the population, but also to a growing body of evidence that supports a link between healthy lifestyle behaviours, most notably PA (and exercise), and cognitive health in later life (e.g., Albert et al., 2007; Butler, Forette, & Greengross, 2004; Depp, Vahia, & Jeste, 2010; Fillit et al., 2002; Hertzog et al., 2008). Although the literature supporting the positive relationship between PA and cognitive health is growing, the findings are mixed and the current body of research is fraught with methodological limitations. Briefly, four of the key methodological issues include:

1) Existing studies often include small sample size/are under-powered.

2) Existing studies frequently involve interventions targeting less than minimum recommended levels of PA to confer health benefits.

3) Poor description and/or selection of cognitive domains under investigation. Neuropsychological measures used in the existing literature often: a) include measures of general cognition rather than focus on specific cognitive domains of

interest, b) are chosen based on popularity rather than driven by hypothesis, and/or c) examine only a limited number of cognitive measures.

4) Existing research has focused almost exclusively on between-group effects while neglecting the individual differences that may contribute to the complex relations between PA and cognition.

Moreover, in addition to these key limitations, it has been suggested that mixed findings may in part be due to the influence of moderator variables that may influence an individual's responsiveness to the beneficial effects of PA on cognition.

Rationale and Study Purpose

It is imperative, given the current and emerging demographic, that further research and public health priorities focus on methodologically rigorous research examining the relations of modifiable risk factors to cognitive functioning and other aspects of health and well-being in older adults (Desai et al., 2010; Hertzog et al., 2008; Lustig et al., 2009; Rikli, 2000). It is also critical that this research focus on the development and evaluation of programs supporting the adoption and maintenance of attitudes, beliefs and behaviours believed to promote healthy cognitive aging (Logsdon, Hochhalter, Sharkey, & Promoting Healthy Aging Research Network, 2009) and to prevent disease and disability in the older adult population (Lustig et al., 2009).

Given the key limitations discussed above and the growing body of literature supporting the beneficial effects of healthy lifestyle behaviours, in particular PA, on cognitive health, the primary purpose of this study was to examine the influence of PA on the cognitive health of apparently healthy inactive older adults using a brief longitudinal, single group design with 5 waves of measurement (Chapter 3: Main Study). To reach this

aim, participants were enrolled in a four-month supervised walking program and provided with materials and coaching to promote the adoption and maintenance of behaviours to enhance and maintain their cognitive health. To improve on some of the methodological limitations of existing literature, the current study:

1) Enrolled a sufficient sample size to detect medium effects;
2) Assessed multiple measures of cognitive function with an emphasis on measures of higher-order cognitive function (executive function, attention, and working memory), given the evidence that they may be preferentially affected by physical activity;
3) Included an intervention that targeted the current minimum PA guidelines for older adults; and
4) Employed multilevel models (i.e., time-varying covariation models) that separated the between-group (difference in mean levels among individuals across the four-month program) and within-group sources of variation (changes relative to an individual's own mean levels across the four-month program) in PA and examined their distinct effects on cognitive function in older adults.

Secondary aims were: 1) to examine the relations between PA, gait and cognition in walking group participants (Chapter 3: Gait and Cognition Paper); and 2) to examine social cognitive and self-regulatory factors that influence supervised walking program attendance and regular leisure time walking (Chapter 4: Adherence Paper).

Research Objectives

Main Study

The primary objectives of this program of research were to determine if changes in PA (moderate to vigorous physical activity and walking) were associated with changes in cognitive outcomes (executive function, attention, working memory, episodic memory) in older adults over a four-month period. An additional primary objective was to examine moderating variables (age, gender, education, cardiovascular disease, midlife PA) that may influence the strength of the relations between changes in PA and cognitive performance in older adults. Secondary objectives were to examine the impact of changes in other health behaviours (i.e., diet, intellectually stimulating activities, and social engagement) on changes in cognitive function over the four-month program. In addition, we examined if changes in PA were also associated with changes on a very brief battery of fitness measures (6 minute walk test, body mass index (BMI), waist circumference) over the four-month program.

Gait and Cognition Paper

Gait characteristics and variability (e.g., gait speed, stride length, stride width, swing time, stance time, normalized velocity, cadence, stride tide time variability) have been linked with cognitive function, incident dementia, mortality, and other important indicators of health and well-being including mobility disability and risk of falls (Brach, Berlin, VanSwearingen, Newman, & Studenski, 2005; Hausdorff, Rios, & Edelberg, 2001; Studenski et al., 2011; Verghese, Wang, Lipton, Holtzer, & Xue, 2007). Despite the vast body of literature on the PA, gait and cognition in older adults, longitudinal studies distinguishing between between-group and within-person sources of variation in the relations between PA, gait and cognition in older adults are non-existent. As such, the

primary objectives of the second paper were to examine between- and within-person effects on the relations between: 1) changes in gait and changes in cognition and 2) changes in PA and changes in gait in a sample of older adults participating in the four-month supervised walking program.

Adherence Paper

Greater understanding of the relations between PA, gait and cognition (Chapters 2 and 3) is of limited use if older adults do not adopt or maintain a physically active lifestyle. The Canadian Physical Activity Guidelines for Older Adults 65 years and over (Canadian Society of Exercise Physiology, 2011) recommends that older adults get 150 minutes of moderate to vigorous PA per week, but most older Canadians fail to meet these guidelines. Research has consistently demonstrated that the majority of older adults are inactive and that the prevalence of inactivity increases with advancing age (Azagba & Sharaf, 2014; Canadian Fitness & Lifestyle Research Institute, 2010; Paterson, Jones, & Rice, 2007; Shaw, Liang, Krause, Gallant, & McGeever, 2010). Understanding the predictors of engagement in PA and other health behaviours associated with reduced risk of dementia is an important piece in the design of interventions to promote the adoption and maintenance of attitudes, beliefs and behaviours believed to promote healthy cognitive aging. Therefore, the third paper examined social cognitive and self-regulatory predictors of *overall* program attendance and regular leisure time walking within two theoretical frameworks: 1) the Theory of Planned Behaviour (Ajzen, 1985, 1991) and 2) the Multi-Process Action Control Model (Rhodes & de Bruijn, 2013). The former has been studied extensively to predict intention and PA behaviour, while the latter is a new and emerging post-intentional theory stemming from research on the weak association

between intention and behaviour. Predictors of ***change*** in program attendance and regular leisure time walking over the 5 waves of measurement were also examined within the same theoretical frameworks.

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Chapter 2: Main Study

Introduction

Engaging in physical activity (PA) contributes to physical and psychological well-being and quality of life. The benefits of PA are numerous, including reduced risk of more than 25 chronic diseases (e.g., coronary heart disease, stroke, hypertension, breast cancer, colon cancer, type 2 diabetes, and osteoporosis), improved fitness, mobility (e.g., cardiovascular fitness, body composition, musculoskeletal strength and endurance functional capacity), and psychological health (e.g., improved mood, reduced anxiety and depression), and prevention of weight gain (Colcombe & Kramer, 2003; Hautier & Bonnefoy, 2007; Paterson, Jones, & Rice, 2007; Warburton, Nicol, & Bredin, 2006). Despite these widespread benefits, our population is overwhelmingly inactive, with research demonstrating that physical inactivity is highest among older age groups (Canadian Fitness and Lifestyle Research Institute, 2009; Chodzko-Zajko et al., 2009; Paterson et al., 2007).

The alarming rate of physical inactivity in older adults is a serious public health concern. With advancing age, not only does physical inactivity increase, but so too does the prevalence of age-related cognitive impairments, such as Alzheimer's disease and related dementias (Alzheimer's Association, 2013; Alzheimer's Society of Canada, 2012; Health Canada, 2002; Desai, Grossberg, & Chibnall, 2010; Lindsay, Sykes, McDowell, Verreault, & Laurin, 2004; World Health Organization, 2012). To compound the problem, the risk of developing dementia is significantly associated with physical inactivity (Ahlskog, Geda, Graff-Radford, & Petersen, 2011; Fratiglioni, Paillard-Borg, & Winblad, 2004; Sofi et al., 2011; Yunhwan et al., 2010). Moreover, with age older

adults experience declines in cognitive function as part of the natural aging process (Beurskens & Bock, 2012; Borel & Alescio-Lautier, 2014; Glisky, 2007; Park, 2000). Age is associated with declines in a broad range of cognitive tasks, including attention, memory, verbal reasoning and processing speed (Park, 2000). Older adults are especially vulnerable to decays in higher-level cognitive functions, including executive function and working memory. These age-related cognitive changes vary not only among individuals (i.e., between-person), but also within individuals (within-person, Borel & Alescio-Lautier, 2014; Glisky, 2007). Between-person sources of variation reflect differences between groups (e.g., cognitive status groups, individuals high on PA engagement and low on PA engagement, treatment and control groups, demographic groups); while, within-person sources of variation reflect changes in an individual's performance relative to their own performance (e.g., fluctuations, both short and long-term, in one's own PA relative to their usual behaviour). Due to the increased prevalence of both inactivity and cognitive impairment in old age, it is important to ensure that while prolonging the lifespan of older adults, we are also developing programs to reduce age-related cognitive and physical impairments, and maximize quality of life and years of independent functioning (Hertzog, Kramer, Wilson, & Lindenberger, 2008).

As of yet, dementia has no cure; engaging in healthy lifestyle behaviours (PA, diet, intellectual stimulation, social engagement) holds promise for promoting cognitive health and preventing age-related cognitive decline or the onset of dementia. PA programs are one such lifestyle intervention target with the potential to impact not only cognitive function and disability, but also broader aspects of the overall health and well-being of older adults. In fact, there is a growing body of evidence for the beneficial

effects of PA and exercise on cognitive abilities and cognitive status in older adults. This includes a variety of populations (healthy older adults, mild cognitive impairment (MCI), dementia, stroke) and research designs including meta-analyses/systematic reviews (e.g., Carvalho, Rea, Parimon, & Cusack, 2014; Colcombe & Kramer, 2003; Gregory, Gill, & Petrella, 2013; Guiney & Machado, 2013; Hamer & Chida, 2009; Heyn, Abreu, & Ottenbacher, 2004; Sofi et al., 2011), quasi-experimental/experimental (e.g., Baker, Frank, Foster-Schubert, Green, Wilkinson, McTiernan, Plymate, et al., 2010; Brown, Liu-Ambrose, Tate, & Lord, 2009; Klusmann et al., 2010; Lautenschlager et al., 2008; Liu-Ambrose et al., 2010; Muscari et al., 2010; Ruscheweyh et al., 2011; Scherder et al., 2005), prospective observational (e.g., Abbott et al., 2004; Buchman et al., 2012; de Bruijn et al., 2013; Larson et al., 2006; Middleton et al., 2011; Weuve et al., 2004; Yaffe, Barnes, Nevitt, Lui, & Covinsky, 2001) and cross-sectional designs (e.g., Boucard et al., 2012; Brown et al., 2012; Farina, Tabet, & Rusted, 2014; Floel et al., 2010; Kerr et al., 2013; Prohaska et al., 2009). Effect sizes from meta-analyses of experimental designs have generally been small to moderate (ES=0.17 to 0.68), with larger estimates being reported for higher-order cognitive functions/executive functions (ES = 0.68; Colcombe & Kramer, 2003) and cognitively impaired samples (ES = 0.57; Heyn et al., 2004) compared to healthy older adult samples (ES = 0.23; Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008).

Recent meta-analytic work of prospective studies has demonstrated that PA is significantly inversely related to cognitive impairment (Hamer & Chida, 2009; Sofi et al., 2011). Sofi and colleagues (2011) found that PA offered significant protection against cognitive decline in individuals without a diagnosis of dementia (i.e., when comparing

high versus low active groups HR= 0.62). Hamer and Chida (2009) restricted their meta-analysis to prospective studies of dementia risk and found that compared to the low active group, high PA offered significant protection against Alzheimer's disease (RR=0.72) and dementia (RR= 0.55).

However, not all literature is supportive. Some research has found no benefits of PA/exercise on cognition (e.g., Hill, Storandt, & Malley, 1993; Kooistra et al., 2014; Okumiya et al., 1996; Podewils et al., 2005; Steinberg, Leoutsakos, Podewils, & Lyketsos, 2009; Sturman et al., 2005; van Uffelen, Chinapaw, Hopman-Rock, & van Mechelen, 2009; Verghese et al., 2003; Yamada et al., 2003), while some of the literature reporting positive effects of physical activity/exercise on cognitive function has found benefits on only a select number of cognitive domains/specific tests from those which were examined (e.g., Angevaren et al., 2008; Blumenthal et al., 1991; Gates, Singh, Sachdev, & Valenzuela, 2013; Kramer et al., 1999; Snowden et al., 2011). For instance, although the meta-analysis conducted by Angevaren et al. (2008) found that aerobic PA had significant effects on motor function, processing speed, and auditory and visual attention in healthy older adults; the authors note that the majority of the comparisons examined were non-significant. Likewise, in a meta-analysis of randomized clinical trials in individuals with mild cognitive impairment, PA had only small significant effects on verbal fluency (ES=0.17), but none of the other cognitive measures (i.e., other measures of executive functioning, information processing or memory) under examination (Gates et al., 2013). For an extensive review of this body of literature, the reader is directed to Appendix 1: Expanded Literature Review.

It has been suggested that mixed findings are largely due to the vast heterogeneity in the methodology (type, duration, and intensity of PA, definitions of PA, length of follow-up, appropriateness of the cognitive functions under investigation, the description of the neuropsychological domains under investigation, the quality of the neurocognitive tests used in the assessment, choice of PA measures) and characteristics of the samples (e.g., sample size, age, gender, health conditions) under investigation. The current research program was designed to address four specific limitations discussed in the current literature.

First, many of the existing studies have small samples sizes and were under-powered for their comparisons (e.g., Amoyal & Fallon, 2012; Farina, Rusted, & Tabet, 2014; Hertzog et al., 2008). Across the literature reviewed, expert consensus has been that larger samples are needed to advance our understanding of the relations between PA/exercise and cognition. There is some evidence that higher quality studies (of which sample size is an important criterion) produce larger effects (Etnier et al., 1997; Hamer & Chida, 2009). Previous literature examining the effects of PA on cognition has found that PA has medium effects on higher order cognitive functions (e.g., ES = 0.68; Colcombe & Kramer, 2003). This study focused on the relations of PA with higher-order cognitive functions, including executive function, working memory, and attention. As such, n=100-150 older adults were recruited in order to detect medium effects.

Second, existing studies have received some criticism because they frequently involve interventions that do not target at least the minimum recommended levels (intensity and duration) of PA to confer health benefits (Kruger, Buchner, & Prohaska, 2009). Current national guidelines for minimum PA levels recommend that older adults

engage in 150 minutes of moderate to vigorous physical activity (MVPA) per week (Canadian Society for Exercise Physiology, 2011). Thus, participants were enrolled in a four-month supervised walking program, asked to attend three or more supervised walking groups per week, and encouraged to engage in 150 minutes of MVPA per week. A walking program was chosen to due to its popularity and ease (i.e., cost, minimal/no equipment, accessibility). Although the cognitive benefits of other non-aerobic activity, such as strength training (e.g., Chang, Pan, Chen, Tsai, & Huang, 2012; Liu-Ambrose & Donaldson, 2009) is accumulating, to date a larger body of evidence exists for the beneficial effects of aerobic activities, including walking, on cognition in older adults (e.g., Miller, Taler, Davidson, & Messier, 2012).

Third, the description of neuropsychology domains under investigation and the selection of neuropsychological tests in the existing studies of PA/exercise and cognition have been highly criticized across the literature (e.g., Etnier & Chang, 2009; Miller et al., 2012; Salthouse, 2008; Tomporowski, 2009). Studies have often examined: 1) measures of general cognitive function rather than focus on specific cognitive domains of interest, 2) tests chosen based on popularity rather than on hypothesis driven test selection, and/or 3) only a limited number of measures of cognition. In their reviews of methodological limitations in the field, Etnier & Chang (2009) and Salthouse (2008) both advocate for the use of multiple measures of cognition (and in particular executive functioning) to the advance our understanding of relations between PA and cognition. Thus, for the current study we carefully selected multiple measures of executive function, attention, and working memory, using both traditional paper and pencil tasks and newer, computerized measures, along with measures of episodic memory. An emphasis was placed on higher

order cognitive functions because considerable research with both humans and animals suggests that PA may preferentially affect executive functioning, working memory, and attention (e.g., Colcombe & Kramer, 2003; Hertzog et al., 2008).

Fourth, it is also very likely that researchers in the field are missing part of the picture by focusing their research efforts almost exclusively on between-group effects of PA on cognition (e.g., high exercisers versus low exercisers, individuals who were active throughout their lives versus those who were inactive, and exercise groups versus controls), while neglecting to acknowledge the within-person differences (i.e., changes in one's PA levels relative to their own mean) that may contribute to the complex relations between PA/exercise and cognitive function in older adults. Longitudinal observational designs *with repeated measurement waves* are an optimal method to examine the relations between intra-individual changes in PA and cognition. The need for multiple waves rather than simple pre- post comparisons of cognitive performance has been recognised in the recent literature (Farina, Rusted, et al., 2014). Lifespan developmental researchers often employ multi-level models with time-varying predictors to achieve a greater understanding of the relations between variables over time. Yet, choice of models and failure to separate constant between-person sources of variation from time-specific within-person sources of variation within these multilevel models has been identified as a source of bias and can obscure results (Hoffman & Stawski, 2009; Morrell, Brant, & Ferrucci, 2009; Thorvaldsson et al., 2012).

Although the need to examine intra-individual variability on the activity-cognition relations has been highlighted in the literature (Hertzog et al., 2008; Salthouse, 2008), it has rarely been examined. To the author's knowledge, only a few studies have examined

the dynamic coupling/time-varying covariation models of leisure activities, including PA and cognitive function in older adults (Lovden, Ghisletta, & Lindenberger, 2005; Small, Dixon, McArdle, & Grimm, 2012). For example, using latent change score models, Small and colleagues examined the dynamic relations between self-reported participation in social, cognitive and physical activities and changes in age-related cognitive declines in a large sample of older adults (n=952) over a twelve-year period. Results indicated that reductions in cognitive activities were significantly associated with subsequent declines in verbal processing speed, episodic memory, and semantic memory and declines in cognitive abilities were significantly related to further declines in engagement leisure activities, especially social activities.

These prospective observational studies examined the dynamic relations and time lag between long-term engagement in lifestyle activities on age-related declines in cognitive skills (i.e., over the long term), rather than examining the time-varying association between PA and cognitive performance due to formal intervention (i.e., more short term). Moreover, these studies also failed to separate between- and within-person sources of variation in PA in their models, which, as noted earlier, can lead to biased results (Hoffman & Stawski, 2009). Based on the current literature review, studies of the effects of PA or walking programs on cognition *in older adults* that made this distinction were not identified. Thus, the current study used advanced statistics methods to distinguish between the effects of between-group differences (i.e., differences in mean levels of PA or walking across individuals) from within-person sources of variation (i.e., changes in PA or walking relative to one's own mean level of PA or walking) on cognitive function.

It has also been suggested that mixed/inconsistent results for the effects of PA/exercise on cognition are in part due to the influence of moderating variables, such as age, gender, education, adherence, and genetics (Bielak, 2010; Clifford, Bandelow, & Hogervorst, 2010). Outside of demographics, adherence and genetics, it seems likely cardiovascular disease status/risk factors and midlife history of PA, for example, might moderate the relations between PA and cognition. In fact, in the existing literature both midlife PA and cardiovascular risk have been associated with reduced risk of cognitive decline and Alzheimer's disease and related dementia in later life (Buchman et al., 2012; de la Monte, 2014; DeFina et al., 2013; Dregan & Gulliford, 2013; Elwood et al., 2013; Feng et al., 2013; Flicker, 2010; Gallucci et al., 2013; Ku, Stevinson, & Chen, 2012; Middleton, Mitnitski, Fallah, Kirkland, & Rockwood, 2008; Morgan et al., 2012; Rockwood & Middleton, 2007; Rovio et al., 2005; Verhaeghen, Borchelt, & Smith, 2003; Yaffe et al., 2004). Cardiovascular disease (glucose intolerance, diabetes, hyperlipidemia, hypertension) is a risk factor for both vascular dementia and Alzheimer's disease (Ahlskog et al., 2011; Barber, Clegg, & Young, 2012). Elucidating the factors that make an individual more responsive to the effects of PA/exercise on cognition is an important step in designing effective interventions to promote healthy cognitive aging and prevent cognitive decline (Etnier, Bielak, 2010; Clifford et al., 2010; 2008; Salthouse, 2008).

Primary Research Objectives

The present study sought to address these four issues by enrolling a sample of community dwelling, apparently healthy older adults in a four-month supervised walking program and providing them with materials and coaching to promote the adoption and maintenance of health behaviours (healthy diet, PA, social and cognitive engagement) to

enhance and maintain their cognitive health. The overall purpose of the study was to examine the dynamic relations between changes in PA and cognitive function in apparently healthy, inactive older adults using multilevel models/hierarchical linear modelling (HLM). HLM allowed for the simultaneous examination of the effects of both between-person and within-person sources of variation in PA on cognitive performance to be examined. Age, gender, education, family history of dementia or other serious cognitive impairment, cardiovascular disease status at baseline and history of midlife PA were included as additional between-group variables that might influence an individual's responsiveness to the effects of PA interventions on cognitive health.

Primary Research Questions and Hypotheses

Multi-level models were used to test the dynamic coupling between changes in PA and changes in cognitive function over a four-month period. Primary research questions focused on the relations between changes in PA and changes in cognitive function in older adults.

1a. Over the four-month supervised walking program, did older adults exhibit significant longitudinal changes in a) PA (weekly minutes of moderate to vigorous walking (MVW), weekly minutes of MVPA) and b) cognitive outcomes (executive function, attention, working memory, and episodic memory)?

1b. For PA and cognitive outcome measures exhibiting significant longitudinal change, was there evidence of time-varying covariation? Specifically, did between-person and within-person changes in PA predict changes in cognitive outcomes?

Hypothesis 1a: It was anticipated that there would be significant increases in both MVW and MVPA over the four-month walking program. Given that there is high discordance between intention and behaviour and poor long-term adherence to a PA programs (Cox et al., 2013; de Bruijn, Rhodes, & van Osch, 2012; Evers, Klusmann, Ziegelmann, Schwarzer, & Heuser, 2012; Rhodes, 2012; Rhodes & De Bruijn, 2013a; Rhodes & De Bruijn, 2013b), it was also anticipated that increases in MVPA and MVW would drop off over time. Significant improvements were expected across all cognitive measures and it was anticipated that these improvements would also occur at a decreasing rate over time.

Hypothesis 1b: It was expected that changes in MVPA and MVW would share significant time-varying covariation with changes in cognitive measures (i.e., increases in MVPA and MVW compared to an individual's own mean levels would be significantly associated with improvements on all cognitive measures). Not controlling for weekly variation in PA (MVW and MVPA), between-group differences were also expected (i.e., individuals who engaged in *more* MVW and MVPA on average would perform significantly *better* on average across the cognitive measures).

1c. Does age, education, presence of cardiovascular disease, family history of dementia, and personal midlife history with PA moderate the relations between changes in PA and changes in cognitive function in older adults?

Hypothesis 1c: It was anticipated that cognitive performance would differ across groups, such that younger, more educated individuals with less cardiovascular disease, no family

history of dementia, and higher midlife PA would perform better on measures of cognitive function than older, less educated individuals with more cardiovascular disease, a family history of dementia and lower midlife PA.

Secondary Research Question

The secondary research question addressed the impact of changes in other health behaviours (changes in diet, social engagement and intellectual stimulation) on cognitive outcomes over the course of the four-month walking program.

2a. Over the four-month period, did older adults exhibit significant longitudinal changes in a) diet (i.e., adherence to a Mediterranean-style diet, adherence to Canada's food guide), b) social engagement, and c) intellectual stimulating activities?

Hypothesis 2a: Given that the intervention only minimally targeted health behaviours other than PA, significant longitudinal changes in other behaviours were not expected.

2b. For health behaviours and cognitive outcome measures exhibiting significant longitudinal change was there evidence of time-varying covariation? Specifically, did between- and within-person changes in these health behaviours predict changes in cognitive outcomes?

Hypothesis 2b: Time-varying covariation (i.e., within-person effects) of engagement in health behaviours and cognitive performance was not anticipated. In contrast, between-group differences were expected. Specifically, it was anticipated that individuals who

engaged in more health behaviours (i.e., adhered *more* to Mediterranean style diet, adhered *more* to the Canadian food guide, engaged in more social and intellectual activities) on average would perform *better* on average on all cognitive measures.

Additional Objectives

Given the vast body of literature on the benefits of PA and walking on fitness, we also examined the dynamic relations between changes in PA and fitness in older adults using a very brief fitness assessment (body mass index (BMI), waist circumference, six minute walk test).

3a. Over the four-month supervised walking program, did older adults exhibit significant longitudinal changes in fitness (6 walk test, body mass index (BMI), waist circumference)?

Hypothesis 3a: It was expected that fitness would significantly improve over time and these changes would occur at a decreasing rate over time.

3b-c. If so, for PA and fitness measures exhibiting significant longitudinal change was there evidence of time-varying covariation? Specifically, do between-person and within-person changes in PA predict changes in fitness over the four-month walking program?

Hypothesis 3b: It was anticipated that changes in fitness would share significant time-varying covariation with changes in PA.

Hypothesis 3c: Between-person effects were also anticipated (i.e., older adults who are *more* physically active on average would perform *better* on average across all three fitness measures).

Methods

Study Design

Healthy Bodies, Healthy Minds – A Supervised Walking Program for Older Adults was a brief longitudinal burst design. The study involved a four-month supervised walking program in which study participants were asked to attend weekly group walks and complete a battery of assessments at each of five measurement waves.

Recruitment and Participant Characteristics

Participants were a convenience sample of sedentary community-dwelling older adults aged 65 years and over living within Greater Victoria, British Columbia, Canada. Exclusion criteria included a diagnosis of dementia by a physician or a score on the modified Telephone Interview for Cognitive Status (Modified TICS; Brandt, Spencer, & Folstein, 1988; de Jager, Budge, & Clarke, 2003) in the moderately to severely impaired range (i.e., < 28 out of 50), a history of significant head injury (defined as loss of consciousness for more than five minutes), other neurological or major medical illnesses (e.g., Parkinson's disease, heart disease, cancer), severe sensory impairment (e.g., difficulty reading newspaper-size print, difficulty hearing a normal conversation), drug or alcohol abuse, current psychiatric diagnoses, psychotropic drug use, and lack of fluency in English. Individuals who were currently meeting the recommended PA guidelines for older adults were also excluded (i.e., 150 minutes of MVPA per week; Canadian Society for Exercise Physiology, 2011). Potential participants were screened for inclusion and exclusion criteria by an informal telephone interview and the 13-item modified TICS.

Results of the telephone interview were recorded on an initial contact sheet (See Appendix 2: Screening Materials).

Rolling recruitment began in July of 2012 and continued until October 2013. Previous literature examining the effects of PA on cognition has found medium effects of PA on higher order cognitive functions (e.g., executive functions, ES = 0.68; Colcombe & Kramer, 2003). This study focused on the relations of PA with higher-order functions, including executive function, working memory, and attention. For this reason, recruitment efforts targeted 100-150 participants based on sample size calculations using medium effect size.

Participants were recruited primarily through advertisements in the local media (newspaper, radio, television, posters at local senior recreation centers, bulletin boards, newsletters; See Appendix 3: Recruitment Materials). Advertisements targeted older adults aged 65 years and over who were not currently meeting the PA guidelines for older adults (i.e., 150 minutes of MVPA per week) and highlighted both the cognitive and physical health benefits of PA. Inactive older adults were invited to participate in a research study examining the effects of PA on the cognitive and physical health of inactive older adults and told to call/email the researcher to find out more about the research study and walking program.

Safety to Exercise

To screen for safety to engage in the walking program and the fitness testing, the researcher administered the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+; Warburton, Bredin, Jamnik, & Gledhill, 2011; Warburton, Jamnik et al., 2011; see Appendix 2) to each participant. The PAR-Q+ can be completed online or via print

format and is a questionnaire that assists an individual of any age to determine whether they are safe to exercise or whether it is necessary to seek advice from a medical doctor or a qualified exercise professional (CSEP certified Exercise Physiologist) before becoming physically active. When participants had a positive response to the PAR-Q+, they were asked to complete the Electronic Physical Activity Readiness Medical Examination ePARmed-X+ (ePARmed-X+; Warburton, Jamnik, et al., 2011; Warburton, Bredin, et al., 2011; see Appendix 2) to further determine whether they were ready to engage in a PA program. When necessary, participants obtained medical clearance before participated in the study.

Demographics and Health

Demographic (age, gender, years of education, marital status, current living arrangement, employment, race/ethnic group, primary language) and self-reported health information was obtained for the purpose of describing the sample. Participants were also asked to report on their family history of dementia/severe memory loss and other serious cognitive problems (mother, father, sister, brother, grandmother, grandfather).

Baseline Cardiovascular Disease Status

To establish baseline cardiovascular disease status, the researcher examined several relevant measures (e.g., the Modified Cumulative Illness Rating Scale, a medication list, resting blood pressure, and waist circumference; See Appendix 5: Questionnaires and Other Data Collection Materials).

First, participants were interviewed about the presence and severity of their health conditions, when they were diagnosed, and how the conditions were being treated/managed using the Modified Cumulative Illness Rating Scale – Geriatric (CIRS-

G; Hudon, Fortin, & Soubhi, 2007; Miller et al., 1992). The CIRS-G scores diseases in 14-organ systems and grades each system according to severity using explicit rules for classification. Severity is ranked on a Likert scale ranging from 1 (no impairment) to 5 (extremely severe problem and/or immediate treatment required and/or organ failure and/or severe functional impairment). Only those organ systems relevant to cardiovascular, cerebrovascular disease, and metabolic conditions were examined (CIRS-G sections: 1) cardiac, 2) vascular, 3) haematological, 4) respiratory, 12) neurological, and 13) endocrine-metabolic). This interview occurred at the baseline individual testing session.

Second, participants were asked to provide the researcher with a list of their current prescription and non-prescription medications, vitamins and supplements. This list was used to identify whether the participants were currently taking any medications for the control of cardiovascular and metabolic conditions (e.g., antihypertensive medication, anti-diabetic medications). To determine which drugs constitute treatment for cardiovascular and metabolic conditions, each drug, vitamin and supplement was classified using the Anatomical Therapeutic Chemical Classification System and the Defined Daily Dose (ATC/DDD; WHO Collaborating Centre for Drug Statistics Methodology, 2012; WHO, 2013). The researcher reviewed this list with the participant at their baseline individual testing session.

Last, factors related to metabolic syndrome and obesity were examined. Resting blood pressure (systolic and diastolic blood pressure (mmHg)) and waist circumference were assessed as part of the fitness testing protocol according to the guidelines established by the Canadian Physical Activity Fitness and Lifestyle Approach 4th Edition

(Canadian Society for Exercise Physiology, 2010; See Appendix 4). Information from the above three measures was used to help establish presence of metabolic syndrome. According to the American Heart Association and the National Heart, Lung, and Blood Institute (Grundy, 2005), an individual has metabolic syndrome if they meet 3 of 5 of the following criteria:

a. Elevated blood pressure (systolic >130 mm Hg or diastolic >85 mm Hg) or drug treatment for hypertension;
b. Large waist circumference (women >88 cm and men >102 cm);
c. Elevated triglycerides levels (≥150 mg/dL) or drug treatment for elevated triglyceride levels;
d. Low High Density Lipoprotein - Cholesterol (HDL-C level; women <50 mg/dL and men <40 mg/dL) or drug treatment for low HDL-C; and
e. Elevated fasting glucose (glucose ≥100 mg/dL) or drug treatment for elevated glucose.

Since the researcher was unable obtain blood samples, two alternate measures were used as a proxy for metabolic syndrome: 1) total number of cardiovascular and metabolic conditions (cardiovascular, respiratory, and endocrine metabolic) and 2) total number of cardiovascular risk factors (cardiovascular and metabolic conditions, elevated systolic blood pressure, elevated diastolic blood pressure, drug treatment for hypertension, triglycerides, low HDL-C or diabetes, and large waist circumference).

Measures of Physical Activity, Walking and Other Health Behaviours

Current MVPA and MVW were measured using the Community Healthy Activities Model Program for Seniors Physical Activity Questionnaire (CHAMPS PAQ;

Stewart et al., 2001). The CHAMPS PAQ is a self-report measure that estimates the frequency (times/week) and duration (total hours) of weekly physical activities in a typical week during the past 4 weeks. The CHAMPS was designed for older adults and includes physical activities in which older adults typically engage. The CHAMPS has been administered in numerous studies with older adults and has been shown to have acceptable measurement properties (Cyarto, Marshall, Dickinson, & Brown, 2006; Giles & Marshall, 2009; Harada, Chiu, King, & Stewart, 2001; Pruitt et al., 2008). An aggregate measure of weekly leisure time MVPA was created by summing the total hours of exercise-related PA of greater than 3 metabolic equivalents (METS; i.e., items 7, 9, 14-16, 19, 21, 23-26, 29-33, 36-38, 40). An aggregate measure of weekly MVW was also created by summing the total hours of walking of greater than 3 metabolic equivalents (METS; i.e., items 25 and 26). These outcome measures were expressed in minutes/week.

Self-reported MVW was also examined using a modified version of the Godin Leisure Time Exercise Questionnaire (GLTEQ; Godin, Jobin, & Bouillon, 1985; Godin, Jobin, & Bouillon, 1986) as has been done in previous walking studies (e.g., Blacklock, Rhodes, & Brown, 2006; Brown & Rhodes, 2006; Rhodes, Blanchard, Courneya, & Plotnikoff, 2009; Rhodes, Brown, & McIntyre, 2006; Rhodes, Courneya, Blanchard, & Plotnikoff, 2007; Rhodes, Murray, Temple, Tuokko, & Higgins, 2012b; Rhodes, Murray, Temple, Tuokko, & Higgins, 2012a). The GLTEQ contains three open-ended questions asking participants to recall their average frequency (times/week) of mild, moderate, and strenuous physical activities during their free time in a typical week. In this study, participants were asked to recall their frequency of leisure time *walking* (i.e., walking during free time and not during occupational and housework) in the last seven days. Mild,

moderate, and strenuous physical activities from the original GLTEQ were changed to mild walking (Minimal effort, no perspiration, a casual walk), moderate walking (Not exhausting, light perspiration, a good brisk pace), and strenuous walking (Heart beats rapidly, sweating, as fast as you could walk). Participants were also asked to report the average duration walked at each of these intensities. An aggregate index of MVW was created by summing the total weekly duration (frequency X duration) of moderate and strenuous walking (minutes/week).

History of PA in midlife was assessed using a modified Historical Physical Activity Questionnaire (Chasan-Taber et al., 2002; Kriska et al., 1988). In previous research, lifetime PA has been linked to the development of chronic disease, including cardiovascular disease (Besson et al., 2010; Chasan-Taber et al., 2002; Orsini, Bellocco, Bottai, Pagano, & Wolk, 2007) and may be an important variable in the study of the relations between PA, cardiovascular disease, and cognition. The researcher provided participants with a list of physical activities and required participants to check off those activities that they participated in more than 10 times in their lifetime. The original questionnaire was modified to include categories from the CHAMPS questionnaire and time periods appropriate for the current study. For each activity that the participants completed more than 10 times in their lifetime, participants indicated the number of years they participated, typical number of months per year and typical hours per year across three relevant midlife time periods (51 to 65 years, 35-50 years, and 20-34 years). Due to difficulty with recall and amount of missing information, it was not possible to calculate a weighted summary lifetime PA estimate using the compendium and previously used methods (Chasan-Taber et al., 2002); instead, the researcher calculated a crude index of

midlife PA by tallying the total number of physical activities participated in ten or more times between 20 and 65 years of age.

Adherence to a Mediterranean style diet (i.e., high fruit and vegetable, legume, and complex carbohydrate intake, moderate fish intake, low to moderate red wine intake) was assessed using a validated diet screen, the Mediterranean Diet Adherence Screener (MEDAS, Estruch et al., 2006; Martinez-Gonzalez, Fernandez-Jarne, Serrano-Martinez, Wright, & Gomez-Gracia, 2004; Schroder et al., 2011). Although food frequency questionnaires, dietary records and 24 hour recalls provide a more in-depth examination of food consumption patterns, given that diet was of secondary importance in the study and that these types of measures put a great deal of burden on participants, the modified MEDAS was chosen as an acceptable alternative. The 16-item diet screener used in the current study required participants to reflect on their current diet (i.e., last 7 days) and included 14 items on the consumption of foods included in the Mediterranean diet (e.g., "How many servings (150 g) of beans & legumes do you consume per week"? "How many servings of fish/seafood do you consume per week?") and 2 items about food habits (e.g., "Do you use olive oil as the principal source of fat for cooking?"). Each item was scored out of 1 with possible total scores on the screener ranging from 0 to 16. Given the study sample was from Canada, the wording of the screener items were modified to reflect serving sizes from Canada's Food Guide (CFG; Health Canada, 2011). Higher scores on the MEDAS reflect greater adherence to a Mediterranean style diet.

In addition, four items measuring adherence to CFG were added to the diet screen. They were open-ended items examining daily consumption of the 4 major food groups (Fruits and Vegetables, Grains, Meats and Alternatives and Milk and Alternatives;

e.g., “How many daily food guide servings of meats and alternative did you consume?”). In a similar vein to the MEDAS, each item was scored out of 1 with possible total scores ranging from 0 to 4. Higher scores on the screen reflected greater adherence to CFG. The MEDAS and CFG diet items were interviewer administered and a copy of the CFG and household items (e.g., deck of cards, tennis ball, die) were used to help participants appreciate serving size and estimate their serving numbers. These diet measures were administered to participants by interview at the time of the baseline and follow-up individual testing sessions.

Participants were asked about their engagement in intellectually stimulating activities and social activities using the CHAMPS PAQ (described above). Aggregate measures of weekly duration of intellectually stimulating activities (items 3, 6, 8, 12, 13, 17, 18, and 23) and social engagement (items 1-5, 7, 9-15, 31, 36, 40) were created by summing the total hours of each endorsed activity. Outcome measures were expressed in hours/week.

Cognitive Function

The battery of cognitive measures consisted of 2 traditional paper and pencil tests and a brief battery of computerized tests, called CogState, designed for repeated administration with minimal practice effects (http://cogstate.com). The latter is a previously validated measure of cognitive change in multiple populations (healthy adults, older adults, MCI, early AD, concussions, and other forms of cognitive impairment (e.g., healthy adults, older adults, MCI, early AD, concussions, and other forms of cognitive impairment; Darby et al., 2011; Darby et al., 2012; Falleti, Maruff, Collie, & Darby, 2006; Fredrickson et al., 2010; Lim et al., 2013; Pietrzak et al., 2008). Tests were chosen

to target executive function, attention, working memory, and episodic memory. The cognitive tests administered, the cognitive domains they assess, and the outcome measures used in the analysis are described in Table 1.

Table 1. Summary of Cognitive Battery

Test	Domain	Outcome Measure
Trail Making Test: Part A Part B	Attention, speed of processing Attention, speed of processing and mental flexibility	Time to completion (seconds)
Verbal Fluency: Phonemic/letter Semantic/category	Executive function, speed of processing, semantic processing, word knowledge	Total correct responses (count)
Groton Maze Learning Test	Executive function (problem solving, error monitoring), spatial working memory	Total errors on learning trials 1 to 5(count)
Groton Maze Learning Test Delayed Recall	Visual learning and memory	Total errors (count) on delayed recall
International Shopping List Task	Verbal learning and memory	Total words recalled on learning trials 1 to 3 (count)
International Shopping List Delayed Recall	Verbal learning and memory	Total words recalled after a delay (count)
One Back	Attention and working memory	Accuracy (proportion of correct responses)
Two Back	Attention and working memory	Accuracy (proportion of correct responses)

The tasks were administered as follows:

1. Trail Making Test (TMT): For part A, the participant is given a pencil and a page with the number 1 through 25 arranged randomly. The participant is required to connect the numbers in proper order as quickly as they can. For part B, the participant is given a

pencil and a sheet of paper with 25 letters and numbers arranged randomly. The participant is asked to connect the number and letters as quickly as they can by alternating between letters and number in proper order (1-A-2-B-3-C). The TMT part A and B takes about 5-10 minutes to administer (Strauss, Sherman, & Spreen, 2006a).

2. Verbal Fluency: Participants completed two fluency measures. For the phonemic (letter) fluency task participants were asked to orally produce as many words as possible beginning with a particular letter in 1 minute. Participants completed the tasks for the letters F, A, and S. The outcome measure was the sum of all admissible words across the three letters. For semantic (category) fluency, the participants were asked to say as many animal names as they could within a one-minute interval. The outcome measure is the total number of admissible words for the animal category. The fluency tasks took approximately 5 minutes to complete (Strauss, Sherman, & Spreen, 2006b).

3. The Groton Maze Learning Test: For the maze-learning task, the participant is shown a 10 by 10 grid of squares on the computer screen. The grid contains a hidden 28 step pathway beginning at the top left and ending at the bottom right of the grid. The participant must find their way through the pathway by clicking on one square at a time by using trial and error feedback (i.e., correct/incorrect). The participant is given two rules they must follow: (1) they cannot move diagonally or touch the same tile twice in succession, and 2) they cannot move backwards along the pathway. Once they complete the pathway, they must return to the start and recall the same hidden path from their memory for 4 additional trials. Administration time is approximately five minutes. The outcome measure is total number of errors made in attempting to learn the same hidden pathway across five consecutive trials.

4. The Groton Maze Learning Test Delayed Recall: Following a delay, the participant is asked to recreate the path they learned in the Groton Maze Learning Task. The administration time is 1 minute and the outcome measure is total errors.

5. International Shopping List Task. The subject is read a list of 12 words from a shopping list at a rate of 1 per 2 seconds and then asked to recall as many words as they can. They are given three learning trials. Test administration takes 5 minutes and the outcome measure is total number of correct responses across all three trials.

6. International Shopping List Task Delayed Recall. Following a delay, the participant is asked to recall as many words from the International Shopping List Task as possible. The list is not repeated. Test administration is about 1 minute and the outcome measure is the total words recalled.

7. One Back Task: The participant is presented with a deck of cards on the computer screen and asked if the card is the same as *one* card back. They must press "yes" if it is and "no" if it is not. They continue this way pressing enter as quickly and as accurately as possible. The administration time is 2 minutes and the outcome measure is the proportion of correct responses.

8. Two Back Task: This task is identical to the one back task, with the exception that the participant must indicate whether the card is the same as *two* cards back. The administration time is 2 minutes and the outcome measure is the proportion of correct responses.

Fitness

A brief fitness assessment included measures of aerobic fitness and body composition. Aerobic fitness was assessed using a submaximal walk test, the 6-minute

walk test. The 6-minute walk test is used primarily for those with respiratory disease and heart failure, but is also appropriate for assessing aerobic capacity of healthy older adults and is easily administered with minimal equipment and training (Faktor, 2010). For the current study, a 30 meter course was marked out in the hallway and the participants were asked to walk back and forth along the course as many times as possible. Resting (i.e., after 5 minutes seated) and post-testing (1, 3, and 5 minute) heart rate and blood pressure were also measured. The outcome measure was distance walked (meters) in the 6 minutes. BMI (kg/m^2) and waist circumference (cm; at the level of iliac crest) were also measured according to standard procedures (Canadian Society for Exercise Physiology, 2010; See Appendix 5).

Procedures

Ethical approval for *Health Bodies, Healthy Minds – A Supervised Walking Program for Older Adults* was obtained from the Human Research Ethics Board at the University of Victoria. Written informed consent was obtained from all participants. Eligible and consenting participants underwent baseline assessment, consisting of a group testing session (fitness and gait assessment) and an individual testing session (cognitive battery and diet screening) at the University. Details of the gait assessment are described in study 2 (Chapter 3).

Participants completed a package of self-report measures assessing safety to exercise, demographics and health, current physical activity and walking levels, midlife history of physical activity, and social cognitive and self-regulatory variables relevant to leisure time walking as part of a mail-out package prior to their baseline assessments.

Social cognitive and self-regulatory variables are described in study 3 (Chapter 4).

Schedule and Follow-Up:

The group walks started in early September 2012 and continued until the end of February 2013. The participants were recruited using rolling recruitment, such that the end date of the 16-week walking program varied for each participant. Approximately 6, 9, 12 and 16 weeks following the start of the walking program participants completed follow-up testing including: 1) fitness and gait testing (group session), 2) cognitive battery and diet screening (individual session), and 3) self-reported PA and walking questionnaires. These measures were identical to baseline measures. Measurement waves were unequal to help better describe the precise shape of cognitive change over the course of the fourth-month walking program.

Majority of testing occurred at the University of Victoria, but individuals who could not make it to the University for their individual sessions were offered the option of in-home testing sessions. The exact testing schedule is summarized in Table 2.

Table 2. Testing Schedule

	Aim	Avg. Time of Actual Measurement[1]
Wave 1	0	0.00 (0.00)
Wave 2	6	6.67 (0.84)
Wave 3	9	9.80 (1.17)
Wave 4	12	13.48 (1.29)
Wave 5	16	18.47 (1.57)

Notes: [1]Average between the time of the fitness/gait assessment and the cognition/diet assessments.

The intervention

Following the baseline testing, participants attended a single one-on-one information session where they were introduced to *Health Bodies, Healthy Minds - A Supervised Walking Program for Older Adults*, educated about health behaviours relevant

to their cognitive and physical health, and received personalized a coaching session focused on self-regulation strategies to help them begin and maintain their walking program. The intervention materials are included in Appendix 6: Intervention Materials.

First, the researcher, a certified personal trainer and group fitness instructor, working under the supervision of a certified Exercise Physiologist, introduced the walking program to the older adults. Similar to previous research examining the effects of aerobic activity on cognition (Colcombe, Kramer, Erickson, et al., 2004; Kramer et al., 1999), the *Healthy Bodies, Healthy Minds Walking Program* participants met in small groups for at least three walks per week at a moderate to vigorous intensity. A four-month duration was selected for the walking program because aerobic fitness benefits are seen within several months of beginning an exercise program and previous work has shown that cognitive benefits in inactive older adults can occur in as early as eight-weeks into an exercise program (Colcombe & Kramer, 2003). Based on the reviewed literature, a clear picture of dose-response relations and the length of PA intervention required for cognitive benefits does not exist. For these reasons and the exploratory nature of this study, a four-month dose was selected as sufficient duration for a preliminary examination of the pure within- and between-person sources of variation in PA and walking and their effects on cognition. A moderate to vigorous intensity was selected because there is some evidence that higher intensity confers greater cognitive benefits than lesser intensity activity (e.g., Angevaren et al., 2007; Brown et al., 2012; Kruger et al., 2009).

Supervised walks were spread throughout the Greater Victoria region and participants were responsible for their own travel. Each walk began with a warm up and

ended with a cool down and stretching. Duration and intensity increased gradually over the course of the walking program from 15 minutes to 45 minutes or more of moderate intensity/brisk walking (not including warm up, cool down and stretching). Participants were taught to monitor their intensity with ratings of perceived exertion. At each walk, the walking group leaders monitored intensity and encouraged participants at each walk to keep their intensity brisk using ratings of perceived exertion and the sing-talk-gasp test. Periodically throughout each walk, the walking group leaders asked participants to rate their perceived exertion and make adjustments to their walking intensity. Fidelity of the intervention was not evaluated using heart rate monitoring. Previous work examining the effects of aerobic activity on cognition using a walking protocol similar to that described above has found significant moderate effects of exercise on cognition (e.g., Colcombe et al., 2004; Kramer et al., 1999). Participants were given a calendar of available walks and asked to attend at least 3 walks per week (See Appendix 5).

Next, the researcher gave each participant a copy of the Canadian Physical Activity Guidelines for Older Adults - 65 Years and Older (Canadian Society for Exercise Physiology, 2011) and Canada's Food Guide (Health Canada, 2011) and explained these materials. Participants were advised to meet the national recommended guidelines of 150 minutes of MVPA per week and encouraged to engage in activities outside of the walking program to meet this goal. The researcher also worked through the food groups, food items that qualify, and appropriate serving sizes. Each individual was further educated about health behaviours supporting cognitive health using a package of brochures produced by the Alzheimer's Society of Canada (e.g., Heads Up for Healthier Brains, Choose Wisely, Reduce Stress, Challenge Yourself, Make Healthy Food Choices,

Be Physically Active, Be Socially Active; 2009). Research examining older adult's knowledge, attitudes and beliefs, and behaviours related to preserving or promoting their cognitive health has demonstrated that older adults have limited knowledge regarding modifiable risk factors and dementia/cognitive health (e.g., Corwin et al., 2007; Gow, Hanlon, & Gilhooly, 2004; Low & Anstey, 2009; Park et al., 2008). The role of cardiovascular risk factors and dementia (Arai, Arai, & Zarit, 2008; Gow et al., 2004; Low & Anstey, 2009; Norrie et al., 2011; Park et al., 2008; Wilcox et al., 2009) and the difference between disease prevention and risk reduction (Wilcox et al., 2009) have also been highlighted as areas that the public has limited knowledge and understanding.

At the end of the information session, participants engaged in a brief individualised coaching session focused on self-monitoring and other self-regulatory strategies and received a take home package of self-regulation worksheets. Research specifically on older adults has found that self-regulation to be a significant predictor for PA behaviour (McAuley et al., 2011; Umstattd & Hallam, 2007; Umstattd, Wilcox, Saunders, Watkins, & Dowda, 2008). In addition, a meta-analysis of interventions to promote PA in older adults found that interventions that targeted self-monitoring (i.e. interventions that included a mechanism for older adults to record the intensity and frequency of their exercise) were significantly better than interventions that did not (Conn, Minor, Burks, Rantz, & Pomeroy, 2003; Conn, Isaramalai, Banks-Wallace, Ulbrich, & Cochran, 2003; Conn, Valentine, & Cooper, 2002; Michie, Abraham, Whittington, McAteer, & Gupta, 2009).

Data Analyzes

Prior to main statistical analyses, data was cleaned using standard procedures.

Data was entered, cross-checked, and examined for data input errors. Variables were visually examined using frequency plots, histograms, and z-scores, and skewness and kurtosis statistics were explored (Field, 2005). Outliers were identified, removed and replaced with scores equal to a Z score of 3.

Hierarchical Linear Modeling (HLM; Raudenbush & Bryk, 2002) was used to examine the associations between changes in PA and walking and changes and cognitive outcomes over a four-month walking program (primary research questions). HLM was also used to examine associations between changes in other health behaviours (HB) and changes in cognitive outcomes (secondary research question). The associations between changes in PA and walking and changes in cognition were also examined. HLM allowed for simultaneous assessment of the effects of within-person variation in predictor variables (level 1) and between-person differences in predictor variables (level 2) on cognition and fitness. These models examined the average individual change across the five waves of measurement (fixed slope effects) and whether trajectories of change varied across individuals (random slope coefficients). Preliminary analyses were conducted using Statistical Package for Social (SPSS 21.0; IBM Corporation, 2012) while multilevel models were fit using HLM 7.01 for Windows (Raudenbush, Bryk, Cheong, Fai, Congsdon, & du Toit, 2011).

First, intercept-only models (dependent measures and no predictors) were fit to examine if variance existed at level 1 and level 2 for each of the PA (i.e., MVW and MVPA), other health behaviours (HB; i.e., adherence to a Mediterranean style diet, adherence to the CFG, intellectually stimulating activities, socially engagement), fitness (6 minute walk test, body mass index, waist circumference) and cognitive measures

(Equation 1: a - h).

Level 1:	Level 2
$PA_{ij} = \beta_{0i} + e_{ij}$ (1a)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (1b)
$Fitness_{ij} = \beta_{0i} + e_{ij}$ (1c)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (1d)
$Cognition = \beta_{0i} + e_{ij}$ (1e)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (1f)
$HB = \beta_{0i} + e_{ij}$ (1g)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (1h)

Variance components were used to calculate an ICC for each measure ($ICC = between - person\ variation/(between\ person\ variation + within - person\ variation)$. Second, whether each of the measures displayed significant longitudinal change was tested using empty longitudinal models. Given that there is high discordance between intention and behaviour and poor long-term adherence to PA programs (Cox et al., 2013; de Bruijn et al., 2012; Evers et al., 2012; Rhodes, 2012; Rhodes & De Bruijn, 2013a; Rhodes & de Bruijn, 2013b), a curvilinear relationship between time in the walking program and PA was anticipated; thus, models of change were fit by including both linear and quadratic time parameters (See equation 2a- p). The time parameters were grand mean centered to reduce multicollinearity (UCLA: Statistical Consulting Group, 2014). Specifically, performance for a given individual (i) at a given time (j) is a function of that individual's performance at the grand mean week since the start of the walking program (the intercept), plus his/her average individual linear and quadratic rates of change across weeks since start of the walking program (the slopes), plus an error term (e_{ij}).

Level 1:	Level 2:
$PA_{ij} = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij}$ (2a)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (2b) $\beta_{1i} = \gamma_{10} + U_{1i}$ (2c) $\beta_{2i} = \gamma_{20} + U_{2i}$ (2d)
$Fitness = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij}$ (2e)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (2f) $\beta_{1i} = \gamma_{10} + U_{1i}$ (2g) $\beta_{2i} = \gamma_{20} + U_{2i}$ (2h)
$Cognition = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij}$ (2i)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (2j)

$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (2k)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (2l)}$$

$$Other\ HB = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \text{ (2m)}$$

$$\beta_{0i} = \gamma_{00} + U_{0i} \text{ (2n)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (2o)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (2p)}$$

Third, for those measures that exhibit significant change, how change in measures of interest travelled <u>together</u> across time in the walking program was examined (i.e., PA and fitness, PA and cognition, other HB and cognition). To identify intra-individual covariates of change in fitness or cognition, "time-varying covariation models" were constructed by including an index of time (time in walking program centered at 0), as well as indices of PA or other HB (Equation 3a-l). To reduce bias, models were fit with both level 1 and level 2 PA or other HB estimates, so that the impact of time specific within-person variation in PA or other HB and the constant between-person differences in PA or other HB on fitness and cognitive outcomes could be examined simultaneously, as recommended by Hoffman and Stawski (2009).

Level 1 PA or other HB were person-mean centered (i.e., value at each week minus the individual's own mean level), such that level 1 PA or other HB parameter estimates represent the effect of variation around each individual's own mean PA or other HB on fitness and cognitive outcomes (i.e., the within-person effect of weekly variation (effect of WP)). The level 2 parameter estimates of PA or other HB represent the effect of between-person differences in the PA or other HB on fitness and cognitive outcomes (effect of PM). Only a linear time parameter (centered at 0) was entered in the model due to lack of sufficient waves for inclusion of the quadratic term from equation 2.

Level 1:

$$Fitness = \beta_{0i} + \beta_{1i}(Time) + \beta_{2i}(Weekly\ PA - PM\ PA) + e_{ij} \text{ (3a)}$$

$$Cognition = \beta_{0i} + \beta_{1i}(Time) + \beta_{2i}\ (Weekly\ PA - PM\ PA) + e_{ij} \text{ (3e)}$$

Level 2:

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(PM\ PA) + U_{0i} \text{ (3b)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (3c)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (3d)}$$

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(PM\ PA) + U_{0i} \text{ (3f)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (3g)}$$

$$Cognition = \beta_{0i} + \beta_{1i}(Time) + \beta_{2i}\left(Weekly\ HB - PM\ HB\right) + e_{ij} \quad (3i)$$

$$\beta_{2i} = \gamma_{20} + U_{2i} \quad (3h)$$

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(PM\ HB) + U_{0i} \quad (3j)$$

$$\beta_{1i} = \gamma_{10} + U_{1i} \quad (3k)$$

$$\beta_{2i} = \gamma_{20} + U_{2i} \quad (3l)$$

The above level 1 equations assume that fitness and cognitive functioning at any given week will depend upon the number of weeks since entering the walking program (β_{1i}), the effect of WP PA or other HB (β_{2i}), as well as person-specific residuals (e_{ij}). The γ_{00} intercept represents mean performance on a given fitness or cognitive outcome at baseline when all other predictor variables (WP and PM PA and other HB) are set at zero. The γ_{10} slope parameter in these models reflects rate of linear change in fitness or cognitive outcomes across weeks, independent of the effects of 1) WP PA or other HB and 2) PM PA or other HB; whereas, the γ_{20} slope parameter assesses whether higher (or lower) WP PA at a given week is linked to higher (or lower) fitness or cognitive outcomes, independent of the effect of time and PM PA or other HB. The γ_{20} parameter estimate has been person-mean centered and represents the *pure* WP effect of weekly PA or HB on fitness or cognitive outcomes. The γ_{01} parameter estimate represents the between-person effect of PA or other HB on cognition or fitness, not controlling for the effect WP PA or other HB at any given week.

Fourth, for time-varying covariation models of cognitive change only (i.e., primary research question 1c), cardiovascular risk factors, age, education, lifetime history of PA, in addition to PM PA were examined as level-2 predictors of change (See equation 4 a –d). Age, cardiovascular risk factors, and midlife history of PA were grand mean centered. Gender was not included in this analysis due to the limited number of males in the study.

Level 1:

$Cognition = \beta_{0i} + \beta_{1i}(Time) + \beta_{2i}(Weekly\ PA - PM\ PA) + e_{ij}$ (4a)

Level 2

$\beta_{0i} = \gamma_{00} + \gamma_{01}(Age) + \gamma_{02}(Educ) + \gamma_{03}(Dementia) + \gamma_{04}(Other\ cog) + \gamma_{05}(risk) + \gamma_{06}(mid\ PA) + \gamma_{07}(PM\ PA) + U_{0i}$ (4b)

$\beta_{1i} = \gamma_{10} + U_{1i}$ (4c)

$\beta_{2i} = \gamma_{20} + U_{2i}$ (4d)

Equation 4a-d is interpreted in identical fashion to equation 3 with the addition of multiple level 2 predictors of change.

Parameters in these models were estimated with full information maximum likelihood. When random effects were not significant, they were trimmed from the models. Effect sizes were calculated for the within-person effects using the following calculations:

Within-person effect: $\frac{\sigma^2_{null} - \sigma^2_{random\ effects\ model}}{\sigma^2_{null}}$. Effect sizes were interpreted using Ferguson's guidelines, where r^2 of .04 is the recommended minimum for a practically significant effect (RPME), .25 is a moderate effect and .64 is a strong effect (Ferguson, 2009).

Results

Participants Characteristics

Of the 438 potential participants who returned the call for volunteers, were screened for eligibility, and provided with more information about the study, 63.70 percent (n=279) were either ineligible or uninterested in participating, while 36.30 percent (n=159) were eligible and agreed to participate. Although they agreed to participate, 25 of these individuals never started the study (i.e., failed to show up to their initial appointments, changed their mind about participating) and a further 17 were

screened as ineligible after the initial appointment (e.g., in poor health/major medical illness, at high fall risk).

The final sample used in this study included 118 participants (n = 91 females, n= 27 males). Dropout rate was 20.33 percent. Four of 118 dropped out following baseline assessments and a further 20 dropped out over the course of the walking program. Flow of participants through the study and completion rates of each of the measurement waves are presented in Figure 1. At baseline, study participants ranged in age from 65 to 87 years of age (M= 72.81, SD = 5.24). The sample's baseline demographic and health characteristics are listed in Table 3 and Table 4.

Table 3. Baseline Demographic Variables

Participant Characteristic	Value
Age (M(SD), range)	72.81(5.24), 64.97 to
Years living in Greater Victoria (M(SD) range)	30.05 (20.01), 0.13 to
Gender - Female (n(%))	91 (77.1%)
Primary Language – English (n(%))	110 (96.5%)
Education –high school diploma (n(%))	107 (93.9%)
Education – Some university or college (n(%))	83 (72.8%)
Ethnicity – Caucasian (n(%))	112 (98.2%)
Marital Status (n(%))	
Single	10 (8.8%)
Married/common-law	64 (56.2%)
Divorced/separated	21(18.4%)
Widowed	19 (16.1%)
Living Arrangement (n(%))	
Single home	73 (64.6)%
Duplex/town home	9 (8.0%)
Apartment/condo	25 (22.1%)
Living alone (n(%))	46 (41.4%)
Handedness – Right (n(%))	107 (90.7%)
Participated in other studies at the University of Victoria (n(%))	15 (13.2%)

Notes: M=Mean, SD = standard deviation.

Table 4. Baseline Health Variables

Participant Characteristic	Value
Compared to a perfect state of health, I believe my overall health to be...	
Very good or good	94 (83.2%)
Fair	19 (16.8%)
Compared to other people my age, I believe my overall health to be...	
Very good or good	98 (88.3%)
Fair	13 (11.7%)
Compared to other people my age, I believe my eyesight to be... (n(%))	
Very good or good	90 (79.7%)
Fair	22 (19.5%)
Poor	1 (.9%)
Compared to other people my age, I believe my hearing to be... (n(%))	
Very good or good	85 (75.25)
Fair	23 (20.4%)
Poor	5 (4.4%)
Compared to other people my age, I believe my memory to be... (n(%))	
Very good or good	82 (72.6%)
Fair	27 (23.9%)
Poor	4 (.3.5%)
Family history of dementia/severe memory loss (n(%))	55 (46.6%)
Total number of cardiovascular or metabolic conditions (M(SD), range)[1]	0.745 (0.97), 0 to 3
Total number of cardiovascular risk factors (M(SD), range)[2]	2.93 (1.70), 0 to 6
TICS score (M(SD), range)	38.36 (4.59), 28 to 49

Notes: M=Mean, SD = standard deviation; 1 – total number of cardiovascular or metabolic conditions (sections a, b, m) of moderate severity (i.e., moderate problem that requires first line therapy) or greater that were reported on the Modified Cumulative Illness Rating Scale (CIRS) during the baseline intake interview; 2.- Total number of cardiovascular/metabolic risk factors at baseline (including resting systolic blood pressure >130 mmHg, resting diastolic blood pressure > 85 mmHg, hypertension at baseline, on drug treatment for hypertension at baseline, high cholesterol at baseline, on drug treatment for high cholesterol at baseline, waist circumference >88 cm for women or 102 cm for men at baseline, presence of cardiovascular or metabolic conditions, on drug treatment for diabetes).

Preliminary Analyses

Preliminary analyses involved examining basic descriptive statistics across wave of testing for the PA, walking, and other health behaviour measures and the outcomes. Table 9 in in the additional files at the end of this chapter summarizes the means and standard deviations of these measures.

Primary Research Questions

Step 1. Identifying % of variance that is between vs. within person-persons

The HLM analyses were conducted in four steps. First, to examine if variance existed at level 1 and level 2, intercept only models (See Equations 1 a-d) were run for each of the PA measures (MVW, MVPA) and cognitive outcomes (category fluency, letter fluency, trail making test A, trail making test B, maze learning, maze recall, list learning, list recall, one back and two back). Results of these preliminary analyses are summarized in tables 10-11 of the additional files of the present chapter.

The intercept-only models for MVPA and MVW (CHAMPS PAQ and GLTQ) revealed interclass correlation coefficients (ICC) ranging from 0.236 to 0.473. The lowest interclass coefficient was 0.236 for MVW on the GTLQ (minutes/week), suggesting that 23.6% of the variance in MVW was at the group level and 76.4% of the variance was at the individual level. The highest ICC was 0.473 for MVPA (minutes/week), suggesting that 47.3% of the variance in weekly minutes of MVPA was at the group level and 52.7% was at the individual level.

The intercept-only models of cognitive performance produced ICCs ranging from 0.59 to 0.76. For example, the ICC of the intercept-only model for letter fluency revealed that 76% of the variance in letter fluency was between-persons, while 24% of the variance was within-persons.

Step 2. Empty longitudinal models

Second, since variance existed at both levels for each of the intercept-only models that were tested, longitudinal models of change for each of the PA measures and cognitive outcomes (primary research question 1a) were examined. Results of these analyses are summarized in Table 5, including the model parameters for each mixed

model. Significant longitudinal change was observed for both measures of walking. Specifically, for each additional week in the walking program over the grand mean, self-reported minutes of MVW increased significantly (p<.001). In line with our expectations, with each additional week in the walking program, increases in walking occurred at a decreasing rate (p<.001). Increases in MVPA with each additional week in the program were modest and non-significant (p>.05), and for each additional week in the program the curvature of the slope was decreasing (p<.05). Effect sizes ranged from small, but practically significant for MVPA (r^2=0.213) to strong for MVW (r^2 =0.660).

Significant improvements were also exhibited across all (p < .001), but one measure of cognitive performance. With each additional week in the walking program above the grand mean, participants had significantly better performance on all cognitive measures (p< .001), except list recall (p=0.183). Moreover, significant quadratic time parameters on category fluency (p=0.051), letter fluency (p <.001), maze learning (p=.006*)*, and the one back task (p=0.053*)* revealed that increases in cognitive performance on these measures occurred at a decreasing rate with each additional week in the walking program above the grand mean. The effect sizes for cognitive measures were generally small, but practically significant (r^2 =.04 for category fluency to r^2 =0.213 for letter fluency. Effects sizes for maze learning and trails A were moderate (r^2 = .274 and r^2 =.300).

Step 3. Time-varying covariation models with level 1 and level 2 person mean centering

Third, for those measures displaying significant longitudinal change, separate time-varying covariation models examining how measures of PA and cognitive measures travelled together over time were constructed. Table 6 summarizes the findings from the

time-varying covariation models. Evidence for time-varying covariation of PA and cognition were limited and mixed. Findings were in the expected direction for self-reported MVPA and MVW and letter fluency. Specifically, independent of weeks in the walking program, there were significant within-person effects of self-reported MVPA, MVW GTLQ, and MVW CHAMPS PAQ on words generated on letter fluency (p<.001, p=0.021 and p<.001). For *each minute per week* increase in MVPA, MVW GLTQ and MVW CHAMPS PAQ *more than usual*, there was a corresponding 0.008, 0.011 and 0.013 increase *above usual* in words generated on letter fluency. Effect sizes were small (r^2 = 0.103 to 0.118).

Findings were generally in the expected direction for time to completion on trail making test B. Specifically, independent of weeks in the walking program, there were significant negative within-person effects of self-reported MVPA (p=0.014*)* and MVW CHAMPS PAQ (p=.052*)*, but not MVW Godin (p=.548), on time to completion on the trail making test B. Effect sizes were all small (r^2 = 0.157 to 0.163). For each minute per week increase in MVPA and MVW *more than usual* on the CHAMPS PAQ, there was a corresponding 0.027 and 0.022 second decrease *below usual* on time to completion on trail making test B, respectively.

In contrast, there was a significant *positive* within-person effect of self-reported MVW based on the CHAMPS PAQ (p=.03; 1 of the 3 MVPA/W measures) on time to completion on the trail making test A (r^2=0.329). For each additional minute per week of MWW there was a corresponding 0.01 second increase in time to completion on trail making test A. All other within-person and between-person effects of self-reported

MVPA and MVW (both GLTQ and CHAMPS) on cognitive tasks were non-significant (*p*'s all <.05).

Step 4. Time-varying covariation models with level 1 and level 2 person-mean centering and additional Level 2 predictors

Last, for models of PA and cognition demonstrating significant time-varying covariation (i.e., letter fluency and MVPA, MVW GTLQ and MVW CHAMPS PAQ, trail making test B and MVPA and MVW CHAMPS PAQ, trail making test A and MVW CHAMPS PAQ), additional level 2 predictors were added to the model. The results of these models are summarized in Table 12 in the additional files at the end of the chapter. None of the additional level 2 predictors (i.e., age, education, family history of dementia, family history of other serious cognitive impairment, midlife PA) made significant contributions to any of the time-covariation models (*p*'s all > .05).

Secondary Research Question

The secondary research question examined the time-varying covariation of other health behaviours and cognitive outcomes over the four-month walking program. Analyses were completed in an identical fashion to those addressing primary research questions (Steps 1-3).

Step 1: Identifying % of variance that is between- vs. within-person

First, intercept-only models of other health behaviours (adherence to the Mediterranean-style diet, adherence to the CFG, participation in intellectually stimulating activities, and social engagement) were run to examine the percentage of variance at level 1 and level 2. ICCs of these models ranged from 0.291 for adherence to the CFG to 0.658 for participation in intellectually stimulating activities, suggesting that 29.1% of the variance in CFG was at the group level and 69.9% at the individual level and 65.8% of

the variance in intellectually stimulating activities was at the group level and 34.2% at the individual level. Findings are summarized in Table 13 in the additional files at the end of this chapter.

Step 2. Empty Longitudinal Models

Next, longitudinal models of change for each of the other health behaviour measures were examined. Results of these analyses are summarized in Table 7, including the model parameters for each mixed model. Significant longitudinal change was observed for adherence to the CFG, participation in intellectually stimulating activities and social engagement. Specifically, participation in intellectually stimulating activities and social engagement decreased with additional week in the program above the grand mean (p=.05). Linear decreases in adherence in CFG with each additional week in the program were small and non-significant (p=0.232), and these changes slowed over time (p=.002). Effect sizes were for health behaviours were small (r^2 = 0.067 to 0.202).

Step 3: Time-varying covariation models with level 1 and level 2 person mean centering

Third, for those measures displaying significant longitudinal change, separate time-varying covariation models examining how measures of other health behaviours and cognitive outcomes travelled together over time were constructed. Table 8 summarizes the findings from the time-varying covariation models. There was no evidence of time-varying covariation for either participation in intellectually stimulating activities and cognitive outcomes or adherence to the CFG and cognitive outcomes (p's all > .05). Evidence of time-varying association and social participation and cognitive outcomes was limited and mixed. There was a significant negative within-person effect of social participation on letter fluency (p=.025, r^2=0.213*)* and a positive within-person effect of

social participation on errors on maze learning (p =.032, r^2=0.128; i.e., poorer performance). All other within-person effects of social participation and adherence to CFG on cognitive outcomes were non-significant (all p's >.05).

There were consistent expected between-person effects of participation in intellectually stimulating activities on cognitive outcomes (p's all less than 0.05, except on letter fluency p=0.057), such that individuals who participated in ***more*** intellectually stimulating activities ***on average*** performed ***better on average*** on the cognitive measures, not controlling for weekly variation in participation in intellectually stimulating activities. Between-person effects of both social participation and adherence to CFG on cognitive outcomes were generally non-significant. Adherence to the CFG had a significant positive between-person effect on errors made on maze learning (i.e., poorer performance; p=0.053).

Additional Analyses: Physical Activity and Fitness

Step 1. Identifying % of variance that is between vs. within person-persons

First, to examine if variance existed at level 1 and level 2, intercept only models (See Equations 1 a-d) were run for each of the fitness measures (waist circumference, body mass index and 6 minute walk test). Results of these preliminary analyses are summarized in Table 14 in the additional files at the end of this chapter.

ICCs for the intercept-only models of fitness ranged from 0.021 to 0.280. The ICC for the six minute walk test, the primary fitness outcome, was 0.280, suggesting that 28% of the variance was at the group level and 72% was at the individual level.

Step 2. Empty longitudinal models

Second, since variance existed at both levels for each of the intercept-only models that were tested, longitudinal models of change for each of the PA measures and fitness

were examined. Results of these analyses are summarized in Table 15 including the model parameters for each mixed model. Significant improvements in aerobic fitness and waist circumference were also observed, such that with each additional week in the program above the grand mean participants walked further on the 6 minute walk task (p<.001) and had decreases in their measured waist circumference (p<.001), but these improvements occurred at a decreasing rate with each additional week in the program above the grand mean ($p \leq .001$). Effect sizes were moderate (r^2=0.413 and r^2=0.546). In contrast, time in the walking program had a positive, but non-significant effect on BMI (p's >.05, r^2=0.680).

Step 3: Time-varying covariation models with level 1 and level 2 person mean centering

Third, for those measures displaying significant longitudinal change, separate time-varying covariation models examining how measures of PA and fitness travelled together over time were constructed. Table 16 summarizes the findings from the time-varying covariation models. In line with expectation, independent of weeks in the walking program, there was evidence of time-varying covariation of PA and aerobic fitness. Specifically, a significant within-person effect of MVW (both GLTQ *(p*=.009) and CHAMPS PAQ (p =.004)), but not MVPA (p=0.104*)* on aerobic fitness was observed. In addition, there were consistent significant between-person effects of person-mean PA (MVW on GLTQ (p=.005) and CHAMPS PAQ (p<.001) and MVPA (p<.001)), not controlling for daily variation in PA on meters walked on the six-minute walk test. Effect sizes generally moderate (r^2=0.240 to r^2=0.472). For example, for every additional minute of person-mean MVW as measured by the CHAMPS PAQ, 0.358 more meters are walked on average on the six-minute walk test. The significant within-person effect of

0.072 indicates that for every minute per week *more than usual* of MVW, 0.072 *more meters than usual* are walked on the six-minute walk test. The effects (between and within-person) of MVPA on waist circumference were non-significant (p's both >.05). Meanwhile the within-person effects of walking on waist circumference were mixed (γ =-.0164, p=0.018 for MVW based on GLTQ, γ =-.0001 p>.05 for MVW based on the CHAMPS), while both between-person effects were non-significant.

Discussion

Primary Research Questions

The present study was undertaken to examine the dynamic coupling of changes in PA and changes in cognitive function in older adults over a four-month walking program. It was hypothesised that older adults would display significant increases in both MVPA and MVW and corresponding improvements in measures of executive function, attention, working memory and episodic memory over the four-month supervised walking program, and that these changes would occur at a decreasing rate over time (*Hypothesis 1a*). Furthermore, it was anticipated that longitudinal changes in both MVW and MVPA would share significant time-varying association with changes in cognitive performance across all measures (*Hypothesis 1b*). It was also anticipated that basic demographic variables, family history of dementia/cognitive impairment, number of cardiovascular risk factors, and midlife PA might moderate the relations (*Hypothesis 1c*).

The main hypotheses (*Hypothesis 1a and b*) were only partially supported. As expected with each additional week in the walking program, older adults engaged in significantly more MVW. This was consistent across both measures of walking. Moreover, measures of cognitive function generally produced significant linear improvements across weeks in the program (all measures except list recall). Linear

increases in MVPA were modest and non-significant, while increases in both MVPA and MVW occurred at a decreasing rate over time. These findings are suggestive of a significant association between MVW and MVPA and measures of executive function, attention and working memory in older adults. In fact, improvements in select measures of cognitive performance, especially measures of executive functioning and working memory (both fluency, maze learning, and one back) displayed parallel patterns as MVW (i.e., improvements in these measures levelled off over time, in line with poorer adherence to the walking program over the course of the walking program).

However, a more stringent test of whether changes in cognitive function were systematically related to changes in PA over the four-month walking program requires fitting time varying-covariation models. Contrary to expectation, *only* two measures of cognitive performance (letter fluency and Trail Making Test B) shared expected time varying association with measures of MVW and MVPA. These effects were small, but practically significant. Individuals who engaged in 60-90 minutes per week MVW more than their mean levels, generated roughly 0.5 to 1 more words on the letter fluency measures compared to usual. Effects of MVPA on letter fluency were smaller (i.e., 0.78 to 1.17 words on MVW based on the CHAMPS, 0.66 to 0.99 on MVW based on GTLQ words, 0.48 to 0.72 based on the CHAMPS MVPA).

The limited within-person effects of PA on cognition do not preclude more widespread cognitive benefits. The null effects may be a reflection of the time-intervals examined in the current study. For example, time-coupling delays may exist, such that changes in PA and associated changes in cognitive function may not occur at the same rate. It is also plausible that PA exerts its effects on cognitive function not only

preferentially (i.e., executive function over other cognitive domains), but also at a different rate across specific cognitive domains and measures. An extension of the current study using additional unequal measurement intervals over a longer period of follow-up may reveal such patterns. Moreover, the imprecision of the self-report measures of PA and walking utilized in the present study may have failed to provide an accurate picture of changes in PA and walking over the course of the four-month walking program.

It is also noteworthy that there were consistent moderate effects of 1) MVW and time and 2) MVPA and time on performance on the groton maze learning task (r^2 =0.299 to r^2=0.538); however, only time contributed significantly to these models, none of the within-person effects of MVW or MVPA reached statistical significance. There was one significant unexpected positive time-varying association between MVW and time to completion on trail making test A; however; the effects were inconsistent across PA/walking measures (only significant for 1 of the 3 measures of MVPA and MVW).

The cognitive domains related to changes in PA and walking in these time-varying covariation models are consistent with prior work that has found that PA, including walking, preferentially impacts measures of executive function, attention, and working memory (e.g., Anderson-Hanley et al., 2012; Baker, Frank, Foster-Schubert, Green, Wilkinson, McTiernan, Cholerton, et al., 2010; Brown et al., 2009; Colcombe & Kramer, 2003; Langlois et al., 2013; Liu-Ambrose et al., 2010; Nagamatsu et al., 2013; Nouchi et al., 2014).

In contrast to these significant within-person effects of MVW and MVPA on measures of executive function, attention, and working memory, it was found that none

of the between-person effects of MVW or MVPA on cognitive measures were significant. In other words, not taking into account weekly variation in MVW and MVPA, it was found that individuals who were on average higher and lower on MVW and MVPA were not significantly better or worse on average on any of the cognitive measures. These findings highlight the importance of separating between- from within-person sources of variation in PA when examining the complex relations between PA and cognition in older adults. It seems likely that some of the null and inconsistent findings in the present body of literature could be explained by the fact that the fast majority of the research fails to examine individual differences in the effects of PA (and walking) on cognitive behaviour in older adults.

Our second primary hypothesis (Hypothesis 1c) was not supported. None of the between-person effects of age, education, family history of dementia, family history of other serious cognitive impairment, and number of cardiovascular risk factors at baseline or history of self-reported midlife PA were significant were significantly related to cognitive performance. However, these analyses were limited to the significant time-varying associations found in this study (letter fluency and MVW QTLQ, MVW CHAMPS, & MVPA, trail making test B and CHAMPS MVPA and MVW, and trail making test A and CHAMPS MVW). In particular, the lack of findings regarding between-person effects of cardiovascular risk factors on cognitive performance was somewhat surprising given the suggested links between vascular risk factors and cardiovascular disease states and cognition in the exiting literature (e.g., Ahlskog et al., 2011; Bielak, 2010; Royall, 2008). However, lack of significant findings regarding cardiovascular disease and does not rule out that cardiovascular risk factors may

influence the time-varying associations between physical activity and cognition. Research over a longer time period is needed to investigate the impact of these risk factors in more detail

Secondary Research Questions

Our secondary research questions addressed the time-varying association between other health behaviours and cognitive performance. It was hypothesized (*Hypothesis 2*) that these health behaviours would not share time-varying association with cognitive performance since they were only minimally targeted by our intervention. However, between-group effects of health behaviours on cognition were expected, such that individuals who engaged in more health behaviours (i.e., adhered more to Mediterranean style diet, adhered more to the Canadian food guide, who engaged in more social and intellectual activities) on average would perform better on average across all cognitive measures. Again, partial support for these hypotheses was found. As anticipated, most within-person effects were non-significant. Generally null findings are consistent with the fact that the intervention employed only minimal intervention to encourage changes in cognitive, social activities and diet. Moreover, it was not anticipated that there would be much natural fluctuation in these behaviours over a short duration.

In line with our expectations, consistent between person-effects of intellectual activities on cognitive performance were found, such that individuals who engaged in more intellectually stimulating activities on average performed better on average across 9 of 10 cognitive measures. This is consistent with prospective and experimental work showing a significant association between cognitive activities and better cognitive health (Daviglus et al., 2011; Hertzog et al., 2008; Kriska et al., 1988; Lustig, Shah, Seidler, &

Reuter-Lorenz, 2009; Schneider & Yvon, 2013; Valenzuela et al., 2012; M. Valenzuela & Sachdev, 2009; Williams, Plassman, Burke, Holsinger, & Benjamin, 2010). However, this generally was not true of other health behaviours (only 1 of 10 cognitive measures and adherence to the CFG). Within research examining the influence of lifestyle engagement (physical activities, cognitive activities and social engagement) on cognitive function in older adults, the bulk of evidence points to the superiority of physical activities and cognitive activities over social participation, though research has supported some association between all three behaviours and cognitive function (Elwood et al., 2013; Laura Fratiglioni & Wang, 2007; Hertzog et al., 2008; Karp et al., 2006; Law, Barnett, Yau, & Gray, 2014; Lustig et al., 2009; Plassman, Williams, Burke, Holsinger, & Benjamin, 2010; Schneider & Yvon, 2013; Wang et al., 2013; Williams et al., 2010). Moreover, a growing body of work is pointing to the superiority of multimodal interventions and engagement in a combination of healthy lifestyle behaviours compared to any of the health behaviour alone (Agrigoroaei & Lachman, 2011; de Andrade et al., 2013; de Melo Coelho et al., 2013; Law et al., 2014; Schneider & Yvon, 2013; Thiel et al., 2012; Thom & Clare, 2011), with some support that engagement in more healthy lifestyle behaviours brings greater benefit (Lee, Kim, & Back, 2009).

Diet also did not influence cognitive performance in the current study. Examining the relations between other health behaviours and cognitive function was a secondary focus in the study; as such, diet measures were chosen to be brief to reduce participant burden. It may be that brief screens on adherence to the Canadian Food Guide and Mediterranean Style diet were not sensitive enough measures to capture change in dietary behaviour over the fourth month period. Diet records or food frequency questionnaires

may have proved useful for a more precise exploration of the effects of changes in diet on changes in cognition in the current sample.

Additional Analyses

Although not a major focus in this study, given the widespread health and fitness benefits of PA (Hautier & Bonnefoy, 2007; Paterson et al., 2007; Warburton, Nicol, & Bredin, 2006), we also sought to examine the dynamic coupling of changes in PA and changes in a brief battery of fitness measures (6 minute walk test, BMI, and waist circumference) in older adults over a four-month walking program. Not surprisingly, there were generally consistent significant positive between and within-person effects of PA (MVW and MVPA) on aerobic fitness, such that: 1) individual who were more active on average had significantly better fitness than those who were less active on average (between-person effect) and 2) individuals who increased their walking relative to their own mean levels of walking, also significantly increased their fitness levels (within-person effect).

Evidence that the walking program resulted in changes anthropometric measures was more limited. Although waist circumference significantly decreased with each additional week in the walking program, only MVW GLTQ (1 of 3 MVPA/W measures) shared significant time-varying association with these declines. Despite significant increases in both MVPA and MVW and improvements in aerobic fitness, none of the other between- or within person effects on BMI or waist circumference were significant (waist circumference and BMI). The null finding could be for several alternative explanations. First, although walking is primarily an aerobic activity, it also load-bearing activity involving muscles of the legs, pelvic girdle and lower trunk and as such,

participants likely gained muscle and associated muscle mass (Morris & Hardman, 1997). Second, changes in PA, without changes in diet, may not have been sufficient to produce weight loss. Research suggests that weight loss from aerobic activity alone is possible, but only at extremely high volumes of aerobic activity (Swift, Johannsen, Lavie, Earnest, & Church, 2014) When it comes to weight loss, current evidence suggest that diet interventions and combined diet and PA interventions are supervisor to PA alone (Stephens, Cobiac, & Veerman, 2014).

Methodological Considerations

The above findings should be interpreted within the context of several key strengths and limitations. Advanced multi-level models were employed to examine the time-varying association between PA and cognition. These models separated the constant between-person sources of variation in PA from the within-person sources of variation. To the best of the author's knowledge, this study was the first to examine time-varying covariation models of PA and cognition that distinguished simultaneously between pure within- and between-person effects of PA on cognition in older adults.

Using a brief single group longitudinal design and five waves of measurement, the current study provided some preliminary evidence, on a select few measures of executive function, that changes in PA and changes in cognitive function may share time-varying association. The study employed carefully selected hypothesis driven tests and multiple measures of executive function, attention and working memory to examine the relations between change in PA and changes in cognition. Moreover, the assessment included a brief battery of computerized measures that were designed specifically for repeated administration with minimal practice effects, in combination with traditional

paper and pencil tests of executive functioning. The battery included a number of measures with alternate forms so that practice effects could be minimized.

The study had several limitations. First, although 159 older adults were recruited into the program, only 114 participants actually started the walking program and only 92 participants completed wave 5 measures. Due to dropout, the study sample size was modest at best and may have been under-powered to detect medium effects. Effect sizes in the current literature on PA and cognition are highly variable, but generally have ranged from small to moderate. It may have been fruitful to include a larger sample allowing for some dropout and detection of smaller effects. Moreover, not all participants completed all measures at each of the measurement waves (See Figure 1). However, the parameter estimates in the multilevel models were estimated with full information maximum likelihood (FML). One of the advantages of FML is its ability to handle missing data.

Second, although participants were encouraged to walk at a brisk intensity and were taught to monitor their intensity using ratings of perceived exertion, heart rate monitoring was not used to provide an objective measurement of intensity levels. To minimize this limitation and to provide some confidence in intervention fidelity, walking group leaders worked with participants at each walk to monitor their intensity, asked for ratings of perceived exertion periodically throughout the walk, and encouraged participants to increase their intensity when they provided ratings below moderate intensity.

Third, self-report measures were used to gather information about the participants' current and midlife PA levels and this limited measurement precision.

Although these measures can be easily administered to large groups and place relatively low burden on the participant, they are prone to over- and under- reporting (e.g., difficulties with recall, social desirability and misinterpretation; Kowalski, Rhodes, Naylor, Tuokko, & MacDonald, 2012). To combat some of these issues and help confirm the findings, three measures of walking and PA behaviour were gathered. This was successful: changes in walking and PA behaviour across time in the walking program exhibited the similar patterns across the three measures of behaviour (i.e., minutes/week of MVW were significantly higher with each additional week in the walking program and improvements occurred at a decreasing rate over time, MVPA improvements were modest, and non-significant, but occurred at significantly decreasing rate over time). Moreover, positive within-person effects of MVW and MVPA on executive function and working memory (letter fluency, trail making test B, and maze learning) were also consistently observed (i.e., significant effects on 2 of 3 or 3 of 3 of MVW/MVPA measures).

Fourth, the number of measurement waves included in the current study put constraints on the multi-level models (e.g., quadratic time-parameters was not included in the time-varying covariation models). Although the possible influence of other health behaviour (i.e., eating well, staying social engaged, participating in cognitive activity) on the relations between PA and cognitive function is intriguing, due to too few measurement waves these influences were not examined. There is accumulating evidence that lifestyle interventions combining multiple lifestyle behaviours may be superior to interventions targeting single behaviours; however, to date the data is inconclusive (Agrigoroaei & Lachman, 2011; Carlson et al., 2009; de Andrade et al., 2013; de Melo

Coelho et al., 2013; Hertzog et al., 2008; Thiel et al., 2012; Thom & Clare, 2011). Furthermore, additional measurement waves over a longer measurement period would have allowed for the examination of possible time-coupling delays previously described.

Future Directions

The current work points to the importance to separating within- and between-sources of variation in PA when studying the effect of PA on cognition. Failure to do so can bias results and lead to incorrect conclusions about the complex relations between PA and cognition. To advance the field, further work should continue to employ time-varying covariation models including parameter estimates that distinguish between both between- and within-person sources of variation in PA on cognition using objective measures of PA. As part of study 3 (Chapter 4) attendance data was taken from participants that attended the walking groups. The impact of this objective measure of PA on cognitive function will be analyzed in future research. Future studies should use other objective measures of PA (e.g., accelerometers, heart rate monitors) to more accurately examine the relations between PA and cognitive function.

It may also prove fruitful to use similar models and objective measures of physical activity to examine these relations in individuals with mild cognitive impairment (MCI), Alzheimer's disease or other chronic disease states affecting cognition. The present findings are restricted to sample of predominately female, apparently healthy older adults with high education. Individuals belonging to at risk groups may have more room for improvement on cognitive measures than the apparently healthy individual in the present sample. A comparison of effects sizes from meta-analyses on the effects of

PA on cognitive function in cognitively impaired (Heyn et al., 2004) compared to healthy older adults (Angevaren et al., 2008) suggests this might be the case.

It might also prove useful to examine these relations between PA and cognitive function in healthy and impaired older samples using measurement burst designs (i.e., blocks of more intensive measurement waves interspersed throughout longer-term follow-up periods over months to years). Such a design would provide a useful means to examine both time-coupling delays and how vascular risk factors might mediate or moderate the relations between changes in PA and cognition over long-term intervention.

Summary

It has been proposed that engagement in healthy lifestyle behaviours, including intellectual, social, and physical activities, can prevent cognitive decline. A growing body of evidence from meta-analyses, prospective research and randomized control trials is accumulating for the beneficial effects of PA on cognitive function. However, due to methodological limitations and mixed findings in the current body of work, the cognitive benefits of PA are highly debated. Longitudinal designs and advanced statistical methods examining both group and individual differences in PA, like those used in the present study, along with large sample RCTs with long-term follow-up, are needed to advance the field. Methodologically rigorous research into the specific cognitive domains and the populations that benefit most from PA is essential to achieving greater understanding of behavioural factors and mechanisms that help older adults preserve their cognitive function. Key questions regarding optimal activities for activity and dose-response relations, and mediators and moderators influencing the relations between PA and cognitive health, as well as contribution of other health behaviours to these relations,

require further exploration.

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Tables and Figures

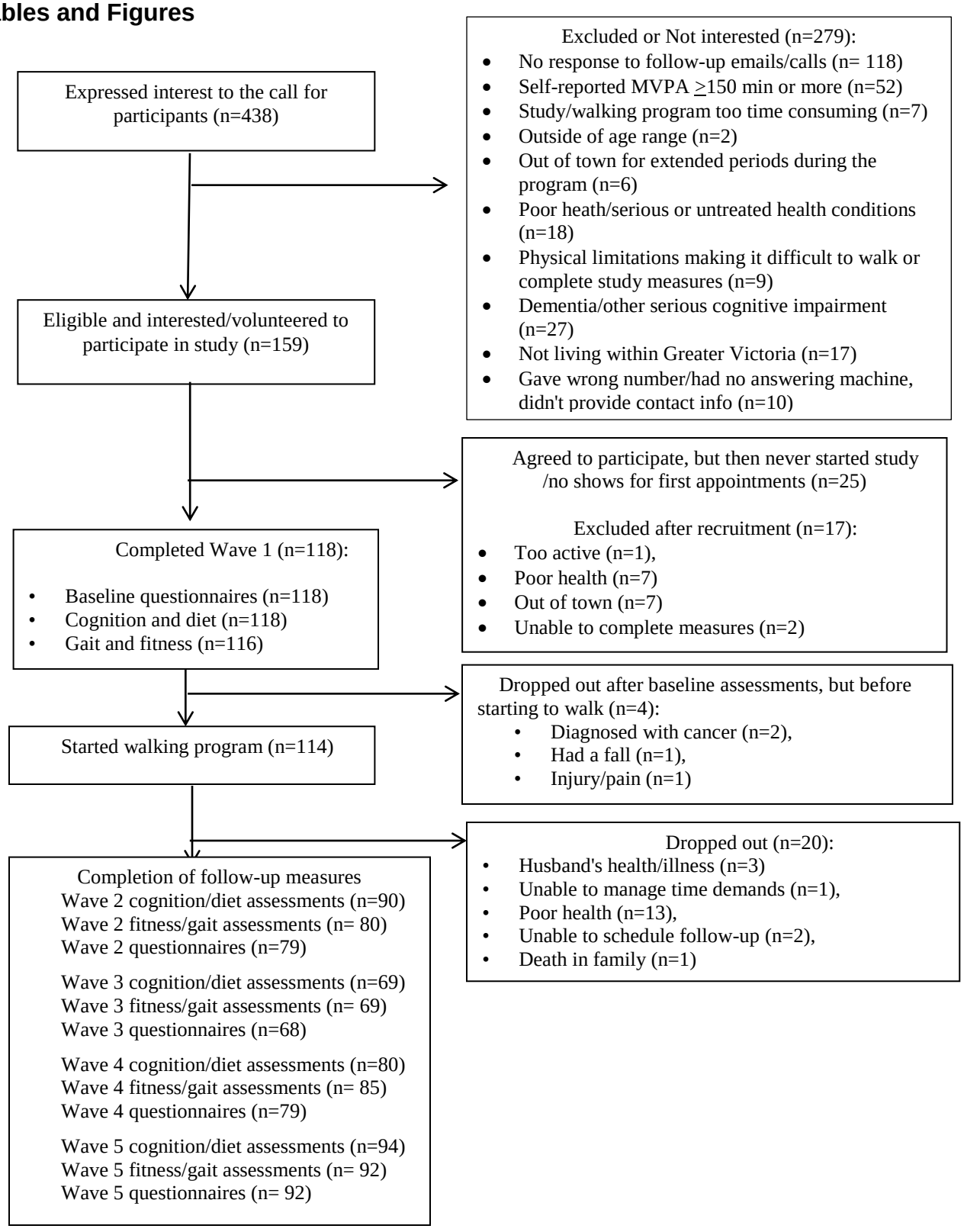

Figure 1. Flow of participants through the program

Table 5. Change in Physical Activity and Cognitive Outcomes as a Function of Time

Variables	Parameter	Coefficient	SE	t-ratio	*df*	p	r^2
PA							
MV Walking – GLTQ	Intercept, γ_{00}	135.807	8.128	16.708	114	<0.001	0.660
	Slope, γ_{10}	5.224	0.502	10.415	114	<0.001	
	Slope, γ_{20}	-0.718	0.083	-8.662	114	<0.001	
MVW CHAMPS PAQ	Intercept, γ_{00}	133.446	7.731	17.261	110	<0.001	0.281
	Slope, γ_{10}	3.805	0.604	6.298	110	<0.001	
	Slope, γ_{20}	-0.580	0.088	-6.582	191	<0.001	
MVPA	Intercept, γ_{00}	242.151	15.243	15.886	110	<0.001	0.213
	Slope, γ_{10}	1.013	1.144	0.886	110	0.378	
	Slope, γ_{20}	-0.362	0.147	-2.452	188	0.015	
Cognition							
Category Fluency	Intercept, γ_{00}	20.140	0.432	46.618	116	<0.001	0.040
	Slope, γ_{10}	0.073	0.023	3.232	330	0.001	
	Slope, γ_{20}	-0.007	0.004	-1.958	330	0.051	
Letter Fluency	Intercept, γ_{00}	43.421	0.997	43.536	116	<0.001	0.213
	Slope, γ_{10}	0.236	0.043	5.444	116	<0.001	
	Slope, γ_{20}	-0.016	0.006	-2.713	214	0.007	
Trail making test A	Intercept, γ_{00}	30.976	0.846	36.622	116	<0.001	0.304
	Slope, γ_{10}	-0.279	0.047	-5.975	116	<0.001	
	Slope, γ_{20}	0.004	0.007	0.550	116	0.583	
Trail making test B	Intercept, γ_{00}	75.006	2.500	30.002	116	<0.001	0.113
	Slope, γ_{10}	-0.832	0.133	-6.274	327	<0.001	
	Slope, γ_{20}	0.028	0.022	1.319	327	0.188	
Maze delayed recall	Intercept, γ_{00}	8.168	0.313	26.131	116	<0.001	0.063
	Slope, γ_{10}	-0.091	0.021	-4.432	327	<0.001	
	Slope, γ_{20}	-0.003	0.003	-0.908	327	0.364	
Maze learning	Intercept, γ_{00}	55.214	1.451	38.052	116	<0.001	0.274
	Slope, γ_{10}	-0.601	0.105	-5.706	116	<0.001	
	Slope, γ_{20}	0.039	0.014	2.805	211	0.006	
List learning	Intercept, γ_{00}	24.262	0.391	62.070	116	<0.001	0.155
	Slope, γ_{10}	0.071	0.022	3.193	116	0.002	
	Slope, γ_{20}	0.001	0.003	0.376	211	0.707	

Variables	Parameter	Coefficient	SE	t-ratio	*df*	p	r^2
List delayed recall	Intercept, γ_{00}	8.670	0.199	43.528	116	<0.001	0.104
	Slope, γ_{10}	0.014	0.011	1.338	116	0.183	
	Slope, γ_{20}	-0.002	0.002	-1.161	209	0.247	
One back	Intercept, γ_{00}	1.302	0.011	117.440	116	<0.001	0.173
	Slope, γ_{10}	0.007	0.001	8.533	327	<0.001	
	Slope, γ_{20}	0.000	0.000	-1.939	327	0.053	
Two back	Intercept, γ_{00}	1.166	0.012	93.931	108	<0.001	0.020
	Slope, γ_{10}	0.003	0.001	3.270	303	0.001	
	Slope, γ_{20}	0.000	0.000	1.446	303	0.149	

Notes: Cognitive coefficients reflect total number of words generated for category fluency and letter fluency, seconds to completion for trail making test A and B, total errors made for maze learning and maze delayed recall, total words recalled for list learning and list learning delayed recall and accuracy of performance for the one back and two back tests; γ_{00} = average performance on a given cognitive measure at wave =9.18 weeks for the overall sample; γ_{01} = average rate of linear change in a given cognitive measure per additional week in the study above the grand mean (9.18 weeks; time centered), holding all other variables constant; γ_{02} = average rate of quadratic change in a given cognitive measure per additional week in the study above the grand mean (9.18 weeks; time centered and then squared), holding all other variables constant.

Table 6.Time-Varying Covariation Models: Change in Cognitive Outcomes as a Function of Time and Level 1 and 2 Person Mean PA

Variables	Intercept, γ_{00}/ Coefficient, γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
MVW - GLTQ											
Category Fluency	18.229	0.816	22.332	102	<0.001	0.100	0.027	3.655	290	<0.001	0.069
	0.006	0.007	0.885	102	0.378	-0.002	0.003	-0.863	290	0.389	
Letter Fluency	41.495	1.876	22.122	102	<0.001	0.147	0.047	3.118	290	0.002	0.118
	0.004	0.016	0.254	102	0.8	0.011	0.005	2.329	290	0.021	
Trail Making Test A	33.756	1.425	23.696	102	<0.001	-0.266	0.049	-5.401	182	<0.001	0.261
	-0.006	0.012	-0.507	102	0.613	-0.002	0.006	-0.329	103	0.743	
Trail Making Test B	84.483	4.914	17.194	102	<0.001	-0.710	0.172	-4.134	103	<0.001	0.157
	-0.026	0.037	-0.702	102	0.484	-0.010	0.016	-0.602	103	0.548	
Maze Recall	8.771	0.564	15.550	102	<0.001	-0.083	0.025	-3.335	288	<0.001	0.108
	0.000	0.005	-0.107	102	0.915	-0.002	0.002	-0.740	288	0.460	
GML	62.311	2.778	22.428	102	<0.001	-0.502	0.124	-4.031	103	<0.001	0.299
	-0.013	0.022	-0.594	102	0.554	-0.012	0.010	-1.148	185	0.252	
ISL	23.504	0.758	31.003	102	<0.001	0.068	0.024	2.785	288	0.006	0.009
	0.002	0.006	0.386	102	0.700	0.001	0.002	0.542	288	0.589	
ONB	1.241	0.020	61.442	102	<0.001	0.007	0.001	6.073	288	<0.001	0.129
	0.000	0.000	-0.552	102	0.582	0.000	0.000	1.375	288	0.170	
TWOB	1.176	0.022	53.305	102	<0.001	0.003	0.001	3.076	285	0.002	0.026
	0.000	0.000	-1.310	102	0.193	0.000	0.000	0.128	285	0.899	
MVW – CHAMPS											
Category Fluency	18.817	0.769	24.477	103	<0.001	0.081	0.025	3.170	281	0.002	0.033
	0.002	0.006	0.317	103	0.752	0.000	0.002	-0.037	281	0.971	
Letter Fluency	42.756	1.778	24.051	103	<0.001	0.172	0.043	3.991	281	<0.001	0.109
	-0.013	0.014	-0.920	103	0.360	0.013	0.004	3.239	281	0.001	

Variables	Intercept, γ_{00}/ Coefficient, γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
Trail Making Test A	33.670	1.339	25.140	103	<0.001	-0.285	0.048	-5.937	104	<0.001	0.243
	-0.002	0.010	-0.214	103	0.831	0.010	0.004	2.202	104	0.03	
Trail Making Test B	84.118	4.552	18.479	103	<0.001	-0.660	0.157	-4.188	104	<0.001	0.075
	-0.026	0.032	-0.800	103	0.425	-0.027	0.014	-1.959	174	0.052	
Maze Recall	9.124	0.543	16.802	103	<0.001	-0.102	0.024	-4.226	104	<0.001	0.192
	-0.001	0.004	-0.340	103	0.735	0.002	0.002	0.736	174	0.462	
GML	61.784	2.574	24.006	103	<0.001	-0.536	0.134	-4.004	104	<0.001	0.470
	-0.001	0.020	-0.049	103	0.961	-0.013	0.009	-1.526	104	0.13	
ISL	24.050	0.694	34.659	103	<0.001	0.080	0.025	3.227	104	0.002	0.157
	-0.004	0.006	-0.734	103	0.465	-0.001	0.002	-0.519	174	0.604	
ONB	1.216	0.019	64.290	103	<0.001	0.007	0.001	6.908	174	<0.001	0.189
	0.000	0.000	0.931	103	0.354	0.000	0.000	0.718	104	0.474	
TWOB	1.151	0.021	55.796	103	<0.001	0.003	0.001	3.572	275	<0.001	0.045
	0.000	0.000	0.024	103	0.981	0.000	0.000	-0.988	275	0.324	
MVPA - CHAMPS											
Category Fluency	19.426	0.782	24.846	103	<0.001	0.084	0.023	3.518	279	<0.001	0.045
	-0.002	0.003	-0.709	103	0.480	-0.003	0.001	-1.703	279	0.090	
Letter Fluency	43.192	1.808	23.894	103	<0.001	0.209	0.041	5.157	279	<0.001	0.103
	-0.009	0.007	-1.407	103	0.162	0.008	0.003	3.300	279	0.001	
Trail Making Test A	33.146	1.358	24.406	103	<0.001	-0.266	0.047	-5.630	104	<0.001	0.329
	0.000	0.005	0.088	104	0.930	0.005	0.003	1.724	170	0.087	
Trail Making Test B	79.907	4.624	17.279	103	<0.001	-0.742	0.148	-5.015	104	<0.001	0.160
	0.010	0.015	0.657	103	0.513	-0.022	0.009	-2.513	104	0.014	
Maze Recall	9.019	0.554	16.278	103	<0.001	-0.094	0.023	-4.147	104	<0.001	0.186

Variables	Intercept, γ_{00}/ Coefficient, γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
	-0.000	0.002	-0.230	103	0.819	-0.002	0.001	-1.240	172	0.217	
GML	62.145	2.645	23.466	103	<0.001	-0.547	0.120	-4.575	104	<0.001	0.538
	-0.002	0.009	-0.231	103	0.818	-0.012	0.007	-1.636	104	0.105	
ISL	24.721	0.701	35.267	103	<0.001	0.077	0.024	3.237	104	0.002	0.152
	-0.005	0.002	-1.852	103	0.067	-0.000	0.001	-0.327	172	0.744	
ONB	1.223	0.019	63.477	103	<0.001	0.007	0.000	7.628	276	<0.001	0.137
	0.000	0.000	0.245	103	0.807	0.000	0.000	0.320	276	0.749	
TWOB	1.156	0.021	54.855	103	<0.001	0.002	0.008	3.415	273	<0.001	0.035
	-0.000	0.000	-0.151	103	0.880	0.000	0.000	0.107	273	0.915	

Notes: Cognitive coefficients reflect total number of words generated for category fluency and letter fluency, seconds to completion for trail making test A and B, total errors made for maze learning and maze delayed recall, total words recalled for list learning, and accuracy of performance for the one back and two back tests; γ_{00} = Average performance on a given cognitive at week =0 for the grand mean of PA (min/week); γ_{01} = the between person (person mean) effect of PA on a given cognitive measure, not controlling for weekly PA; γ_{10} = effect of time (uncentered) on a given cognitive measure; γ_{20} = the within person (person mean) effect PA on a given cognitive measure, independent of time).

Table 7. Change in Other Health Behaviours as a Function of Time in the Walking Program.

	Coefficient	SE	*t*-ratio	*df*	*p*	Effect size
Adherence to the CFG						
Intercept, γ_{00}	0.648	0.064	10.099	115	<0.001	0.070
Slope, γ_{10}	-0.006	0.005	-1.202	115	0.232	
Slope, γ_{20}	0.003	0.001	3.134	115	0.002	
Adherence to MED						
Intercept, γ_{00}	8.154	0.182	44.791	115	<0.001	0.202
Slope, γ_{10}	0.014	0.012	1.194	115	0.235	
Slope, γ_{20}	0.001	0.002	0.328	115	0.743	
Intellectually Stimulating Activities						
Intercept, γ_{00}	16.211	0.648	25.022	110	<0.001	0.099
Slope, γ_{10}	-0.068	0.034	-1.98	110	0.05	
Slope, γ_{20}	0.000	0.005	0.024	190	0.981	
Social Activities						
Intercept, γ_{00}	10.965	0.585	18.744	110	<0.001	0.067
Slope, γ_{10}	-0.054	0.028	-1.937	190	0.054	
Slope, γ_{20}	0.010	0.005	1.916	110	0.058	

Notes: MED = Mediterranean diet screen (total score out of 16), CFG – Canada's Food Guide screen (total score out of 4); IA = intellectually stimulating activities (hours/week), and SA = socially engaging activities (hours/week); γ_{00} = average performance on a given health behaviour measure (e.g., CFG) at wave =9.18 weeks for the overall sample; γ_{01} = average rate of linear change in a given health behaviour (e.g., CFG) measure per additional week in the study above the grand mean (9.18 weeks; time centered), holding all other variables constant; γ_{02} = average rate of quadratic change in a given health behaviour (e.g., CFG) measure per additional week in the study above the grand mean (9.18 weeks; time centered and then squared), holding all other variables constant.

Table 8. Time-Varying Covariation Models: Change in Cognitive Outcomes as a Function of Time and Other Health Behaviours

Variables	Intercept γ_{00}/ Coefficient, γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	
Category Fluency											
CFG	19.272	0.733	26.288	106	<0.001	0.071	0.024	2.961	302	<0.001	-1.693
	-0.256	0.710	-0.360	106	0.719	0.099	0.256	0.389	302	0.698	
IA	15.188	1.072	14.163	106	<0.001	0.071	0.0240	2.947	287	0.003	0.015
	0.240	0.060	3.990	106	<0.001	-0.027	0.045	-0.611	287	0.542	
SA	17.542	0.997	17.598	106	<0.001	0.069	0.026	2.662	107	0.009	0.087
	0.137	0.078	1.753	106	0.082	-0.025	0.048	-0.511	181	0.610	
Letter Fluency											
CFG	42.8141	1.643	26.049	106	<0.001	0.222	0.040	5.555	302	<0.001	0.213
	-2.046	1.627	-1.258	106	0.211	0.055	0.424	0.130	302	0.897	
IA	36.120	2.678	13.490	106	<0.001	0.221	0.040	5.474	287	<0.001	0.101
	0.292	0.152	1.922	106	0.057	-0.077	0.075	-1.035	287	0.301	
SA	39.985	2.363	16.920	106	<0.001	0.217	0.045	4.820	107	<0.001	0.213
	0.081	0.186	0.433	106	0.666	-0.182	0.081	-2.260	181	0.025	
TMTA											
CFG	32.528	1.253	25.956	106	<.001	-0.257	0.047	-5.497	107	<.001	0.755
	0.961	1.187	0.809	106	0.420	0.586	0.541	1.083	107	0.281	
IA	37.605	1.940	19.380	106	<0.001	-0.268	0.046	-5.768	107	<0.001	0.179
	-0.267	0.108	-2.461	106	0.015	-0.046	0.082	-0.559	175	0.577	
SA	33.589	1.704	19.713	106	<0.001	-0.263	0.044	-5.987	283	<0.001	0.121
	-0.030	0.133	-0.224	106	0.823	0.030	0.088	0.341	283	0.734	
TMTB											
CFG	77.392	3.981	19.442	106	<.001	-0.757	0.136	-5.563	299	<.001	0.663
	5.208	3.850	1.353	106	0.179	-1.206	1.433	-0.841	299	0.401	

Variables	Intercept γ_{00}/ Coefficient, γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	
IA	104.366	6.199	16.836	106	<0.001	-0.799	0.140	-5.699	284	<0.001	0.091
	-1.339	0.348	-3.853	106	<0.001	0.263	0.264	0.995	284	0.321	
SA	88.418	5.748	15.382	106	<0.001	-0.814	0.140	-5.802	285	<0.001	0.084
	-0.479	0.451	-1.061	106	0.291	0.222	0.284	0.780	285	0.436	
GMR											
CFG	8.253	0.503	16.418	106	<0.001	-0.090	0.022	-4.106	300	<0.001	0.046
	0.796	0.470	1.694	106	0.093	0.310	0.233	1.330	300	0.185	
IA	10.396	0.789	13.182	106	<0.001	-0.095	0.022	-4.354	284	<0.001	0.033
	-0.087	0.044	-1.978	106	0.051	0.020	0.041	0.485	284	0.628	
SA	9.306	0.707	13.158	106	<0.001	-0.088	0.021	-4.116	285	<0.001	0.063
	-0.036	0.055	-0.658	106	0.512	0.065	0.044	1.491	285	0.137	
GML											
CFG	58.727	2.406	24.412	106	<0.001	-0.592	0.113	-5.241	107	<0.001	0.301
	4.397	2.244	1.959	106	0.053	-1.249	0.976	-1.280	193	0.202	
IA	72.275	3.736	19.347	106	<0.001	-0.628	0.114	-5.491	107	<0.001	0.299
	-0.604	0.208	-2.898	106	0.005	0.150	0.174	0.862	177	0.390	
SA	65.324	3.384	19.304	106	<0.001	-0.594	0.094	-6.297	285	<0.001	0.128
	-0.283	0.264	-1.071	106	0.286	0.415	0.192	2.157	285	0.032	
ISL											
CFG	24.156	0.633	38.180	106	<0.001	0.066	0.022	2.939	107	0.004	0.127
	-0.394	0.626	-0.628	106	0.531	0.369	0.213	1.732	193	0.085	
IA	21.413	1.042	20.553	106	<0.001	0.068	0.021	3.289	284	0.001	-0.011
	0.140	0.059	2.373	106	0.019	-0.024	0.039	-0.628	284	0.530	
SA	22.892	0.931	24.581	106	<0.001	0.065	0.021	3.181	285	0.002	-0.009
	0.071	0.073	0.961	106	0.339	-0.019	0.042	-0.457	285	0.648	

Variables	Intercept γ_{00}/ Coefficient, γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	
ONB											
CFG	1.224	0.017	70.769	106	<0.001	0.007	0.001	7.657	300	<0.001	0.184
	0.006	0.015	0.372	106	0.710	-0.010	0.010	-1.070	300	0.285	
IA	1.156	0.025	45.450	106	<0.001	0.007	0.001	7.881	284	<0.001	0.149
	0.004	0.001	3.155	106	0.002	0.001	0.0021	0.665	284	0.507	
SA	1.190	0.024	50.621	106	<0.001	0.007	0.001	7.647	285	<0.001	0.155
	0.003	0.002	1.916	106	0.058	-0.001	0.002	-0.711	285	0.478	
TWOB											
CFG	1.170	0.018587	62.938	105	<0.001	0.003	0.001	3.336	298	<0.001	
	-0.021	0.017382	-1.181	105	0.240	-0.012	0.008	-1.473	298	0.142	
IA	1.058	0.028396	37.262	106	<0.001	0.003	0.001	3.759	281	<0.001	0.009
	0.006	0.001579	3.701	106	<0.001	0.001	0.002	0.790	281	0.430	
SA	1.147	0.026	43.412	106	<0.001	0.003	0.001	3.755	282	<0.001	0.015
	0.000	0.002	0.168	106	0.867	0.003	0.002	1.791	282	0.074	

Notes: cognitive coefficients reflect total number of words generated for category fluency and letter fluency, seconds to completion for trail making test A and B, total errors made for maze learning and maze delayed recall, total words recalled for list learning, and accuracy of performance for the one back and two back tests; γ_{00} = Average performance on a given cognitive measure) at week =0 for the grand mean of a given health behaviour (i.e., intellectually stimulating activities (hours/week) or socially engaging activities (hours/week)); γ_{01} = the between person (person mean) effect of engagement in HB on a given cognitive measure, not controlling for weekly variation in that measure; γ_{10} = the effect of time on a cognitive measure (uncentered); γ_{20} = the within person (person mean) effect of HB on a given cognitive measure.

Additional Files

Table 9. Descriptive Statistics by Wave of Testing

	Wave 1			Wave 2			Wave 3			Wave 4			Wave 5		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
PA and HB															
GTLQ	115	26.53	37.48	82	117.62	77.69	65	149.46	81.82	77	138.14	92.14	91	122.09	91.09
CHAMPS	107	47.80	67.53	77	118.83	83.65	61	156.39	115.04	77	122.34	86.75	92	124.08	105.34
MVPA	107	200.05	195.09	77	232.21	165.57	59	264.15	162.37	76	231.32	165.10	92	224.35	177.73
IA	107	16.73	7.01	77	16.13	7.14	60	15.47	7.34	77	15.69	7.86	92	15.03	7.43
SA	107	12.26	6.19	76	10.97	6.04	60	10.73	6.10	78	11.18	6.80	92	11.14	5.50
MED	114	8.12	2.31	86	7.95	1.76	67	8.43	2.51	78	8.26	2.15	92	8.38	2.46
CFG	110	0.92	0.80	84	0.76	0.79	67	0.55	0.74	76	0.58	0.77	90	0.89	0.99
Fitness															
BMI	114	28.52	4.79	80	28.34	4.57	68	27.94	4.85	83	27.99	4.41	92	28.12	4.49
WC	114	98.50	12.34	77	98.11	12.46	62	96.55	12.21	78	96.78	12.06	86	96.58	11.34
6MWT	107	483.26	66.32	80	521.02	68.71	68	526.00	69.33	83	536.91	71.99	91	541.18	77.56
Cognition															
TMTA	115	33.95	8.85	86	31.40	8.66	72	31.60	10.67	80	29.59	8.68	93	28.64	7.90
TMTB	116	85.39	33.57	87	76.34	32.61	72	73.23	26.73	80	73.90	26.51	93	70.10	24.51
Category Fluency	117	18.91	5.01	88	19.49	5.11	72	20.53	5.25	80	20.09	5.30	94	19.91	4.51
Letter fluency	118	39.83	11.81	88	41.83	10.97	72	45.32	11.47	79	44.01	10.19	94	43.96	10.78
GMR	118	8.71	3.66	87	8.46	3.79	71	8.27	4.35	79	7.72	3.70	92	7.13	3.49
GML	118	64.23	18.49	87	57.39	15.71	71	52.42	16.96	79	54.19	14.62	92	53.21	20.61
ISL	118	23.68	4.20	87	23.94	4.60	71	24.25	4.72	79	24.43	4.81	92	24.96	4.83
ISLR	116	8.39	2.29	87	8.55	2.30	71	8.52	2.39	79	8.56	2.35	92	8.63	2.32
ONB	118	1.21	0.13	87	1.28	0.13	71	1.33	0.15	79	1.32	0.14	92	1.35	0.16
TWOB	118	1.16	0.15	86	1.16	0.14	71	1.17	0.13	78	1.19	0.12	91	1.21	0.15

Note: GLTQ = modified Godin Leisure Time Questionnaire; CHAMPS = Community Healthy Activities Model Program for Seniors Physical Activity Questionnaire, MVPA = moderate to vigorous physical activity, IA = intellectually stimulating activities, SA = social activities, MED = Mediterranean diet screen (total score out of 16), CFG – Canada's Food Guide screen (total score out of 4) WC=waist circumference (centimeters), 6MWT = 6 minute walk test, BMI = body mass index, TMTA and TMTB = Trail Making Test A and B, GML and GMR = Groton Maze Learning and Delayed Recall, ISL and ISLR = International Shopping List Learning and Delayed Recall, ONB and TWOB = One Back and Two Back tasks

Table 10. Intercept-Only Models for Physical Activity and Walking Outcomes

	SD	Variance	*df*	χ^2	*p*	ICC
MVW-GLTQ						
intercept, r_0	43.308	1875.624	115	246.090	<0.001	0.236
level-1, *e*	77.995	6083.145				
MVW– CHAMPS PAQ						
intercept, r_0	51.620	2664.592	110	268.506	<0.001	0.277
level-1, *e*	83.313	6941.051				
MVPA						
intercept, r_0	122.781	15075.095	110	461.4892	<0.001	0.473
level-1, *e*	129.628	16803.483				

Note: GLTQ = modified Godin Leisure Time Questionnaire; CHAMPS = Community Healthy Activities Model Program for Seniors Physical Activity Questionnaire, MV=moderate to vigorous, PA = physical activity, MVPA = moderate to vigorous physical activity. Attendance represents the weekly group walks attended. Values for all other PA and walking measures are reported in minutes/week; SD = standard deviation, df = degrees of freedom, ICC = intraclass correlation coefficient.

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Table 11. Intercept-Only Models for Cognitive Outcomes

		SD	Variance	*df*	χ^2	*p*	ICC
Category Fluency							
	intercept, r_0	3.839	14.737	117	778.624	<0.001	0.590
	level-1, *e*	3.199	10.234				
Letter Fluency							
	intercept, r_0	9.950	99.010	117	1484.311	<0.001	0.760
	level-1, *e*	5.599	31.344				
Trail making test A							
	intercept, r_0	6.749	45.549	117	640.063	<0.001	0.544
	level-1, *e*	6.175	38.135				
Trail making test B							
	intercept, r_0	22.687	514.705	117	732.881	<0.001	0.579
	level-1, *e*	19.356	374.649				
Maze learning							
	intercept, r_0	12.251	150.080	117	484.050	<0.001	0.454
	level-1, *e*	13.446	180.807				
Maze recall							
	intercept, r_0	2.377	5.650	117	412.825	<0.001	0.394
	level-1, *e*	2.948	8.693				
List learning							
	intercept, r_0	3.600	12.957	117	956.302	<0.001	0.638
	level-1, *e*	2.712	7.352				
List recall							
	intercept, r_0	1.800	3.239	109	931.435	<0.001	0.648
	level-1, *e*	1.327	1.762				
One Back							
	intercept, r_0	0.070	0.005	117	245.262	<0.001	0.218
	level-1, *e*	0.132	0.017				
Two Back							
	intercept, r_0	0.092	0.008	106	417.792	<0.001	0.417
	level-1, *e*	0.108	0.012				

Notes: SD = standard deviation, df = degrees of freedom, ICC = intraclass correlation coefficient

Table 12.Time-varying Covariation Models: Change in Cognition as a Function of Time and Level 1 and Level 2 Person Mean PA and other level 2 predictors

	Coefficient	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*
Letter Fluency										
Intercept, γ_{00}	43.467	2.326	18.687	97	<0.001	0.210	0.041	5.176	279	<0.001
Age, γ_{01}	-0.246	0.302	-0.816	97	0.417	0.008	0.002	3.301	279	0.001
Education, γ_{02}	3.199	3.656	0.875	97	0.384					
Family history of dementia, γ_{03}	-3.241	3.821	-0.848	97	0.398					
Family history of other cognitive impairment, γ_{04}	3.546	3.080	1.151	97	0.252					
Cardiovascular risk, γ_{05}	-0.590	0.886	-0.666	97	0.507					
Mild life physical activity γ_{06}	0.225	0.270	0.832	97	0.407					
PM MVPA, γ_{07}	-0.011	0.009	-1.604	97	0.112					
Intercept, γ_{00}	41.307	2.276	18.148	96	<0.001	0.148	0.047	3.141	290	0.002
Age, γ_{01}	-0.135	0.301	-0.45	96	0.654	0.011	0.005	2.312	290	0.021
Education, γ_{02}	2.862	3.681	0.778	96	0.439					
Family history of dementia, γ_{03}	-2.256	3.838	-0.588	96	0.558					
Family history of other cognitive impairment, γ_{04}	2.940	3.090	0.951	96	0.344					
Cardiovascular risk, γ_{05}	-0.543	0.883	-0.615	96	0.54					
Mild life physical activity γ_{06}	0.188	0.278	0.676	96	0.501					
MVW GLTQ, γ_{07}	0.003	0.0169	0.179	96	0.859					
Intercept, γ_{00}	42.540	2.190	19.422	97	<0.001	0.173	0.043	4.01	281	<0.001
Age, γ_{01}	-0.159	0.301	-0.529	97	0.598	0.013	0.004	3.229	281	0.001

	Coefficient	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*
Education, γ_{02}	2.862	3.691	0.775	97	0.44					
Family history of dementia, γ_{03}	-2.371	3.866	-0.613	97	0.541					
Family history of other cognitive impairment, γ_{04}	3.537	3.114	1.136	97	0.259					
Cardiovascular risk, γ_{05}	-0.339	0.890	-0.381	97	0.704					
Mild life physical activity γ_{06}	0.177	0.273	0.65	97	0.517					
MVW CHAMPS PAQ, γ_{07}	-0.014	0.015	-1.002	97	0.319					
Trail Making Test A										
Intercept, γ_{00}	33.232	1.601	20.759	97	<0.001	-0.284	0.047	-6.037	104	<0.001
Age, γ_{01}	0.001	0.213	0.003	97	0.997	0.010	0.005	2.201	104	0.03
Education, γ_{02}	1.413	2.602	0.543	97	0.588					
Family history of dementia, γ_{03}	1.083	2.733	0.396	97	0.693					
Family history of other cognitive impairment, γ_{04}	-2.104	2.198	-0.957	97	0.341					
Cardiovascular risk, γ_{05}	0.047	0.632	0.074	97	0.941					
Mild life physical activity γ_{06}	-0.219	0.194	-1.129	97	0.262					
MVW CHAMPS PAQ, γ_{07}	-0.003	0.010	-0.284	97	0.777					
Trails Making Test B										
Intercept, γ_{00}	75.959	5.564	13.652	97	<0.001	-0.751	0.148	-5.074	104	<0.001
Age, γ_{01}	0.8199	0.661	1.240	97	0.218	-0.022	0.009	-2.477	104	0.015
Education, γ_{02}	-9.114	8.036	-1.134	97	0.260					
Family history of dementia, γ_{03}	14.567	8.463	1.721	97	0.088					
Family history of other cognitive impairment, γ_{04}	-2.545	6.859	-0.371	97	0.711					
Cardiovascular risk, γ_{05}	-0.668	1.964	-0.340	97	0.735					

	Coefficient	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*
Mild life physical activity γ_{06}	-0.821	0.608	-1.350	97	0.180					
PM MVPA, γ_{07}	0.012	0.015	0.763	97	0.447					
Trails Making Test B										
Intercept, γ_{00}	80.748	5.223	15.459	97	<0.001	-0.670	0.157	-4.259	104	<0.001
Age, γ_{01}	0.662	0.648	1.022	97	0.309	-0.026	0.014	-1.94	174	0.054
Education, γ_{02}	-8.675	7.966	-1.089	97	0.279					
Family history of dementia, γ_{03}	13.921	8.405	1.656	97	0.101					
Family history of other cognitive impairment, γ_{04}	-1.579	6.821	-0.232	97	0.817					
Cardiovascular risk, γ_{05}	-0.867	1.943	-0.446	97	0.656					
Mild life physical activity, γ_{06}	-0.789	0.602	-1.31	97	0.193					
MVW CHAMPS PAQ, γ_{07}	-0.028	0.032	-0.88	97	0.381					

Notes: coefficients reflect number of words generated (Letter fluency) or time to completion in seconds (Trail Making Test A and B), where more words generated and less time to completion, reflects better cognitive performance; γ_{00} = average performance on a given cognitive measure at week =0 for the grand mean of MVW (minutes/week); γ_{01} = average difference in performance on a given cognitive measure for every additional year above the grand mean age of the overall sample at baseline, holding all other variables constant; γ_{02} = average difference in performance on a given cognitive measure for a change in education from less than a Bachelor's degree to a Bachelor's degree (or more), holding all other variables constant; γ_{03} = average difference in performance on a given cognitive measure for a change from no history of dementia in the family to a history of dementia in at least 1 family member, holding all other variables constant; γ_{04} = average difference in performance on a given cognitive measure for a change from no history of other serious cognitive impairment in the family to a history of other serious cognitive impairment in at least 1 family member, holding all other variables constant; γ_{05} =average difference in performance on a given cognitive measure for every additional cardiovascular risk factor above the grand mean cardiovascular risk of the overall sample at baseline, holding all other variables constant; γ_{06} = average difference in performance on a given cognitive measure for each additional leisure time PA participated in during midlife (including only those activities engaged in 10 or more times) above the grand mean midlife PA of the overall sample, holding all other variables constant; γ_{07} =, the between person (person mean) effect of MVW on cognitive performance; γ_{10} = the effect of time on a cognitive measure (uncentered); γ_{20} = the within person (person mean) effect of MVW on a given cognitive measure

Table 13. Intercept Only Models for Other Health Behaviours

		SD	Variance	*df*	χ^2	*p*-value	ICC
CFG							
	INTRCPT1, r_0	0.450	0.203	116	291.555	<0.001	0.291
	level-1, *e*	0.703	0.495				
MED							
	INTRCPT1, r_0	1.593	2.537	116	601.180	<0.001	0.516
	level-1, *e*	1.543	2.381				
IA							
	INTRCPT1, r_0	5.849	34.207	110	944.699	<0.001	0.658
	level-1, *e*	4.218	17.790				
SA							
	INTRCPT1, r_0	4.734	22.409	110	739.014	<0.001	0.601
	level-1, *e*	3.853	14.849				

Note: CFG= Canada's food guide screen (total score out of 4), MED = Mediterranean diet screen (score out of 16), IA = intellectually stimulating activities (hours/week), and SA = socially engaging activities (hours/week); df = degrees of freedom, ICC = intraclass correlation coefficient

Table 14. Intercept-Only Models for Fitness Outcomes

Variables	SD	Variance	*df*	χ^2	*p*-value	ICC
6MWT						
intercept, r_0	62.687	3929.691	112	1227.991	<0.001	0.280
level-1, *e*	39.050	1524.933				
WC						
intercept, r_0	12.003	144.063	114	19477.566	<0.001	0.021
level-1, *e*	1.752	3.068				
BMI						
intercept, r_0	4.612	21.270	114	15198.790	<0.001	0.027
level-1, *e*	0.775	0.600				

Note: BMI = body mass index (kilograms/meters^2, WC=waist circumference (centimeters), 6MWT = 6 minute walk test (meters), SD = standard deviation, df = degrees of freedom, ICC = intraclass correlation coefficient

Table 15. Change in Other Fitness as a Function of Time in the Walking Program

Variables	Parameter	Coefficient	SE	t-ratio	*df*	p	r^2
Fitness							
6MWT	Intercept, γ_{00}	522.385	6.453	80.952	112	<0.001	0.413
	Slope, γ_{10}	2.622	0.282	9.286	112	<0.001	
	Slope, γ_{20}	-0.157	0.042	-3.779	112	<0.001	
BMI	Intercept, γ_{00}	28.389	0.438	64.748	114	<0.001	0.680
	Slope, γ_{10}	0.002	0.008	0.195	114	0.845	
	Slope, γ_{20}	0.002	0.001	1.689	114	0.094	
WC	Intercept, γ_{00}	97.643	1.134	86.069	114	<0.001	0.546
	Slope, γ_{10}	-0.052	0.019	-2.797	114	0.006	
	Slope, γ_{20}	0.005	0.002	3.206	114	0.002	

Notes: BMI = body mass index, WC = waist circumference, and 6MWT – six minute walk test. Fitness coefficients reflect meters walked in 6 minutes, BMI in kg/m2 and waist circumference in cm; γ_{00} = average performance on a given fitness measure at wave =9.18 weeks for the overall sample; γ_{01} = average rate of linear change in a given fitness measure per additional week in the study above the grand mean (9.18 weeks; time centered), holding all other variables constant; γ_{02} = average rate of quadratic change in a given fitness measure per additional week in the study above the grand mean (9.18 weeks; time centered and then squared), holding all other variables constant.

Table 16. Time-Varying Covariation Models: Change in Fitness Outcomes as a Function of Time and Level 1 and 2 Person Mean PA

Variables	Intercept, γ_{00}/ Coefficient, γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
MVW - GLTQ											
6MWT	470.670	9.773	48.162	105	<0.001	2.830	0.343	8.244	106	<0.001	0.425
	22.384	7.782	2.876	105	0.005	4.407	1.661	2.653	208	0.009	
WC	100.858	1.929	52.275	106	<0.001	-0.052	0.022	-2.433	107	0.017	0.623
	-2.531	1.527	-1.658	106	0.1	-0.164	0.069	-2.396	193	0.018	
MVW – CHAMPS											
6MWT	455.654	10.490	43.437	105	<0.001	2.362	0.275	8.597	280	<0.001	0.256
	0.385	0.085	4.541	105	<0.001	0.072	0.025	2.873	280	0.004	
WC	100.927	2.006	50.322	106	<0.001	-0.051	0.019	-2.705	107	0.008	0.472
	-0.026	0.016	-1.572	106	0.119	-0.001	0.001	-0.728	160	0.467	
MVPA - CHAMPS											
6MWT	459.930	11.125	41.343	105	<0.001	2.616	0.264	9.917	277	<0.001	0.240
	0.146	0.041	3.556	105	<0.001	0.026	0.016	1.632	277	0.104	
WC	97.579	2.092	46.649	106	<0.001	-0.056	0.018	-3.028	107	0.003	0.475
	0.004	0.008	0.480	106	0.632	0.000	0.000	0.348	107	0.728	

Notes: BMI = body mass index, WC = waist circumference, and 6MWT – six minute walk test. Fitness coefficients reflect meters walked in 6 minutes, BMI in kg/m2 and waist circumference in cm; γ_{00} = Average performance on a given fitness measure at week =0 for the grand mean of a given PA behaviour; γ_{01} = the between person (person mean) effect of PA on a given fitness measure, not controlling for weekly variation in that measure; γ_{10} = the effect of time on a given fitness measure (uncentered); γ_{20} = the within person (person mean) effect of PA on a given fitness measure

Chapter 3. Gait and Cognition Paper

Introduction

With the steady growth of the elderly population and the increased prevalence of chronic diseases, disability, and cognitive impairment in the elderly (Alzheimer's Association, 2014; Statistics Canada, 2010; Statistics Candada, 2014; National Institutes on Health, 2011), maintaining the cognitive and physical health, as well as, the quality of life of the older adult is an important public health and research agenda. Staying mobile, functioning independently, and living a disability-free life are key to maintaining quality of life throughout the lifespan (Brown & Flood, 2013; Paterson & Warburton, 2010). However, gait disturbances and cognitive impairment are highly prevalent among this segment of the population and can compromise both mobility and independent functioning to varying degrees. One of the most troubling consequences of both cognitive and gait impairments in older adults is falls and their related challenges (e.g., injury, hospitalization, health care costs, caregiver burden, morbidity, mortality, poor quality of life; Ambrose, Paul, & Hausdorff, 2013; Cesari et al., 2005; Holtzer, Wang, & Verghese, 2012; Liu, Chan, & Yan, 2014; Terroso, Rosa, Marques, & Simoes, 2014).

Older adults are at an increased risk of falls and the prevalence increases with increasing age (Amboni, Barone, & Hausdorff, 2013; Grundstrom, Guse, & Layde, 2012; Holtzer et al., 2012; Montero-Odasso, Verghese, Beauchet, & Hausdorff, 2012). Approximately 30 to 40% of the older adult population falls each year, and of those that fall, about 50% will be hospitalized (Ambrose et al., 2013; Liu et al., 2014; Terroso et al., 2014). Fall risk is multifactorial and among the older population certain groups have greater risk of falls (Ambrose et al., 2013; Deandrea et al., 2010; Terroso et al., 2014).

For example, both gait abnormalities and cognitive impairment (dementia and mild cognitive impairment) in the elderly have been identified as independent risks factors for falls (Amboni et al., 2013; Mirelman et al., 2012; Montero-Odasso, Verghese, et al., 2012). Although it was once thought that gait and mobility were largely unrelated to cognition, we are becoming increasingly aware that cognitive function makes a key contribution to gait-related fall risk in the elderly.

Literature Review:

In this body of literature, several lines of evidence are suggestive of a strong cognitive contribution to gait and associated fall risk, including:

1. Gait characteristics of healthy and cognitive impaired older adults (the context);
2. Changes in the cognitive demands of walking with aging (the problem);
3. Dual task paradigms (the evidence); and
4. Physical activity (PA) and cognition (a possible solution).

1. Gait characteristics of healthy and cognitive impaired older adults

Gait and cognitive disturbances are common in the elderly, as part of both the natural aging process and age-related disorders (e.g. dementia and other neurodegenerative diseases (Amboni et al., 2013; Borel & Alescio-Lautier, 2014; de Melo Coelho et al., 2013; Holtzer et al., 2012; Montero-Odasso, Verghese, et al., 2012; Parihar, Mahoney, & Verghese, 2013; Verghese et al., 2006). With normal aging, gait is characterized by slower cadence, decreased stride length and swing phase, and wider base of support compared to younger adults (Haworth, 2008; Wollesen & Voelcker-Rehage, 2014). Compared to healthy older adults, gait abnormalities (e.g., slower gait speed, shorter stride length, increased step frequency, stride time variability, postural sways,

poor ability to maintain stable stance during perturbations) are more frequently observed in older adults with dementia and mild cognitive impairment (Alexander & Hausdorff, 2008; Amboni et al., 2013; Beauchet, Allali, Launay, Herrmann, & Annweiler, 2013; de Melo Coelho et al., 2013; Hageman & Thomas, 2002; Montero-Odasso, Muir, & Speechley, 2012; Parihar et al., 2013; Verghese et al., 2002). Additional evidence also suggests that gait and cognitive impairments not only co-exist, but gait abnormalities can also precede cognitive decline by many years (Alexander & Hausdorff, 2008; Parihar et al., 2013).

Considerable research has also demonstrated a strong association between specific gait characteristics (e.g., gait speed, gait instability, stride time variability) and specific cognitive functions (e.g., executive function, attention, processing speed), cognitive impairment (e.g., mild cognitive impairment, dementia) and mortality (Beauchet, Allali, Launay, Herrmann, & Annweiler, 2013; Beauchet et al., 2012; Buracchio, Dodge, Howieson, Wasserman, & Kaye, 2010; Doi et al., 2014; Kearney, Harwood, Gladman, Lincoln, & Masud, 2013; Studenski et al., 2011; Verghese, Wang, Lipton, Holtzer, & Xue, 2007; Verlinden, van der Geest, Hofman, & Ikram, 2014). These characteristics have also been linked with other important indicators of health and well-being, including mobility disability and falls (Beauchet, 2008; Brach, Studenski, Perera, VanSwearingen, & Newman, 2007; Brach, Berlin, VanSwearingen, Newman, & Studenski, 2005; Hausdorff, Rios, & Edelberg, 2001).

2. Changes in the cognitive demands of walking with age

Control of locomotion and posture is largely automated. Walking has traditionally been viewed as an automated, over-learned, rhythmic movement that is “hard-wired” and

mainly controlled by subcortical and spinal systems of the nervous system (Allali et al., 2007; Dubost et al., 2006; Grubaugh & Rhea, 2013; Hausdorff, Yogev, Springer, Simon, & Giladi, 2005; Montero-Odasso, Muir, et al., 2012). However, research on the attentional demands of walking in older adults is challenging this idea. It may be that walking is a repetitive daily activity ingrained in us at an early age; yet for the elderly walking is similar to a complex motor task, even in "routine" walking (Hausdorff et al. 2005). Moreover, in everyday life, walking is more purposeful; individuals find themselves walking in complex environments where avoiding obstacles and multi-tasking (e.g., walking when talking, walking while talking on the phone, walking while recalling a shopping list, walking when carrying groceries) can put demands on higher cognitive function (executive functions and divided attention) and sensory systems. This is especially evident in older adults (Al-Yahya et al., 2011).

Purposeful locomotion involves widespread regions of the brain including cerebellum, basal ganglia, parietal and frontal cortices (Holtzer, Epstein, Mahoney, Izzetoglu, & Blumen, 2014). This has been confirmed by a recent review of neuroimaging data, which suggests that these areas are implicated in mobility outcomes (i.e., gait, balance, fall risk). The same review also found evidence of increased recruitment of prefrontal/frontal cortical regions under both imagined walking and in dual task walking (Holtzer et al., 2014). Walking successfully in a complex environment requires executive function, attention, visual spatial function, along with motor functions of the basal ganglia and cerebellum (Buracchio et al., 2010). As part of the natural aging process and in Alzheimer's disease and related dementias, older adults experience changes in some of the same areas. As such, it seems likely that gait impairments in the

elderly could be related to these cognitive processes and underlying neuropathology (Bridenbaugh & Kressig, 2011; Kearney et al., 2013; Montero-Odasso, Verghese, et al., 2012; Verghese & Holtzer, 2010). Deficits in attention and executive functioning have been proposed as the common link between gait disturbances, dementia, and subsequent fall risk.

3. Dual task paradigm

Until recently cognitive and gait disturbances were examined largely as separate entities; however, over the last decade their shared association has been studied extensively using variations of an experimental manipulation called the dual task paradigm. Dual task paradigms require individuals to walk while performing secondary cognitive or motor tasks in order to experimentally manipulate the attentional demands of walking (Holtzer et al., 2012; Wollesen & Voelcker-Rehage, 2014). The dual cost on gait, cognitive performance, or both is then examined. These dual task paradigms have generally demonstrated expected changes in gait parameters (e.g., decreased speed, decreased cadence, decreased stride length, increased stride time, and increase stride time variability) during dual tasks compared to single tasks with greater cognitive and/or motor interference (i.e., dual cost) being found in the elderly compared to younger adults (Al-Yahya et al., 2011; Beurskens & Bock, 2012; Dubost et al., 2006; Li, Abbud, Fraser, & DeMont, 2012; Wollesen & Voelcker-Rehage, 2014). As noted earlier, gait impairments are more severe in individuals with cognitive impairment and research also suggests that cognitively impaired individuals show greater impairment, in particular on stride time variability and gait speed, while dual task walking (Gilles Allali, van der Meulen, & Assal, 2010; Amboni et al., 2013; Beurskens & Bock, 2012). Moreover,

impairments in dual task walking are associated with greater fall risk (Ayers, Tow, Holtzer, & Verghese, 2014; Beachet et al., 2008; Hall, Echt, Wolf, & Rogers, 2011; Haworth, 2008).

4. Physical Activity (PA) and Cognition

A vast body of literature has accumulated suggesting that PA is beneficial for cognitive functioning, in particular executive functioning, in older adults (Colcombe & Kramer, 2003; Aarsland, Sardahaee, Anderssen, Ballard, & Alzheimer's, 2010; Carvalho, Rea, Parimon, & Cusack, 2014; Cumming, Tyedin, Churilov, Morris, & Bernhardt, 2012; Etnier et al., 1997; Farina, Rusted, & Tabet, 2014; Hamer & Chida, 2009; Heyn, Abreu, & Ottenbacher, 2004; Sofi et al., 2011). Effect sizes from meta-analyses of experimental designs have generally been small to moderate (ES=0.17 to 0.68), with larger estimates being reported for higher-order cognitive functions/executive functions (ES = 0.68; Colcombe & Kramer, 2003) and cognitively impaired samples (ES = 0.57; Heyn et al., 2004) compared to healthy older adults (ES = 0.23; Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008). For a more in depth description of this field the reader is directed to Appendix 1.

Literature describing fall risk, gait characteristics in the elderly population, gait control in purposeful locomotion, and dual task paradigms described above point to a strong cognitive contribution to gait and fall risk. In light of the research suggesting that aerobic exercise is beneficial to executive function, it seems plausible that aerobic PA, including moderate to vigorous walking, may also improve gait.

Intra-individual change: Separating between-person and within-person sources of variation

Longitudinal observational designs with repeated measurement waves are an optimal method to examine intra-individual changes in cognition and gait, both in the short- and long-term and to examine factors associated with changes. However, choice of models in such longitudinal analyses can obscure results (Hoffman & Stawski, 2009; Morrell, Brant, & Ferrucci, 2009; Thorvaldsson et al., 2012). Lifespan developmental researchers often employ multi-level models with time-varying predictors to achieve a greater understanding of the relations between variables over time. Yet, failure to separate constant between-person sources of variation from time-specific within-person sources of variation within these multilevel models has been identified as a source of bias and can lead to incorrect conclusions (Hoffman & Stawski, 2009).

Although the relations between gait and cognition are increasingly being recognized, to the best of the author's knowledge, the majority of this work is cross-sectional. There is a paucity of longitudinal studies examining changes in gait and cognitive performance and their relations in the elderly. Moreover, few studies combine multiple parameters related to cognitive health and falls (i.e., cognition, gait and PA). The need for longitudinal studies involving measures of: 1) real world PA and gait, 2) laboratory PA and gait, and 3) domain specific cognitive functions rather than global cognition has been highlighted in the literature (Bruce-Keller et al., 2012).

As with the cognition and PA literature (See Chapter 2 and Appendix 1), literature focusing on between-group differences cannot be generalized to the individual owing to intra-individual variability in gait and cognition. Studies that distinguish between both between-person sources of variation (e.g., individuals who had faster gait

speed on average compared to individuals who had slower gait speed on average) and within-person sources of variation (e.g., changes in gait speed relative to an individual's own gait speed) are needed to advance our understanding of gait and cognition in older adults. As such, the current study combined measures of real world PA, laboratory gait and fitness assessment (GAITRite, 6 minute walk test), cognition and the dual task paradigm to examine the relations between changes in PA, gait, fitness, and cognitive performance in older adults across five measurement waves of a four-month supervised walking program.

In the present investigation, the distinction between constant between-person sources of variation and time-specific within-person of variation in the relations between gait and cognition over a four-month walking program were examined. Secondary objectives were to examine relations between changes in PA and changes in gait. Greater understanding of these relations and both between- and within-person sources of variation in gait and PA is an important step in designing intervention strategies focused on improving cognition, gait and associated fall risk in the elderly. Additional analyses of the dynamic coupling of relations between gait and fitness were also examined. They were not part of primary research interest but are included in the additional files at the end of this chapter for interest.

Research Questions and Hypotheses

Multi-level models were used to test the dynamic coupling between changes in gait and changes in cognitive function over a four-month period. Research questions focused on the relations between changes in gait and changes in cognitive outcomes in older adults.

Primary Research Questions

1a-b. Over the four-month supervised walking program, did older adults exhibit significant longitudinal changes in gait (velocity and stride time variability in normal walking and dual task walking conditions) and cognitive outcomes (executive function, attention, working memory, and episodic memory)?

Hypothesis 1a: Significant improvements were expected across all cognitive measures. It was anticipated that these improvements would also occur at a decreasing rate over time.

Hypothesis 1b: Significant improvements were expected on both normal (condition 1) and dual task (condition 2) measures of gait velocity and stride time variability. It was anticipated that these improvements would also occur at a decreasing rate over time.

1c-d. If so, for gait and cognitive outcomes exhibiting significant longitudinal changes was there evidence of time-varying covariation? Specifically, do between-person and within-person changes in gait predict changes in cognitive outcomes?

Hypothesis 1c: It was expected that measures of executive function and attention, but not memory would share significant time-varying association with the dual task walking, but not normal walking.

Hypothesis 1d: Between-group effects of dual taking walking velocity and stride time variability (i.e., condition 2), but not normal walking (i.e., condition 1), on measures of executive function, attention and working memory were expected. In other words, older

adults with better cognitive performance on average would also perform better on average on dual task walking.

Secondary Research Questions

Q2a: Over the four-month supervised walking program, did older adults exhibit significant longitudinal changes in PA (self-reported moderate to vigorous walking (MVW), moderate to vigorous physical activity (MVPA))?

Hypothesis 2a: It is anticipated that there would be significant increases in both MVW and MVPA over the four-month walking program and that increases in MVW and MVPA would occur at a decreasing rate over time.

2b-c. If so, for gait and PA measures exhibiting significant longitudinal changes was there evidence of time-varying covariation? Did between-person and within-person effects of PA predict changes in gait measures?

Hypothesis 2b: Moreover, it was expected that changes in MVPA and MVW would share significant time-varying covariation with dual task walking (i.e., increases in MVPA and MVW compared to own mean levels would be significantly associated with improvements in velocity and stride time variability during dual task walking (condition 2) and reductions in the dual cost of walking and serial 7s on both velocity and stride time variability).

Hypothesis 2c: Not controlling for weekly variation in activity (MVW and MVPA), between-group differences were also expected on both normal and dual task walking (i.e., individuals who engaged in *more* MVW and MVPA *on average* would perform *better on average* on all gait measures).

Methods

The detailed study methods of *Healthy Bodies, Healthy Minds – A supervised walking program for older adults* are described previously (See Chapter 2: Main Study). The study involved a four-month walking program in which study participants were asked to attend weekly group walks and to complete a battery of gait and fitness and cognitive assessments at each of five measurement waves. The primary aim of the brief longitudinal study was to use multilevel modelling to examine the relations between changes in PA and changes in cognition over a four-month walking program in a group of inactive older adults. The current paper reports secondary aims of the overall study (i.e., to examine the relations between 1) changes in PA and changes in gait and 2) changes in gait and changes in cognition).

Participants and Procedures

Participants were a convenience sample of inactive older adults that that were recruited through the local media (See Appendix 3). Exclusionary criteria included a diagnosis of dementia by a physician or a score on the Telephone Interview for Cognitive Status (TICS) in the moderately to severely impaired range (i.e., < 28 out of 50), a history of significant head injury (defined as loss of consciousness for more than 5 min), other neurological or major medical illnesses (e.g., Parkinson's disease, heart disease, cancer), severe sensory impairment (e.g., difficulty reading newspaper-size print, difficulty

hearing a normal conversation), drug or alcohol abuse, current psychiatric diagnoses, psychotropic drug use, and lack of fluency in English. Individuals who were meeting the minimum national guidelines for PA for older adults were also excluded (e.g., reduced risk of chronic diseases, reduced all cause mortality fitness, prevention of weight gain; Warburton et al., 2010).

Flow of participants through the study is described previously (Chapter 2: Main Study). At baseline, these participants (n=118) ranged in age from 65 to 87 years of age (M= 72.81, SD = 5.24). The vast majority were Caucasian and had completed at least some university or college education. Eighty-eight percent of the sample reported that compared to other people their age, their health was "very good or good".

Exercise Intervention

All study participants were asked to attend at least three supervised walking groups per week for four months. Each walk began with a warm up and ended with a cool down and stretching. Duration and intensity increased gradually over the course of the walking program from 15 to 45 minutes or more of moderate intensity/brisk walking (not including warm up, cool down and stretching). Participants were also encouraged to walk or engage in other PA outside of the walking group in order to meet national guidelines of 150 minutes of moderate to vigorous PA per week.

Participants completed baseline and follow-up (6, 9, 12 and 16 weeks) assessments of 1) gait and fitness and 2) cognitive performance. Self-report measures of PA and walking were also administered at baseline and follow-up. Only measures relevant to the aims of the current paper are discussed next. Full details of the testing protocol and measures are described in Chapter 2.

Measures

Measures of Physical Activity, Walking and Other Health Behaviours

Self-reported MVPA and MVW were measured using the Community Healthy Activities Model Program for Seniors Physical Activity Questionnaire (CHAMPS PAQ; Stewart et al., 2001), a valid and reliable measure of physical activity in older adults (Cyarto, Marshall, Dickinson, & Brown, 2006; Giles & Marshall, 2009; Harada, Chiu, King, & Stewart, 2001; Pruitt et al., 2008). Self-reported MVW was also examined using a modified version of the Godin Leisure Time Exercise Questionnaire (GLTEQ; Godin, Jobin, & Bouillon, 1985; Godin, Jobin, & Bouillon, 1986), as has been done in previous walking studies (e.g., Blacklock, Rhodes, & Brown, 2006; Brown & Rhodes, 2006; Rhodes, Blanchard, Courneya, & Plotnikoff, 2009; Rhodes, Brown, & McIntyre, 2006; Rhodes, Courneya, Blanchard, & Plotnikoff, 2007; Rhodes, Murray, Temple, Tuokko, & Higgins, 2012a; Rhodes, Murray, Temple, Tuokko, & Higgins, 2012b). Outcome measures (i.e., MVPA, MVW) from these questionnaires were expressed in minutes per week. Further details of these measures are described elsewhere (See Chapter 2. Main Study).

Fitness and Gait Assessment

Fitness and gait were examined at the same appointment. First, a brief fitness assessment included measures of aerobic fitness and body composition. Aerobic fitness was assessed using a submaximal walk test, the 6-minute walk test. The 6 minute walk test is used primarily for those with respiratory disease and heart failure, but it is also appropriate for assessing aerobic capacity of healthy older adults and is easily administered with minimal equipment and training (Faktor et al., 2010). For the current study, a 30 meter course was marked out in the hallway and the participants were asked

to walk back and forth along the course as many times as possible. Resting (i.e., after 5 minutes seated) and post-testing (1, 3, and 5 minute) heart rate and blood pressure were also measured. The outcome measure was distance walked (meters) in the 6 minutes. Body mass index (kg/m^2) and waist circumference (cm; at the level of iliac crest) were also measured according to standard procedures (Canadian Society for Exercise Physiology, 2010; See Appendix 5).

Next, gait velocity (cm/s) and gait variability (stride time SD (ms)) was measured using the GAITrite system. The GAITRite system is a 20 foot portable pressure sensitive mat with sensors that are used to gather quantitative data about stride length, stride width, swing time, stance time, normalized velocity, cadence (step rate), and gait variability. Walking trials commenced five feet before the mat to account for initial acceleration and ended six feet from the end of the mat to account for deceleration. Participants completed two conditions (normal walking and dual task walking) of three trials each (back and forth, i.e., 6 passes) on the GAITRite mat. On each trial, participants were instructed to walk at a pace they were comfortable with, as quickly and as safely as possible.

1. Condition 1: Walk-only.
2. Condition 2: Walk + serial sevens. Participants walked across the gait mat while counting backwards by sevens (Luria, 1966; Smith, 1967).

Outcome measures included velocity (cm/s) and stride time variability (sd) in each condition. Dual cost of walking while counting back by 7s was calculated for both velocity and stride time variability (i.e., dual cost = condition 2 - condition 1/condition 1). Values closer to 0 reflect less dual cost.

Cognitive Measures.

The battery of cognitive measures consisted of 2 traditional paper and pencil tests and a brief battery of computerized tests, called CogState, designed for repeated administration with minimal practice effects (http://cogstate.com). The latter is a previously validated measure of cognitive change in multiple populations (healthy adults, older adults, MCI, early AD, concussions, and other forms of cognitive impairment (e.g., healthy adults, older adults, MCI, early AD, concussions, and other forms of cognitive impairment; Darby et al., 2011; Darby et al., 2012; Falleti, Maruff, Collie, & Darby, 2006; Fredrickson et al., 2010; Lim et al., 2013; Pietrzak et al., 2008). Tests were chosen to target executive function, attention, working memory, and episodic memory and are described in detail in Chapter 2 (Main Study). The battery included verbal fluency (category and letter), trail making test parts A and B, groton maze learning test (learning and delayed recall), international shopping list task (learning and delayed recall), and one back and two back tasks.

Data Analyzes

Hierarchical Linear Modeling (HLM; Raudenbush & Bryk, 2002) was used to examine the time-varying covariation of a) gait and cognitive outcomes and b) PA and gait measures (primary and secondary research questions). In addition, the time-varying covariation of gait and fitness was explored. These supplementary analyses are presented in Table 21 of the additional files at the end of this chapter.

HLM allowed for simultaneous assessment of the effects of within-person variation in predictor variables (level 1) and between-person differences in predictor variables (level 2) on gait and cognition. These models examined the average individual change across the 5 waves of measurement (fixed slope effects) and whether trajectories

of change varied across individuals (random slope coefficients). Multilevel models were fit using HLM 7.01 for Windows (Raudenbush, Bryk, Cheong, Fai, Congsdon, & du Toit, 2011).

First, intercept-only models (dependent measures and no predictors) were fit to examine if variance existed at level 1 and level 2 for each of the gait, cognitive outcomes, fitness, and PA measures (Equation 1: a - h).

Level 1:	Level 2
$Gait_{ij} = \beta_{0i} + e_{ij}$ (1a)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (1b)
$Cognition = \beta_{0i} + e_{ij}$ (1c)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (1d)
$PA_{ij} = \beta_{0i} + e_{ij}$ (1e)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (1f)
$Fitness_{ij} = \beta_{0i} + e_{ij}$ (1g)	$\beta_{0i} = \gamma_{00} + U_{0i}$ (1h)

We calculated an intraclass correlation coefficient (ICC) for each intercept-only model of gait, cognitive outcomes, fitness, and PA measures

($ICC = between - person\ variation/(between\ person\ variation + within - person\ variation)$.

Second, whether each of the measures displayed significant longitudinal change was tested using empty longitudinal models. Since adherence to exercise programs tends to decline over time (Biddle & Fuchs, 2009), models of change were fit by including both linear and quadratic time parameters (See equation 2a-p). The time parameters were grand mean centered to reduce multicollinearity (UCLA: Statistical Consulting Group, 2014). Specifically, performance for a given individual (i) at a given time (j) is a function of that individual's performance at the grand mean week since the start of the walking program (the intercept), plus his/her average individual linear and quadratic rates of change across weeks in the walking program (the slopes), plus an error term (e_{ij}).

Level 1: Level 2:

$$Gait_{ij} = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \text{ (2a)}$$

$$\beta_{0i} = \gamma_{00} + U_{0i} \text{ (2b)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (2c)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (2d)}$$

$$Cognition = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \text{ (2e)}$$

$$\beta_{0i} = \gamma_{00} + U_{0i} \text{ (2f)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (2g)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (2h)}$$

$$PA = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \text{ (2i)}$$

$$\beta_{0i} = \gamma_{00} + U_{0i} \text{ (2j)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (2k)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (2l)}$$

$$Fitness = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \text{ (2m)}$$

$$\beta_{0i} = \gamma_{00} + U_{0i} \text{ (2n)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (2o)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (2p)}$$

Third, for those measures that exhibit significant change, whether change in measures of interest travelled <u>together</u> across time in the walking program was examined (i.e., a) gait and cognition, b) PA and gait, and c) fitness and gait) by constructing "time-varying covariation models" (See Equation 3a-h). For example, Level 1 parameter estimates were person-mean centered (i.e., value at each week minus the individual's own mean level), such that level 1 parameter estimates represented the effect of variation around each individual's own mean levels in PA on gait measures (i.e., effect of WP; Hoffman & Stawski, 2009). The level 2 parameter estimates represented the effect of between-person differences in the PA on gait measures (i.e., effect of PM). Only a linear time parameter (centered at 0) was entered in the model due to lack of sufficient waves for inclusion of the quadratic term from equation 2. The time-varying models of a) gait and cognition and b) gait and fitness were constructed in an identical fashion.

Level 1: Level 2:

$$Gait = \beta_{0i} + \beta_{1i}(Time\ ) + \beta_{2i}\ (Weekly\ PA\ - PM\ PA) + e_{ij}\ (3a)$$

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(PM\ PA) + U_{0i} \text{ (3b)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (3c)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (3d)}$$

$$Gait = \beta_{0i} + \beta_{1i}(Time\ ) + \beta_{2i}\ (Weekly\ Fitness\ - PM\ Fitness) + e_{ij}\ (3e)$$

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(PM\ Fitness) + U_{0i} \text{ (3f)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (3g)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (3h)}$$

$$Cognition = \beta_{0i} + \beta_{1i}(Time) + \beta_{2i}(Weekly\ Gait\ - PM\ Gait) + e_{ij}\ (3i)$$

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(PM\ Gait) + U_{0i} \text{ (3j)}$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \text{ (3k)}$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \text{ (3l)}$$

The above 3a-d equations assume gait at any given week will depend upon the number of weeks since entering the walking program (β_{1i}), the effect of WP PA (β_{2i}), as well as person-specific residuals (e_{ij}). The γ_{00} intercept represents mean performance on a given gait measure at baseline and when all other predictor variables (level 1 WP and level 2 PM PA) are set at zero. The γ_{10} slope parameter in these models reflects rate of linear change in gait across weeks, independent of the effects of 1) WP PA and 2) PM PA; whereas, the γ_{20} slope parameter assesses whether higher (or lower) WP PA at a given week is linked to higher (or lower) gait outcomes, independent of the effect of time and PM PA. The γ_{20} parameter has been person-mean centered and represents the *pure* WP effect of weekly physical activity on gait outcomes. The γ_{01} parameter represents the between-person effect of PA on gait, not controlling for the effect of time and WP gait at any given week. Equations 3e-h and 3i-l can be interpreted in a similar manner.

Results

Primary and Secondary Research Questions

Step 1: Identifying % of variance that is between- vs. within-person

The HLM analyses were conducted in three steps. First, to examine if variance existed at level 1 and level 2, intercept only models were run for each of the gait, fitness, cognitive outcomes, and physical activity measures (See equations 1 a-d). Results of these preliminary analyses are summarized in the additional files at the end of Chapter 2 and 3 (Tables 10-11 and 20). The intercept-only models for gait revealed ICCs ranging from 0.360 on dual cost velocity to 0.791 for velocity condition 1, suggesting that 36.0 percent of the variance in the dual cost of walking and counting backwards by 7s on velocity was at the group level, while 64.0 percent was at the individual level. While, 79.1 percent of the variance in velocity condition 1 was at the group level and 20.9 was at

the individual level. ICCs for the intercept-only models ranged from 0.021 to 0.280 for fitness, 0.59 to 0.76 for cognition, and 0.236 to 0.473 for PA.

Step 2: Empty Longitudinal Models of Change

Next, whether PA, gait, cognitive and fitness measures exhibited significant longitudinal change was examined by fitting longitudinal models of change with linear and quadratic time parameters. Results of these analyses are summarized in Table 17. Significant longitudinal change was also observed for both measures of walking. Specifically, for each additional week in the walking program over the grand mean, self-reported minutes of weekly MVW increased significantly ($p<.001$). In line with our expectations, with each additional week in the walking program, increases in MVW occurred at a decreasing rate ($p<.001$). Effect sizes were moderate to strong ($r^2 = 0.281$ and 0.660). Increases in MVPA with each additional week in the program were modest and non-significant ($p >.05$), and for each additional week in the program improvements in MVPA occurred at a decreasing rate ($p<.05$, $r^2=0.213$).

Significant longitudinal change was observed for all measures of gait. Specifically, for each additional week in the walking program above the grand mean, velocity during normal (condition 1) and dual task walking (condition 2) increased significantly ($p<.001$), and increases in velocity in both conditions occurred at a decreasing rate over time ($p<.001$). Meanwhile, with each additional week in the walking program above the grand mean, stride time variability during normal (condition 1) and dual task walking (condition 2) decreased significantly ($p=0.009$ and $p<.001$). Moreover, with each additional week in the program, improvements (i.e., decreases) in stride time variability during dual task walking, but not normal walking, occurred at a decreasing

rate (p<.001). The dual cost of walking and serial 7s on both velocity and stride time variability also improved with each additional week in the walking program (both p<.001) and these improvements occurred at a decreasing rate over time (p=.001 and p<.001). Effect sizes for the effect of time across the gait measures were strong for velocity (r^2=0.627 to 0.700) and moderate to strong for stride time variability (r^2 =0.333 to 0.740).

Significant improvements were also exhibited across all (p < .001), but one measure of cognitive performance. With each additional week in the walking program above the grand mean, participants had significantly better performance on all cognitive measures (p < 0.001), except list recall (p=0.183). Moreover, improvements in category fluency, letter fluency, maze learning, and the one back task occurred at a decreasing rate with each additional week in the walking program above the grand mean (p=.002 to p<.001). The effect sizes for the effect of time on cognitive measures were generally small to moderate (r^2 =0.020 to r^2= 0.304).

Step 3: Time-Varying Covariation Models with Level 1 and Level 2 Person Mean Centering

Next, for measures exhibiting significant longitudinal change (i.e., all cognitive, PA and gait measures, except list learning delayed recall) time-varying covariation model of a) gait and cognition and b) PA and gait were examined. These findings are summarized in Table 18 and described briefly below. For interest, the reader is directed to Table 21 in the additional files at the end of the current chapter for summaries of the time-varying covariation models of fitness and gait. Effects sizes for the within-person effect of time and gait and time and PA are presented in their respective sections.

Evidence of time-varying association of gait and cognitive measures was limited. Specifically, all, but two, within-person effects of gait on cognitive measures were non-significant (p>.05). There was a significant positive time-varying association between 1) increases in velocity during normal walking (condition 1) and accuracy on the one back task (p=0.013, r^2 = 0.183) and 2) reductions in the dual cost of walking and serial 7s on stride time variability and words generated on letter fluency (p=.034, r^2=0.258). Effect sizes were small to moderate.

The within-person effects of a) dual task walking stride time variability on errors made on the maze learning task (p=0.057, r^2=284), b) dual cost of walking and serial 7s stride time variability on errors on the maze learning task (p=.073, r^2=0.325), and c) dual task walking velocity and accuracy on the one back task (p=.096, r^2 = 0.176) all approached significance. Effect sizes (gait and time together) were small to moderate. As such, decreases in stride time variability and increases in velocity during dual task walking were associated with better cognitive performances on these measures. The positive within-person effects of stride time variability during normal walking on words generated on letter fluency and the negative within-person effect on time to complete trail making test A (p=0.061, r^2=0.137 and p=0.072, r^2=170) also approached significance. However, improvements in gait were associated with poorer performance on both cognitive measures.

In contrast to the limited within-person effects (i.e., time-varying covariation of gait and cognitive outcomes), significant between-person effects of person-mean gait on cognitive outcomes were more numerous. Velocity during normal walking had significant between-person effects on trail making test A (p<.001), trail making test B

(*p*=.029), maze-learning (*p*=.049), maze-learning delayed recall (*p*=0.023), and list learning (*p*=.051). Individuals who walked ***faster on average*** during normal walking took less time to complete trail making test A and B, made fewer total errors on maze learning trials 1-5 and delayed recall, and recalled more total words on list learning trials 1-3. Between-person effects on category fluency, letter fluency, the one back and two back tests were non-significant (*p*'s >.05).

Similarly, velocity during dual-task walking had significant between-person effects on 7 of 9 measures (i.e., category fluency (*p*=0.020), letter fluency (*p*=0.045), trail making test A (*p*<0.001), trail making test B (*p*<0.001), maze-learning (*p*=0.022), maze learning delayed recall (*p*=0.007), and the two back task (*p*=0.019)). Individuals who walked ***faster on average*** in condition 2 generated more words on category and letter fluency, took less time to complete trail making test A and B, made fewer total errors on maze learning trials 1-5 and delayed recall, and had better accuracy on the two back task. Positive effects of list learning and the one back task on dual task walking velocity approached significance (*p*=0.082 and *p*=0.069).

Meanwhile, stride time variability during normal walking had significant between-person effects on trail making test A (*p* =0.003), maze learning (*p*=0.020), maze learning delayed recall (*p*=0.017), list learning (*p* =0.028) and the two back task (*p*=0.010). Specifically, as stride time variability decreased *on average*, time to complete trail making test A, total errors made on maze learning trials 1 to 5 and delayed recall also decreased *on average*; while, words recalled on list learning and accuracy on the two back task increased *on average*. The negative between-person effects of stride time variability on category fluency (*p*=0.095) and the one back task (*p*=0.068) and the

positive-between person effect of stride time variability on trail making test B (p=0.083; improved gait and improved cognitive performance. The negative between-person effect of letter fluency on stride time variability during normal walking also approached significance (p=0.080; improved gait was associated with *poorer* cognitive performance on average).

In addition, stride time variability during dual task walking had significant between-person effects on trail making test b (p=0.008), maze learning (p=0.039) and the two back task (p=0.011), such that *decreases* in stride time variability *on average* were associated with decreases in time to complete the trail making test B, fewer total errors made on maze learning trials 1 to 5 and greater accuracy on the two back task. The positive between-person effects of trail making test A also approached significance (p=0.092; i.e., improvements in gait associated with improvements in cognitive performance).

Between-person effects of person-mean dual cost of walking on stride time variability were generally non-significant. There were significant between-person effects of 1) dual cost of walking velocity on accuracy on the two back task (p=.006), and 2) dual cost of walking velocity on trail making test B (p=.007). Individuals, who on average had lower dual costs of walking on gait velocity, performed better on average on both cognitive measures. The negative effect of dual cost of walking on stride time variability and letter fluency was also significant (p=0.014; lower dual cost associated with poorer performance).

PA and Gait

Independent of weeks in the walking program, there was some evidence of time-varying association between PA (MVW and MVPA) and gait. Specifically, consistent significant within-person effects of MVW and MVPA on velocity (MVW GLTQ, MVW CHAMPS and MVPA: *p*'s all <.001) and stride time variability (i.e., stride time SD) during dual task walking (MVW GLTQ: *p*=<.001, MVW CHAMPS *p*=.002, CHAMPS MVPA: *p*=.052) were observed. The significant within-person effect of 0.038 indicates that for every minute per week *more than usual* of MVW GLTQ, an individual walks 0.038 *cm/second faster than usual* in condition 2. In contrast, within-person effects of MVW and MVPA on velocity and stride time variability during *normal walking* were generally non-significant (*p*'s all >.05, except on GLTQ MVW: *p*<.001).

Within-person effects of MVW and MVPA on dual costs were limited and mixed. Significant within-person effects of MVW on the dual cost of walking velocity (GLTQ; CHAMPS MVW *p*>.05, CHAMPS MVW: *p*=.008) and stride time variability (GTLQ MV: *p*=.016, CHAMPS MVW *p*>.05) were also found on some, but not all measures. Within-person effects of MVPA on the dual cost of walking gait velocity (*p*>.05) and stride time variability (*p*>.05) were non-significant.

In addition, there were consistent significant positive between-person effects of person-mean MVW (GLTQ: *p*=0.033 and CHAMPS: *p*=.024), but not MVPA (*p*>.05) on velocity during dual task walking, not controlling for daily variation in MVW and MVPA. There were consistent between-person effects of MVW (both MVW GLTQ and MVW CHAMPS *p*'s both <.001)) and MVPA (*p*=.005) on velocity during normal walking. Person-mean MVPA and MVW did not significantly effect stride time variability during either normal or dual task walking conditions (*p*>.05). Between-person

effects of MVW and MVPA on the dual cost of walking on both velocity and stride time variability were also non-significant (*p*'s all>.05).

Discussion

Primary Research Questions

This study was undertaken to explore the dynamic relations between changes in gait (normal walking and dual task walking) and changes in cognitive function (executive function, attention, working memory, and episodic memory) in a sample of older adults participating in a four-month supervised walking program. Using time-varying covariation models, separate between-person (differences in person-mean gait between individuals) and within-person sources of variation (changes in gait relative to an individual's *own* mean levels) in gait on cognitive functioning were examined in a sample of inactive older adults. It was hypothesized that participants would exhibit significant improvements in both cognitive measures and normal and dual task walking (*Hypothesis 1a and Hypothesis 1b*) and that dual tasking walking would share time varying-association with measures of executive function, attention, and working memory, but not episodic memory (*Hypothesis 1c*). It was also expected that participants with better person-mean dual task walking, but not normal walking, would have better performance on average on measures of executive function, attention and working memory (*Hypothesis 1d*).

Primary hypotheses had substantial support. First, significant improvements in all gait measures were observed across waves in the walking program. Improvements in gait generally occurred at a decreasing rate over time in the program (all but stride time variability condition 1; i.e., 3 of 4 gait measures). Second, in line with expectations, with each additional week in the walking program, there were significant consistent linear

improvements in cognitive functioning across weeks (all cognitive measures, except list recall). Second, improvements in select measures of cognitive performance, especially executive function and working memory measures (both fluency measures, maze learning, and one back task) displayed parallel patterns as gait (i.e., improvements in these measures occurred at a decreasing rate over time, in line with poorer adherence to the walking program over time). Third, the dual cost of walking (i.e., dual cost = dual task- single task/single task) displayed similar patterns, which in itself is suggestive of a link between gait and executive function, attention and working memory (i.e., the cognitive load of the secondary task was reduced with each additional week in the program).

To further test this notion, time-varying covariation models were fit to examine both within-sources (*Hypothesis 1c*) and between-sources (*Hypothesis 1d*) of variation in gait on cognitive function. Different patterns were seen across the two sources of variation. Although only two of the time-varying covariation models of gait and cognitive function were significant (i.e., normal walking velocity and working memory, reduction in dual cost walking on stride time variability and verbal fluency), there was additional support for hypotheses that dual task walking in particular would share time-varying association with measures of executive function, attention and working memory. Within-person effects of stride time variability on maze learning errors (executive functioning, error monitoring, spatial working memory) approached significance and together with time accounted for about 28% to 33% of the variability in errors made on maze learning. These patterns were in the expected direction, such that improvements in gait relative to one's own mean levels were related to better cognitive performance. In line with

expectations, time-varying covariation models of gait and episodic memory were non-significant. Further, of the limited time-varying models that were significant or approached significance, within-person effects were larger for dual task walking compared to normal walking.

Consistent and significant between-person effects of dual task walking velocity on cognitive measures (fluency, attention, speed of processing and mental flexibility, executive function, spatial working memory and working memory) were observed. Between-person effects of normal walking on cognitive measures were numerous, as well (attention, speed of processing and mental flexibility, executive function, spatial working memory, episodic memory). The effects were in the expected direction, such that, individuals who walked faster on average, also performed better on average on the cognitive measures. Individuals who walked faster on average in dual task walking, but not normal walking, also performed significantly better on average on measures of verbal fluency (letter and category) and working memory (i.e., two back task).

Compared to velocity findings, between-person effects of stride time variability measures were fewer under dual task conditions. Dual tasking stride time variability was associated with measures of executive function, working memory, and attention and mental flexibility (trail making test B, maze learning, two back task). Stride time-variability under normal walking conditions was associated with similar cognitive domains (trail making test A, maze learning, two back), with the addition of episodic memory (maze learning delayed recall, list learning).

Gait and Cognition

In summary, there was considerable evidence for between-group effects of dual task walking velocity and stride time variability on measures of executive function, attention and working memory. However, the association between executive function and gait was more widespread than anticipated (i.e., also extended to normal walking conditions). Interestingly, both velocity and stride time variability under normal walking conditions were associated with episodic memory (verbal and visual), contrary to expectations.

The between-group findings are consistent with previous work that has found that gait variability is inversely related to executive functioning and attention and that gait speed is positively related to executive functioning and attention across a wide spectrum of older adult populations (e.g., older adults, MCI, Alzheimer's disease, Parkinson's disease), especially during dual task walking (Alexander & Hausdorff, 2008; Amboni et al., 2013; Hausdorff, Schweiger, Herman, Yogev-Seligmann, & Giladi, 2008; Martin et al., 2013; Persad, Jones, Ashton-Miller, Alexander, & Giordani, 2008; Springer et al., 2006; van lersel, Kessels, Bloem, Verbeek, & Rikkert, 2008). Although the relations between memory and gait in the current study were unexpected, previous work has also found associations between gait characteristics and other cognitive domains including memory and visual spatial skills (Amboni et al., 2013).

Secondary Research Questions

Secondary objectives concerned the dynamic relations between changes in PA and changes gait over the four-month walking program. It was hypothesised that older adults would display significant increases in both MVPA and MVW and that these

changes would occur at a decreasing rate over time (*Hypothesis 2a*). Further, it was expected that changes in MVPA and MVW would share significant time-varying covariation with dual task walking, but not normal walking (Hypothesis 2b). Between-group differences of MVW and MVPA were also expected in both walking conditions (i.e., individuals who engaged in *more* MVW and MVPA on average would perform on average significantly *better* on all gait measures).

Findings generally supported these hypotheses. First, in line with expectations (Hypothesis 2a), participants increased their minutes of MVW over time and these increases occurred at a decreasing rate over time. Linear increases in MVPA were modest and non-significant, while increases in MVPA decreased significantly over time. Meanwhile, all measures of gait improved significantly across weeks in the program and generally displayed the same pattern as MVW (i.e., 3 of 4 gait measures, both dual cost measures). These findings are suggestive of a significant association between PA, especially MVW, and measures of executive function, attention and working memory in older adults.

Again, a more stringent test of the association between changes in MVW and MVPA and gait measures was conducted. Hypothesis 2b was partially confirmed. Changes in dual task stride time variability, but not normal walking, shared significant time-varying association with changes in MVW (both measures) and MVPA. However, within-person effects of MVW and MVPA on velocity were more widespread than anticipated (e.g., 5 of 6 comparisons). Effect sizes were moderate to strong, with stronger effects of dual task measures on cognitive performance. Time-varying association of dual

cost on velocity and dual cost on stride time variability were minimal (dual cost stride time variability and MVW GLTQ, dual cost velocity and MVW CHAMPS).

Hypotheses regarding between-person effects of person-mean MVPA and MVW on gait were generally confirmed for velocity (5 of 6 comparisons), but not stride time variability and dual cost measures. Individuals who engaged in more MVW and more MVPA walked significantly faster on average in both conditions.

Gait and PA

In summary, the present study provides encouraging evidence regarding the benefits of MVW and MVPA on gait speed and variability in older adults. Walking had consistent and expected between- and within-person effects on gait velocity during normal and dual walking conditions; while, walking had significant within-person effects on stride time variability in dual task walking only. In line with present findings, there is some evidence from recent work that PA can benefit gait in older adults (Doi et al., 2013; Gine-Garriga, Roque-Figuls, Coll-Planas, Sitja-Rabert, & Salva, 2014; Gobbo, Bergamin, Sieverdes, Ermolao, & Zaccaria, 2014; Wollesen & Voelcker-Rehage, 2014). However, this body of work is limited and findings are mixed. Much of the research in this area focuses on the effects of multi-component (balance and resistance training) or dual task training on gait and balance.

Methodological Considerations

Using a brief single group longitudinal design and five waves of measurement, the current study provided interesting insight into the complex relations between changes in gait, cognition, and PA over a four-month program. The findings highlight the importance of distinguishing between-person and within-person sources of variation

when fitting time-varying covariation models. A distinctly different pattern of results was seen across the two sources of variation.

The study employed carefully selected hypothesis driven tests and multiple measures of executive function, attention and working memory to examine the relations between changes in gait, PA and cognition. Moreover, the assessment included a brief battery of computerized measures that were designed specifically for repeated administration with minimal practice effects, in combination with traditional paper and pencil tests of executive functioning. Alternate forms were used to minimize practice effects.

The findings of current investigation should be interpreted within the context of several limitations. First, as noted in the methodological limitations of chapter 2, study sample size was modest due to missing data and drop out (See Figure 1). Second, the study relied on self-report measures to gather information about our participants' PA levels. Although these measures can be easily administered to large groups and place relatively low burden on the participant, they are prone to over- and under- reporting (e.g., difficulties with recall, social desirability and misinterpretation; Kowalski, Rhodes, Naylor, Tuokko, & MacDonald, 2012). To combat some of these issues, several measures of walking and PA were gathered and consistency across measures was examined. Changes in walking and PA behaviour across time in the walking program exhibited the similar patterns across the three measures of behaviour (i.e., minutes/week of MVW was significantly higher with each additional week in the walking program and improvements occurred at a decreasing rate over time, improvements in MVPA with each additional week in the walking program were modest and non-significant and occurred at a

decreasing rate over time). Moreover, consistent widespread within- and between-person effects of PA on gait were observed and these findings were confirmed across measures of PA.

Third, models were confined to five waves of measurement, which put constraints on the time-varying covariation models. Since these types of models are computationally intensive, time-varying covariation models were fit with only the linear effects of time, despite most of variables displaying both significant linear and quadratic effects. It also could be criticized that in the present paper, only the dual cost of walking on gait and not the dual cost on the secondary task (i.e., serial sevens), was examined. Study participants were audio and video-recorded and the secondary task results (serial 7s) are in preparation for a future publication. Participants were encouraged to place equal effort on both tasks, and audio and video recordings provided confirmation that participants were following this instruction and to check any ambiguities during gait data processing.

Future Directions

Although the results point to strong interrelations between gait, cognition and PA, the current study did not examine the impact of physical activity on the relations between gait and cognition. Future work should examine whether PA moderates the effect between- and within-person effect of PA on cognition.

An important next step will be to measure PA objectively using accelerometry to more accurately examine the relations between gait, PA and cognitive function. Accelerometers are an excellent measure for study in gait and PA research since they can provide data on both real-world PA and gait. The current study used a laboratory assessment of gait; however, as has been suggested by others (e.g., Bruce-Keller et al.,

2012), future work should employ multiple measures of gait analysis in both laboratory and real-world conditions. While gait analysis in a laboratory provides a controlled opportunity to examine gait and cognition relations and fall risk, accelerometry is more generalizable to the real world.

Given our modest sample and a number of results approaching significance (small to moderate effects sizes), similar analyses of within-person effects of velocity and stride time variability under dual and normal walking conditions on cognitive function with a larger sample and longer follow-up and additional waves of measurement may provide additional insight into the complex relations between gait and cognitive function.

In light of the accumulating evidence of the benefits of walking to cognitive function in older adults (Abbott et al., 2004; Dustman et al., 1984; Kramer et al., 1999{Colcombe, 2004 #24; Weuve et al., 2004) and the cognitive contributions to gait control (Al-Yahya et al., 2011; Amboni et al., 2013; Parihar et al., 2013), it has been suggested that the reason walking might benefit cognitive function is through its relations with gait. Amboni et al. (2013) proposes that walking could be superior to other forms of PA because of it requires the 'coactivation and interfacing of multiple cognitive domains' involved in gait control. Findings from the present study are consistent with this idea, but further studies comparing walking with other forms of activity are needed.

The study results also point to an intriguing idea that mentally stimulating PA, in particular aerobic activity (i.e., walking while performing cognitive tasks/walking while engaging in stimulating activity), and multi-modal intervention (i.e., combination of separate cognitive training and PA components within a single intervention) may be more beneficial than walking or other aerobic PA alone. There is accumulating evidence that

lifestyle interventions combining multiple lifestyle behaviours may be superior to interventions targeting single behaviours; however, to date the data is inconclusive (Agrigoroaei & Lachman, 2011; Carlson et al., 2009; de Andrade et al., 2013; de Melo Coelho et al., 2013; Hertzog, Kramer, Wilson, & Lindenberger, 2008; Thiel et al., 2012; Thom & Clare, 2011). Further methodologically rigorous research examining the types of PA, the combinations of activities, and in whom these activities confer the most benefit is sorely needed.

Summary

As evidenced by the findings of the main study (Chapter 2: Main Study), and extensive literature review (See Appendix 1), a growing body of evidence supports the link between PA and cognitive function, especially executive functioning, in older adults. Findings from the current study provide even stronger support for the cognitive contribution to gait characteristics in older adults. Moreover, PA had widespread within- and between-person effects on gait measures.

Further work is needed examining which types of PA and the optimal doses for improving cognitive functioning and gait in the elderly. A combination of well-designed larger sample prospective observational and RCT designs exploring both within-person and between-person effects of the complex relations between gait, cognition and PA in older adults, including research involving older adults across the continuum of healthy aging to dementia is needed to further our understanding. Greater understanding of the cognitive and PA contribution to gait and fall risk will be critical for developing PA and fall prevention programs for older adults.

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Results Tables and Figures

Table 17. Change in Gait, Cognition and PA as a Function of Time in the Walking Program.

Variables	Parameter	Coefficient	SE	t-ratio	*df*	p	r^2
Gait							
Velocity Condition 1	Intercept, γ_{00}	154.951	1.666	93.001	115	<0.001	0.627
	Slope, γ_{10}	0.508	0.073	6.995	115	<0.001	
	Slope, γ_{20}	-0.057	0.010	-5.662	115	<0.001	
Velocity Condition 2	Intercept, γ_{00}	138.441	1.868	74.130	115	<0.001	0.740
	Slope, γ_{10}	1.270	0.093	13.689	115	<0.001	
	Slope, γ_{20}	-0.079	0.010	-7.946	115	<0.001	
Dual Cost Velocity	Intercept, γ_{00}	-.108	0.007	-14.576	115	<0.001	0.685
	Slope, γ_{10}	0.005	0.453×10^{-3}	11.550	115	<0.001	
	Slope, γ_{20}	-0.180×10^{-3}	0.054×10^{-3}	-3.345	115	0.001	
Stride Time SD Condition 1	Intercept, γ_{00}	0.020	0.001	37.298	115	<0.001	0.333
	Slope, γ_{10}	-0.107×10^{-3}	0.040×10^{-3}	-2.646	115	0.009	
	Slope, γ_{20}	0.003×10^{-3}	0.006×10^{-3}	0.571	197	0.569	
Stride Time SD Condition 2	Intercept, γ_{00}	0.029	0.001	23.464	115	<0.001	0.700
	Slope, γ_{10}	-0.001	0.116×10^{-3}	-7.526	115	<0.001	
	Slope, γ_{20}	0.080×10^{-3}	0.013×10^{-3}	6.301	115	<0.001	
Dual Cost Stride Time SD	Intercept, γ_{00}	0.547	0.081	6.793	115	<0.001	0.728
	Slope, γ_{10}	-0.046	0.009	-4.878	115	<0.001	
	Slope, γ_{20}	0.005	0.001	3.719	115	<0.001	
Cognition							
Category Fluency	Intercept, γ_{00}	20.140	0.432	46.618	116	<0.001	0.040
	Slope, γ_{10}	0.073	0.023	3.232	330	0.001	
	Slope, γ_{20}	-0.007	0.004	-1.958	330	0.051	
Letter Fluency	Intercept, γ_{00}	43.421	0.997	43.536	116	<0.001	0.213
	Slope, γ_{10}	0.236	0.043	5.444	116	<0.001	
	Slope, γ_{20}	-0.016	0.006	-2.713	214	0.007	
Trail making test A	Intercept, γ_{00}	30.976	0.846	36.622	116	<0.001	0.304
	Slope, γ_{10}	-0.279	0.047	-5.975	116	<0.001	
	Slope, γ_{20}	0.004	0.007	0.550	116	0.583	
Trail making test B	Intercept, γ_{00}	75.006	2.500	30.002	116	<0.001	0.113

Variables	Parameter	Coefficient	SE	t-ratio	*df*	p	r^2
	Slope, γ_{10}	-0.832	0.133	-6.274	327	<0.001	
	Slope, γ_{20}	0.028	0.022	1.319	327	0.188	
Maze delayed recall	Intercept, γ_{00}	8.168	0.313	26.131	116	<0.001	0.063
	Slope, γ_{10}	-0.091	0.021	-4.432	327	<0.001	
	Slope, γ_{20}	-0.003	0.003	-0.908	327	0.364	
Maze learning	Intercept, γ_{00}	55.214	1.451	38.052	116	<0.001	0.274
	Slope, γ_{10}	-0.601	0.105	-5.706	116	<0.001	
	Slope, γ_{20}	0.039	0.014	2.805	211	0.006	
List learning	Intercept, γ_{00}	24.262	0.391	62.070	116	<0.001	0.155
	Slope, γ_{10}	0.071	0.022	3.193	116	0.002	
	Slope, γ_{20}	0.001	0.003	0.376	211	0.707	
List delayed recall	Intercept, γ_{00}	8.670	0.199	43.528	116	<0.001	0.104
	Slope, γ_{10}	0.014	0.011	1.338	116	0.183	
	Slope, γ_{20}	-0.002	0.002	-1.161	209	0.247	
One back	Intercept, γ_{00}	1.302	0.011	117.440	116	<0.001	0.173
	Slope, γ_{10}	0.007	0.001	8.533	327	<0.001	
	Slope, γ_{20}	-0.271×10^{-3}	0.140×10^{-3}	-1.939	327	0.053	
Two back	Intercept, γ_{00}	1.166	0.012	93.931	108	<0.001	0.020
	Slope, γ_{10}	0.003	0.001	3.270	303	0.001	
	Slope, γ_{20}	0.190×10^{-3}	0.131×10^{-3}	1.446	303	0.149	
PA							
MV Walking – GLTQ	Intercept, γ_{00}	135.807	8.128	16.708	114	<0.001	0.660
	Slope, γ_{10}	5.224	0.502	10.415	114	<0.001	
	Slope, γ_{20}	-0.718	0.083	-8.662	114	<0.001	
MVW CHAMPS PAQ	Intercept, γ_{00}	133.446	7.731	17.261	110	<0.001	0.281
	Slope, γ_{10}	3.805	0.604	6.298	110	<0.001	
	Slope, γ_{20}	-0.580	0.088	-6.582	191	<0.001	
MVPA	Intercept, γ_{00}	242.151	15.243	15.886	110	<0.001	0.213
	Slope, γ_{10}	1.013	1.144	0.886	110	0.378	
	Slope, γ_{20}	-0.362	0.147	-2.452	188	0.015	

Notes: Velocity 1 = velocity condition 1, velocity 2 = velocity condition 2, STSD 1 = stride time variability condition 1, STSD 2 = stride time variability condition 2; γ_{00} = average performance on a given gait measure (e.g., velocity 2) at wave =9.18 weeks for the overall sample; γ_{01} = average rate of linear change in a measure (e.g., velocity condition 2) measure per additional week in the study above the grand mean (9.18 weeks; time centered), holding all other variables constant; γ_{02} = average rate of quadratic change in a given measure (e.g., velocity condition 2) measure per additional week in the study above the grand mean (9.18 weeks; time centered and then squared), holding all other variables constant.

Table 18. Time Covarying Covariation Models

Variables	Intercept γ_{00}/ Coefficient γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
Gait and PA											
Velocity 1											
MVW – GLTQ	140.421	2.756	50.946	105	<0.001	0.368	0.076	4.865	106	<0.001	0.446
	0.093	0.024	3.785	105	<0.001	0.031	0.007	4.333	106	<0.001	
MVW – CHAMPS	140.322	2.761	50.824	105	<0.001	0.473	0.075	6.281	106	<0.001	0.310
	0.082	0.023	3.590	105	<0.001	0.009	0.006	1.483	172	0.14	
MVPA	141.292	2.899	48.743	105	<0.001	0.500	0.072	6.905	106	<0.001	0.300
	0.031	0.011	2.855	105	0.005	0.004	0.004	1.023	169	0.308	
Velocity 2											
MVW – GLTQ	118.922	3.202	37.143	105	<0.001	1.106	0.102	10.850	106	<0.001	0.629
	0.061	0.028	2.155	105	0.033	0.038	0.008	4.832	178	<0.001	
MVW - CHAMPS	118.195	2.999	39.416	105	<0.001	1.194	0.098	12.242	106	<0.001	0.602
	0.057	0.025	2.285	105	0.024	0.024	0.007	3.441	171	<0.001	
MVPA	118.962	3.123	38.093	105	<0.001	1.274	0.095	13.398	106	<0.001	0.598
	0.019	0.012	1.605	105	0.112	0.009	0.004	1.965	168	0.051	
Dual Cost Velocity											
MVW – GLTQ	-0.155	0.015	-10.348	107	<0.001	0.005	0.510×10^{-3}	9.793	108	<0.001	0.000
	-0.085×10^{-3}	0.124×10^{-3}	-0.682	107	0.497	0.058	0.039×10^{-3}	1.493	176	0.137	
MVW - CHAMPS	-0.152	0.014	-10.833	107	<0.001	0.005	0.471×10^{-3}	10.541	108	<0.001	0.333
	-0.121×10^{-3}	0.112×10^{-3}	-1.079	107	0.283	0.089×10^{-3}	0.033×10^{-3}	2.674	169	0.008	
MVPA	-0.157	0.015	-10.645	107	<0.001	0.005	0.457×10^{-3}	11.479	108	<0.001	0.000
	-0.041×10^{-3}	0.054×10^{-3}	-0.772	107	0.442	0.013×10^{-3}	0.021×10^{-3}	0.602	166	0.548	
Stride time variability 1											
MVW – GLTQ	0.022	0.001	23.653	105	<0.001	-0.118×10^{-3}	0.044×10^{-3}	-2.685	285	0.008	0.600

Variables	Intercept γ_{00}/ Coefficient γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
	-0.006×10^{-3}	0.008×10^{-3}	-0.668	105	0.506	0.002×10^{-3}	0.004×10^{-3}	0.396	285	0.692	
MVW - CHAMPS	0.022	0.001	23.769	105	<0.001	-0.089×10^{-3}	0.043×10^{-3}	-2.078	106	<0.040	0.500
	-0.010×10^{-3}	0.007×10^{-3}	-1.426	105	0.157	-0.004×10^{-3}	0.004×10^{-3}	-1.008	172	0.315	
MVPA	0.022	0.001	23.290	105	<0.001	-0.108×10^{-3}	0.038×10^{-3}	-2.836	275	0.005	0.500
	-0.003×10^{-3}	0.002×10^{-3}	-0.852	105	0.396	-0.002×10^{-3}	0.002×10^{-3}	-1.067	275	0.287	
Stride Time SD 2											
MVW – GLTQ	0.039	0.003	13.744	105	<0.001	-0.001	0.104×10^{-3}	-6.901	106	<0.001	0.571
	0.005×10^{-3}	0.021×10^{-3}	0.221	105	0.825	-0.037×10^{-3}	0.011×10^{-3}	-3.527	106	<0.001	
MVW - CHAMPS	0.040	0.003	13.643	105	<0.001	-0.001	0.115×10^{-3}	-6.992	106	<0.001	0.576
	0.005×10^{-3}	0.020×10^{-3}	0.230	105	0.818	-0.025×10^{-3}	0.008×10^{-3}	-3.098	171	0.002	
MVPA	0.041	0.003	13.351	105	<0.001	-0.001	0.112×10^{-3}	-7.931	106	<0.001	0.574
	0.003×10^{-3}	0.009×10^{-3}	0.325	105	0.746	-0.001×10^{-3}	0.005×10^{-3}	-1.958	168	0.052	
Dual Cost Stride Time SD											
MVW – GLTQ	0.913	0.170	5.369	107	<0.001	-0.027	0.007	-4.040	176	<0.001	0.566
	0.001	0.001	0.887	107	0.377	-0.003	0.001	-2.447	108	0.016	
MVW - CHAMPS	1.051	0.201	5.238	107	<0.001	-0.042	0.010	-4.244	108	<0.001	0.418
	0.001	0.001	1.076	107	0.285	-0.001	0.001	-1.305	169	0.194	
MVPA	1.009	0.206	4.910	107	<0.001	-0.042	0.009	-4.557	108	<0.001	0.462
	0.740×10^{-3}	0.527×10^{-3}	1.404	107	0.163	0.054×10^{-3}	0.391×10^{-3}	0.138	108	0.890	
Cognition and Gait											
Category Fluency											
Velocity 1	14.310	3.317	4.314	113	<0.001	0.075	0.030	2.533	114	0.013	0.083
	0.032	0.022	1.453	113	0.149	-0.068×10^{-3}	0.024	0.003	114	0.998	
Velocity 2	13.000	2.673	4.863	113	<0.001	0.057	0.033	1.700	300	0.090	-0.026
	0.047	0.020	2.362	113	0.020	0.013	0.018	0.695	300	0.488	

Variables	Intercept γ_{00}/ Coefficient γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
Dual cost Velocity	20.299	0.754	26.911	114	<0.001	0.058	0.032	1.817	300	0.070	-0.029
	8.645	4.849	1.783	114	0.077	3.109	3.853	0.807	300	0.420	
STSD 1	21.707	1.623	13.371	113	<0.001	0.078	0.027	2.937	114	0.004	0.057
	-127.958	75.899	-1.686	113	0.095	15.140	37.275	0.406	187	0.685	
STSD 2	20.355	0.963	21.143	113	<0.001	0.055	0.028	1.970	300	0.05	-0.020
	-31.898	24.668	-1.293	113	0.199	-21.180	14.878	-1.424	300	0.156	
Dual cost Stride Time SD	19.421	0.545	35.651	114	<0.001	0.064	0.026	2.490	300	0.013	-0.023
	-0.263	0.374	-0.704	114	0.483	-0.235	0.177	-1.323	300	0.187	
Letter Fluency											
Velocity 1	31.905	7.974	4.001	113	<0.001	0.177	0.048	3.701	114	<0.001	0.083
	0.060	0.052	1.146	113	0.254	0.062	0.037	1.688	187	0.093	
Velocity 2	28.176	6.420	4.389	113	<0.001	0.170	0.059	2.888	114	0.005	0.245
	0.097	0.048	2.029	113	0.045	0.029	0.030	0.965	186	0.336	
Dual cost Velocity	42.547	1.795	23.700	114	<0.001	0.226	0.0563	4.006	115	<0.001	0.243
	17.577	11.743	1.497	114	0.137	-2.321	6.363	-0.365	185	0.716	
STSD 1	34.110	3.827	8.914	113	<0.001	0.223	0.045	4.940	114	<0.001	0.137
	316.655	179.366	1.765	113	0.080	112.331	59.555	1.886	187	0.061	
STSD 2	44.225	2.255	19.608	113	<0.001	0.183	0.045	4.023	300	<0.001	0.255
	-96.360	58.575	-1.645	113	0.103	-31.399	24.073	-1.304	300	0.193	
Dual Cost STSD	42.562	1.279	33.274	114	<0.001	0.184	0.047	3.935	115	<0.001	0.258
	-2.204	0.880	-2.503	114	0.014	-0.624	0.292	-2.137	185	0.034	
TMTA											
Velocity 1	58.989	5.381	10.963	113	<0.001	-0.231	0.058	3.993	114	<0.001	0.221
	-0.168	0.035	-4.806	113	<0.001	-0.028	0.046	0.615	114	0.54	
Velocity 2	54.964	4.414	12.453	113	<0.001	-0.240	0.064	3.732	114	<0.001	0.154

Variables	Intercept γ_{00}/ Coefficient γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
	-0.161	0.033	-4.934	113	<0.001	-0.014	0.035	-0.407	181	0.684	
Dual Cost Velocity	32.144	1.338	24.025	114	<0.001	-0.289	0.059	-4.941	295	<0.001	0.072
	-14.146	8.559	-1.653	114	0.101	5.243	7.267	0.721	295	0.471	
STSD 1	25.657	2.789	9.198	113	<0.001	-0.284	0.050	-5.671	114	<0.001	0.170
	395.439	130.534	3.029	113	0.003	-124.872	69.022	-1.809	182	0.072	
STSD 2	31.041	1.692	18.348	113	<0.001	-0.252	0.051	-4.886	295	<0.001	0.071
	73.574	43.287	1.700	113	0.092	11.274	28.382	0.397	295	0.691	
Dual Cost STSD	33.636	0.988	34.052	114	<0.001	-0.259	0.052	-5.018	115	<0.001	0.156
	-0.074	0.657	-0.113	114	0.910	0.161	0.358	0.449	180	0.654	
TMTB											
Velocity 1	123.333	17.979	6.860	113	<0.001	-0.788	0.169	-4.663	114	<0.001	0.173
	-0.259	0.117	-2.217	113	0.029	0.050	0.139	0.359	114	0.72	
Velocity 2	136.572	15.151	9.014	113	<0.001	-0.720	0.195	3.698	297	<0.001	0.063
	-0.400	0.112	-3.562	113	<0.001	-0.043	0.107	0.404	297	0.687	
Dual Cost Velocity	73.538	4.319	17.026	114	<0.001	-0.661	0.184	-3.592	297	<0.001	0.069
	-76.549	27.717	-2.762	114	0.007	-24.496	22.282	-1.099	297	0.273	
STSD 1	68.169	9.348	7.293	113	<0.001	-0.798	0.145	5.513	298	<0.001	0.054
	768.180	438.570	1.752	113	0.083	143.710	218.618	0.657	298	0.511	
STSD 2	70.664	5.482	12.889	113	<0.001	-0.775	0.162	4.788	297	<0.001	0.063
	381.590	140.432	2.717	113	0.008	8.015	86.438	0.093	297	0.926	
Dual Cost STSD	81.859	3.489	23.463	114	<0.001	-0.785	0.153	-5.145	115	<0.001	0.065
	2.558	2.097	1.220	114	0.225	-0.115	1.024	-0.112	182	0.911	
GMR											
Velocity 1	13.831	2.230	6.201	113	<0.001	-0.074	0.024	-3.103	299	0.002	0.025
	-0.033	0.015	-2.298	113	0.023	-0.021	0.020	-1.039	299	0.299	

Variables	Intercept γ_{00}/ Coefficient γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
Velocity 2	13.530	1.813	7.462	113	<0.001	-0.052	0.029	-1.763	298	0.079	0.027
	-0.037	0.013	-2.772	113	0.007	-0.027	0.016	-1.667	298	0.097	
Dual Cost Velocity	8.005	0.542	14.771	114	<0.001	-0.065	0.028	-2.321	298	0.021	0.024
	-5.287	3.353	-1.577	114	0.118	-4.039	3.445	-1.173	298	0.242	
STSD 1	6.210	1.117	5.559	113	<0.001	-0.082	0.022	-3.754	299	<0.001	0.031
	126.532	52.134	2.427	113	0.017	35.832	33.466	1.071	299	0.285	
STSD 2	7.914	0.675	11.723	113	<0.001	-0.076	0.023	3.244	298	0.001	0.026
	24.960	18.111	1.378	113	0.171	12.348	9.648	1.280	298	0.202	
Dual Cost STSD	8.850	0.394	22.484	114	<0.001	-0.087	0.023	-3.833	298	<0.001	0.021
	-0.018	0.258	-0.068	114	0.946	-0.033	0.160	-0.207	298	0.836	
GML											
Velocity 1	84.406	10.979	7.688	113	<0.001	-0.561	0.123	-4.561	114	<0.001	0.277
	-0.143	0.072	-1.993	113	0.049	-0.039	0.089	-0.440	185	0.660	
Velocity 2	82.899	8.838	9.380	113	<0.001	-0.540	0.158	-3.423	114	<0.001	0.309
	-0.152	0.066	-2.323	113	0.022	-0.033	0.072	-0.463	114	0.644	
Dual cost velocity	59.634	2.6309	22.670	114	<0.001	-0.542	0.139	-3.903	115	<0.001	0.311
	-22.899	16.350	-1.401	114	0.164	-8.296	15.305	-0.542	183	0.588	
STSD 1	50.599	5.437	9.307	113	<0.001	-0.590	0.115	-5.114	114	<0.001	0.273
	598.358	253.454	2.361	113	0.020	29.671	145.109	0.204	185	0.838	
STSD 2	56.224	3.251	17.293	113	<0.001	-0.488	0.125	-3.895	114	<0.001	0.284
	171.403	81.903	2.093	113	0.039	112.704	58.956	1.912	184	0.057	
Dual cost STSD	61.400	1.892	32.453	114	<0.001	-0.521	0.126	-4.136	115	<0.001	0.325
	1.074	1.206	0.891	114	0.375	1.343	0.742	1.810	115	0.073	
ISL											
Velocity 1	17.625	3.049	5.780	113	<0.001	0.066	0.025	2.649	114	0.009	0.180

Variables	Intercept γ_{00}/ Coefficient γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
	0.039	0.020	1.975	113	0.051	0.014	0.019	0.742	185	0.459	
Velocity 2	19.261	2.491	7.734	113	<0.001	0.068	0.030	2.277	114	0.025	0.028
	0.032	0.019	1.753	113	0.082	0.005	0.015	0.321	184	0.749	
Dual cost velocity	1.235	0.019	63.722	114	<0.001	0.007	0.001	6.424	298	<0.001	0.178
	0.127	0.115	1.105	114	0.271	-0.045	0.141	-0.320	298	0.749	
STSD 1	26.684	1.452	18.379	113	<0.001	0.073	0.023	3.114	114	0.002	0.175
	-152.024	68.183	-2.230	113	0.028	-17.790	30.505	0.583	185	0.560	
STSD 2	24.704	0.892	27.692	113	<0.001	0.070	0.023	3.067	298	0.002	0.047
	-33.462	23.003	-1.455	113	0.149	-6.478	12.255	-0.529	298	0.597	
Dual cost STSD	1.225	0.014	86.723	114	<0.001	0.007	0.001	7.296	298	<0.001	0.176
	-0.001	0.009	-0.082	114	0.935	-0.007	0.007	-1.074	298	0.284	
ONB											
Velocity 1	1.132	0.077	14.788	113	<0.001	0.006	0.001	6.194	299	<0.001	0.184
	0.001	0.499×10^{-3}	1.312	113	0.192	0.002	0.001	2.501	299	0.013	
Velocity 2	1.120	0.063	17.738	113	<0.001	0.006	0.001	4.747	298	<0.001	0.176
	0.001	0.465×10^{-3}	1.839	113	0.069	0.001	0.001	1.669	298	0.096	
Dual cost velocity	1.235	0.019	63.722	114	<0.001	0.007	0.001	6.424	298	<0.001	0.179
	0.127	0.115	1.105	114	0.271	-0.045	0.141	-0.320	298	0.749	
STSD 1	1.291	0.039	33.142	113	<0.001	0.007	0.001	7.875	299	<0.001	0.172
	-3.331	1.810	-1.841	113	0.068	0.518	1.383	0.374	299	0.708	
STSD 2	1.249	0.023	53.060	113	<0.001	0.006	0.001	6.411	298	<0.001	0.173
	-0.655	0.583	-1.124	113	0.134	-0.616	0.549	-1.121	298	0.263	
Dual cost STSD	1.225	0.014	86.723	114	<0.001	0.007	0.001	7.296	298	<0.001	0.178
	-0.001	0.009	-0.082	114	0.935	-0.007	0.007	-1.074	298	0.284	
TWOB											

Variables	Intercept γ_{00}/ Coefficient γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*	r^2
Velocity 1	1.078	0.087	12.466	113	<0.001	0.003	0.001	3.107	296	0.002	0.004
	0.484×10^{-3}	0.001	0.857	113	0.394	0.001	0.001	1.011	296	0.313	
Velocity 2	0.983	0.069	14.157	113	<0.001	0.003	0.001	3.078	114	0.003	0.018
	0.001	0.001	2.371	113	0.019	-0.352×10^{-3}	0.001	-0.568	114	0.571	
Dual cost velocity	1.182	0.020	58.498	114	<0.001	0.004142	0.001035	4.003	295	<0.001	0.085
	0.349	0.125	2.785	114	0.006	-0.206	0.127291	-1.618	295	0.107	
STSD 1	1.257	0.042	29.754	113	<0.001	0.003	0.001	3.712	296	<0.001	0.009
	-5.199	1.973	-2.635	113	0.010	-1.255	1.254	-1.001	296	0.318	
STSD 2	1.201	0.025	47.832	113	<0.001	0.004	0.001	3.822	295	<0.001	0.006
	-1.644	0.633	-2.597	113	0.011	0.511	0.496	1.121	295	0.304	
Dual cost STSD	1.154	0.015	77.995	114	<0.001	0.003	0.001	3.878	295	<0.001	0.006
	-0.008	0.010	-0.811	114	0.419	0.005	0.006	0.804	295	0.422	

Notes: STSD = stride time variability; γ_{00} = Average performance on a given cognitive measure (e.g., category fluency, one back) at week =0 for the grand mean of a given gait measure (e.g., velocity (centimeters/second) or stride time variability (seconds); γ_{01} = average difference in performance on a given cognitive measure (e.g., category fluency, one back test) for every additional unit (cm/s or seconds) of person mean performance on a given gait measure, not controlling for weekly performance on a given gait measure (i.e., the between person (person mean) effect of a given gait measure on a given cognitive measure); γ_{10} = the effect of time on a cognitive measure (uncentered); γ_{20} = the within person (person mean) effect of gait/physical activity on a given cognitive/gait measure.

Additional Files

Table 19. Descriptive Statistics for Gait Outcomes by Wave of Testing

	Wave 1			Wave 2			Wave 3			Wave 4			Wave 5		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
Velocity 1	114	145.44	18.43	83	154.18	16.02	65	156.24	18.68	81	157.37	20.37	87	155.26	21.74
STSD 1	114	0.02	0.01	83	0.02	0.01	65	0.02	0.01	81	0.02	0.01	87	0.02	0.01
Velocity 2	113	119.91	19.42	83	135.73	18.79	65	139.65	18.20	81	143.56	22.26	87	141.88	23.01
STSD 2	113	0.05	0.03	83	0.03	0.01	65	0.03	0.01	81	0.03	0.01	87	0.03	0.01

Notes: M=mean, SD = standard deviation, STSD 1 = stride time variability condition 1 (seconds), STSD 2 = stride time variability condition 2 (seconds), velocity 1 = velocity during normal walking (centimeters/second), velocity 2 = velocity during dual task walking (centimeters/second)

Table 20. Intercept-Only Models of Gait Outcomes

		SD	Variance	*df*	χ^2	*p*	ICC
Velocity 1							
	INTRCPT1, r_0	17.349	300.995	115	1771.168	<0.001	0.791
	level-1, *e*	8.913	79.435				
Velocity 2							
	INTRCPT1, r_0	17.851	318.671	115	837.740	<0.001	0.630
	level-1, *e*	13.689	187.400				
STSD 1							
	INTRCPT1, r_0	0.004	0.000	115	383.579	<0.001	0.400
	level-1, *e*	0.005	0.000				
STSD 2							
	INTRCPT1, r_0	0.014	0.000	115	483.884	<0.001	0.474
	level-1, *e*	0.014	0.000				

Note: velocity 1 = velocity during normal walking (centimeters/second), velocity 2 = velocity during dual task walking (centimeters/second), STSD 1 = stride time variability during normal walking (standard deviation, seconds) and STSD 2 = stride time variability during dual task walking (standard deviation, seconds). SD = standard deviation, df = degrees of freedom, ICC = intraclass correlation coefficient.

Table 21. Time-Varying Covariation Models of Gait and Fitness

Variables	Intercept γ_{00}/ Coefficient γ_{01}	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*
Gait and Fitness										
Velocity condition 1										
6 minute walk test	38.193	7.374	5.180	109	<0.001	0.242	0.086	2.804	110	0.006
	0.219	0.014	15.314	109	<0.001	0.083	0.020	4.096	110	<0.001
Waist Circumference	177.105	13.147	13.471	110	<0.001	0.521	0.075	6.953	111	<0.001
	-0.301	0.133	-2.262	110	0.026	-0.602	0.284	-2.122	174	0.035
Velocity condition 2										
6 minute walk test	40.527	10.883	3.724	109	<0.001	1.098	0.099	11.129	110	<0.001
	0.165	0.021	7.816	109	<0.001	0.042	0.016	2.685	188	0.008
Waist Circumference	135.085	14.375	9.397	110	<0.001	1.290	0.095	13.514	111	<0.001
	-0.124	0.146	-0.852	110	0.396	-0.796	0.356	-2.237	111	0.027
Stride Time SD Condition 1										
6 minute walk test	0.032	0.003	10.049	109	<0.001	-0.61×10^{-4}	0.40×10^{-4}	-1.506	299	0.133
	-2.3×10^{-5}	0.6×10^{-5}	-3.649	109	<0.001	-0.3×10^{-5}	0.8×10^{-5}	-0.336	299	0.737
Waist Circumference	0.017	0.004	4.565	110	<0.001	-0.99×10^{-4}	0.39×10^{-4}	-2.503	285	0.013
	0.40×10^{-4}	0.38×10^{-4}	1.047	110	0.297	0.98×10^{-4}	0.171×10^{-3}	0.575	285	0.566
Stride Time SD Condition 1										
6 minute walk test	0.056	0.010	5.495	109	<0.001	-0.744×10^{-3}	0.120×10^{-3}	-6.199	110	<0.001
	-0.32×10^{-4}	0.20×10^{-4}	-1.642	109	0.103	-0.28×10^{-4}	0.19×10^{-4}	-1.498	188	0.136
Waist Circumference	0.034	0.011	3.243	110	0.002	-0.856×10^{-3}	0.117×10^{-3}	-7.343	111	<0.001
	0.69×10^{-4}	0.105×10^{-3}	0.651	110	0.517	0.001	0.408×10^{-3}	2.919	173	0.004

Note: velocity 1 = velocity during normal walking (centimeters/second), velocity 2 = velocity during dual task walking (centimeters/second), STSD 1 = stride time variability during normal walking (standard deviation, seconds) and STSD 2 = stride time variability during dual task walking (standard deviation, seconds). γ_{00} = Average performance on a given gait measure at week =0 for the grand mean of a given fitness measure; γ_{01} = average difference in performance on a given gait measure for every additional unit of person mean performance on a given fitness measure, not controlling for weekly performance on a given fitness measure (i.e., the between-person (person mean) effect of a given fitness measure on a given gait measure); γ_{10} = the effect of time on a gait measure (uncentered); γ_{20} = the within-person (person mean) effect of fitness on a given gait measure.

Chapter 4. Adherence Paper

Introduction

Physical inactivity is a serious public health concern because it contributes to the prevalence of chronic disease, disability and premature death in the Canadian population (Chodzko-Zajko et al., 2009; Patterson & Warburton, 2010; Warburton et al., 2006; Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010). Despite the numerous health benefits of physical activity (PA; e.g., reduced risk of chronic diseases, reduced all cause mortality fitness, prevention of weight gain; Shields et al., 2010; Warburton et al., 2010), only an estimated 15% of Canadian adults aged 20 to 79 years are getting the recommended 150 minutes of moderate to vigorous PA per week (Colley et al., 2011). Studies have shown that older adults are among the most inactive and that the prevalence of inactivity increases with advancing age (Azagba & Sharaf, 2014; Canadian Fitness & Lifestyle Research Institute, 2010; Paterson, Jones, & Rice, 2007; Shaw, Liang, Krause, Gallant, & McGeever, 2010). This is particularly concerning because physically inactive older adults may experience declines in mental and physical functioning, social isolation, loss of functional independence, and poorer quality of life (Paterson & Warburton, 2010; Reed, Crespo, Harvey, & Andersen, 2011).

Due to the rapid aging of the population and the increasing prevalence of physical inactivity in older adults, the development of interventions to promote PA is of paramount importance. A necessary first step in designing interventions for this purpose is to gain better understanding of the antecedents of PA. Researchers in Exercise/Health Psychology often use theories of behaviour change to help make sense of and organize our understanding of these antecedents and the mechanisms through which individuals

change (do not change) their PA behaviours (Baranowski, Anderson, & Carmack, 1998; Biddle & Nigg, 2000; King, Stokols, Talen, Brassington, & Killingsworth, 2002). Moreover, there is some evidence that theoretically-framed interventions produce larger intervention effects than those developed without a theoretical frame (Ammerman, Lindquist, Lohr, & Hersey, 2002; Dombrowski et al., 2012; Glanz & Bishop, 2010; Michie & Johnston, 2012; Taylor, Conner, & Lawton, 2012; Webb, Joseph, Yardley, & Michie, 2010). Many of the theories used to predict PA behaviour and develop interventions include intention as the most proximal antecedent of behaviour (Rhodes & De Bruijn, 2013a; Rhodes & Dickau, 2012). One of the most prominent, parsimonious, and well-validated of these theories is Ajzen's Theory of Planned Behaviour (Ajzen, 1985; Ajzen, 1991; Symons-Downs & Hausenblas, 2005; Symons-Downs & Hausenblas, 2005; Hausenblas, Carron, & Mack, 1997; McEachan, Conner, Taylor, & Lawton, 2011; Rhodes, Blanchard, & Matheson, 2006).

The Theory of Planned Behaviour (TPB)

The TPB holds that the most proximal determinant of behaviour is intention (i.e., an individual's readiness to perform the given behaviour/motivation to perform the behaviour, Ajzen, 1985; Ajzen, 1991). Attitude (i.e., the overall evaluation of the behaviour), subjective norm (SN; i.e., perceived social pressure to perform the behaviour) and perceived behavioural control (PBC; i.e., perceived ability to perform the behaviour; skills, opportunity, resources) are the antecedents of intention (Figure 2). Of these constructs, PBC and attitude are most the most reliable correlates of intention; while, SN has received less empirical support (Symons-Downs & Hausenblas, 2005; Hagger, Chatzisarantis, & Biddle, 2002; McEachan et al., 2011).

A recent meta-analysis of prospective prediction of health-related behaviours found that PA behaviour was among the best predicted by TPB; despite this, 76.1% of the variance in PA behaviour was *unexplained* by TPB (McEachan et al., 2011). After controlling for past behaviour and examining change in behaviour, TPB constructs accounted for even less variance in PA behaviour (i.e., 95% of variance in PA was *unexplained* by TPB). The authors found that of the TPB constructs and past behaviour, past behaviour was the strongest predictor of behaviour change (β=0.388), while intention (β=0.222), but not PBC (β=.074) remained significant. Likewise, past behaviour was the strongest predictor of intention (β=0.320), followed by attitude (β=0.316) and PBC (β=0.250). The meta-analysis also found that age was a significant moderator of TPB-PA relations, such that adolescent samples were better predicted by TPB than student and adult samples; however, the review did not examine older adults specifically.

The ability of the model to predict PA behaviour is centered on the relations between intention and PA. Although there is considerable research support for the ability of TPB to predict PA intentions and behaviour in a variety of populations (Symons-Downs & Hausenblas, 2005; Hagger et al., 2002; McEachan et al., 2011), including older adults (Benjamin, Edwards, & Bharti, 2005; Dean, 2004; Dean, Farrell, Kelley, Taylor, & Rhodes, 2007; Kosma, 2014; Lucidi, Grano, Barbaranelli, & Violani, 2006; White et al., 2012), much of this research is correlational and experimental research has generally not supported the assumptions of TPB (Sniehotta, Presseau, & Araujo-Soares, 2014).

For example, several prospective studies examining the predictive utility of TPB in older adults have found that intentions have explained little or no variance in the exercise behaviour in older adults enrolled in an exercise program. Lucidi et al. (2006) examined whether TPB constructs and Bandura's self-efficacy significantly predicted

attendance at twice-weekly exercise classes over a three-month period. In this older adult sample of 65 to 90 year olds, the model explained 55% of the variance in intention to be physically active, but this translated to only 9% of the variance in exercise class attendance (i.e., 91% of the variance in exercise behaviour was *unexplained* by TPB). In a study conducted by Brenes and colleagues, PA intentions did not significantly predict exercise behaviour in a group of older adults aged 53 to 84 years who were attending an exercise class (Brenes, Strube, & Storandt, 1998).

Moreover, associations between intention and actual behaviour based on experimental evidence are weak. In fact, a recent meta-analysis of experimental research specific to PA suggests that the effect size for PA intention is moderate (*d*= .45 (95% CI .30 to .60), yet trivial for PA behaviour (d= .15 (95% CI .06 to .23); Rhodes & Dickau, 2012). This discordance between intention and behaviour is highly problematic for experimental researchers, given that intention is viewed as the most proximal antecedent of behaviour in models like TPB. Yet, individuals who participate in intervention research show up with positive intentions to be active in the first place (Rhodes & De Bruijn, 2013b).

In fact, evidence suggests that 48% of those high intentions fail to act on their intentions to be active (Rhodes & De Bruijn, 2013a; Rhodes & de Bruijn, 2013b; Rhodes & Dickau, 2012; Rhodes & Dickau, 2013). Intentions may be necessary for PA, but they certainly are not sufficient. To help translate high intention into action, it has been suggested that researchers should incorporate other factors, in addition to those targeting intention formation, into their theoretical frameworks and research (de Vries, Mesters, Van de Steeg, & Honing, 2005; Gollwitzer & Brandstatter, 1997; Rhodes & de Bruijn, 2013a; Schwarzer, 2008).

The Action Control Framework and the Multi-Process Action Control Model

A recent review conducted by Rhodes & Yao (2014) identified 12 post-intentional theories of behaviour change (Integrated Change Theory; de Vries et al., 2005; Information Motivation Behavioral Skills Model; Fisher & Fisher, 1992; MoVo Process Model; Fuchs, Goehner, & Seelig, 2011; Rubricon Model of Action Phases; P.M. Gollwitzer, 1991; Integrated Behavior Change Model; Hagger & Chatzisarantis, 2014; Rubricon Model of Action Phases; Heckhausen, 1991; Action Control Theory; Kuhl, 1984; J. Kuhl & Beckmann, 1985; Multi-Process Action Control Model; Rhodes & de Bruijn, 2013; Health Action Process Approach; Schwarzer & Luszczynska, 2008; Triandis, 1980; PRIME; West, 2008). Of these, the action control framework/Multi-process Action Control Model (M-PAC) proposed by Rhodes and De Bruijn (2013a) is among the most validated in the PA domain and therefore, it was used as the conceptual model for the present study.

In the M-PAC, action control refers to intention-behaviour discordance, as originally proposed by Kuhl (1984). The intention-behaviour relationship is divided into four quadrants based on the recommended public health guidelines for PA (i.e., 150 minutes of moderate to vigorous PA per week (2011), such that two concordant quadrants (non-intenders who are subsequently not active, successful intenders) and two discordant quadrants (unsuccessful intenders, non-intenders who are subsequently active) are created (Rhodes & de Bruijn, 2013a). A recent meta-analysis using the Action Control Framework found that approximately 36% of participants were unsuccessful intenders, 42% were successful intenders, 2% were non-intenders who performed PA and 21% were non-intenders who did not perform PA (Rhodes & de Bruijn, 2013b). These findings suggest that while intention clearly remains an important construct within this framework

(i.e., a substantial proportion of intenders do act on their intentions), other social cognitive and self-regulatory constructs that may predict intention-behaviour discordance need to be explored.

According to M-PAC, action control exists along a continuum from motivation initiation to behavioural continuation. Intention choice (defined as a binary decisional choice variable rather than intention strength) is determined by instrumental attitude/outcome expectations, affective attitude/ experiential expectations and PBC (i.e., ability/skills, opportunity). Translating intention choice into PA is proposed as the product of higher affective attitude and PBC than what was required to form the initial intention, as well as self-regulatory behaviours (e.g., coping planning, enlisting support, self-monitoring). Self-regulatory behaviours are viewed as particularly important when adopting new behaviours. Whereas, maintenance of these behaviours is thought to also include more reflexive constructs such as habit and identity formation (Figure 3; Rhodes & de Bruijn, 2013a). Habit is defined as behaviour performed as the result of triggers and routinized cues (Gardner & Tang, 2014; Gardner, de Bruijn, & Lally, 2011); while identity formation is behaviour that is performed as a result of an assumed role and desire to maintain that role (Stryker & Burke, 2000).The model was developed based on a review of the literature that highlighted the above variables as significant predictors of intention-behaviour discordance (Rhodes & de Bruijn, 2013a). The summary statement in M-PAC is that action control unfolds from motivation to behavioural regulation and finally to reflexive action across the motivational initiation, adoption, and maintenance process of behaviour change, respectively.

Studies examining intention-behaviour discordance from the perspective of the Action Control Framework are emerging (Godin, Shephard, & Colantonio, 1986; Orbell

& Sheeran, 1998; Rhodes, Courneya, & Jones, 2003; Rhodes, Fiala, & Nasuti, 2012; Rhodes & Plotnikoff, 2006; Rhodes, de Bruijn & Matheson, 2010; Rhodes, Blanchard, & Bellows, 2008; Rhodes, Plotnikoff & Courneya, 2008). For example, Rhodes and colleagues (2012) examined whether automaticity (i.e., habit) and cross-behavioural regulation (i.e., planning for other highly sought behaviours), in addition to standard social cognitive constructs significantly predicted action control in a sample of college students. In this study, affective attitude, and PBC had significant large effects on both intention and action control, while instrumental attitude had significant large effects on intention only. Automaticity and cross-behavioural regulation had significant large and medium effects on action control only. Other work by Rhodes and colleagues has also demonstrated the importance of habit in action control: in their study an additional 7% variance in action control was explained by habit, after controlling for TPB variables and intention stability (Rhodes et al., 2010). Individuals with high habit were significantly more likely to be intenders who were regularly engaging in PA (70%); while, individuals with low habit were significantly more likely to be classified as inactive non-intenders (69%) in this sample of undergraduate students.

Although there is emerging evidence for the validity of the action control framework, the literature is generally limited to college or workplace samples. The literature examining PA intention-behaviour relations in older adults from the perspective of the Action Control Framework, and the M-PAC in particular, is non-existent. The current examination of PA behaviour involved participants of a supervised walking program, and as such, arguably, the participants already intended to be active. Thus, the objective of this paper was to examine walking behaviour in older adults first, from the perspective of TPB (a motivational theory focused on intention) and then, from the M-

PAC/Action Control Framework (a contemporary post-intentional model of behaviour). Given that PA patterns fluctuate from day to day and week to week, we examined the ability of these models to predict both *overall* walking behaviour and *change* in walking behaviour across the 5 measurement waves.

Research Questions and Hypotheses

Primary research questions concerning TPB were:

1. Do TPB constructs significantly predict a) intention and *overall program* b) self-reported moderate to vigorous walking and c) group attendance?

Hypothesis 1a: Attitude (instrumental attitude, affective attitude), PBC, and SN (descriptive and injunctive norm) would predict a significant amount of variance in intention.

Hypothesis 1b-c: However, given the high discordance between intention and behaviour, it was expected that TPB constructs of intention, PBC, attitude (instrumental, affective), and SN (descriptive, injunctive) would NOT predict a significant amount of variance in *overall* a) self-reported walking behaviour or b) group attendance.

2. Over the four-month walking program, do older adults exhibit significant longitudinal *change* in a) self-reported moderate to vigorous walking and b) group attendance over the 5 measurement waves? If so, do between-group differences in TPB constructs significantly predict changes in a) self-reported moderate to vigorous walking and b) group attendance?

Hypothesis 2a: It was hypothesized that walking group participants would significantly increase their walking (self-reported moderate to vigorous walking, group attendance) over time, especially in initial stages of the supervised walking program.

Hypothesis 2b-c: Again, since there is a weak association between intention and behaviour, it was expected that none of the TPB constructs would significantly predict *change* in a) self-reported walking and b) group attendance over the five measurement waves.

Secondary research questions concerning the M-PAC were:

3. What is the distribution of intention-behaviour profiles in the walking group participants?

Hypothesis 3a: Given that people who show up for a PA program, arguably, have high intention in the first place, it is anticipated that this sample would be comprised of successful and unsuccessful intenders, and not non-intenders.

4. Do motivational constructs (affective attitude, instrumental attitude, PBC), self-regulatory strategies (self-monitoring) and habit significantly predict odds of being a successful intender based on *overall program* a) self-reported moderate to vigorous walking and b) group attendance?

Hypothesis 4a-b: Given that self-regulation and habit formation are viewed as important for translating intention into adoption and maintenance of behaviour, respectively, it was

anticipated that action control constructs would significantly predict odds of being a successful intender based on both *overall program* a) self-reported moderate to vigorous walking and b) group attendance. Since individuals in the walking program were in the process of adopting walking as a regular behaviour, it was expected that self-regulation (self-monitoring) would be the critical variable, while habit might also be important.

5. Does odds of being a successful intender change significantly over time? Do motivational constructs (affective attitude, instrumental attitude, PBC), self-regulatory strategies (self-monitoring) and habit significantly predict action control across the 5 measurement waves based on a) self-reported moderate to vigorous walking and b) group attendance?

*Hypothesis 5a-b***:** It was hypothesized that the odds of being a successful intender would significantly change over time. Moreover, action control constructs were expected to be significant predictors of the odds of being a successful intender. Again, it was expected that self-regulation (self-monitoring) would be the critical variable, while habit might also be important.

Methods

The detailed study methods of *Healthy Bodies, Healthy Minds – A Supervised Walking Program for Older Adults* are described previously (See Chapter 2: Main Study). The study involved a four-month walking program in which study participants were asked to attend weekly group walks and complete a battery of assessments at each of five measurement waves. The primary aim of the brief longitudinal study was to use multilevel modelling to examine the relations between changes in PA and changes in

cognition over a four-month walking program in a group of inactive older adults. The current paper reports on one of secondary aims of the study (i.e., to examine social cognitive and self-regulatory factors that influence walking group attendance and regular leisure time walking over the four-month program).

Participants and Procedures

Participants were a convenience sample of sedentary community-dwelling older adults that were living within Greater Victoria, British Columbia, Canada and were recruited primarily through advertisements in the local media (Appendix 3: Recruitment Materials). Exclusionary criteria included a diagnosis of dementia by a physician or a score on the TICS in the moderately to severely impaired range (i.e., < 28 out of 50), a history of significant head injury (defined as loss of consciousness for more than 5 min), other neurological or major medical illnesses (e.g., Parkinson's disease, heart disease, cancer), severe sensory impairment (e.g., difficulty reading newspaper-size print, difficulty hearing a normal conversation), drug or alcohol abuse, current psychiatric diagnoses, psychotropic drug use, and lack of fluency in English. Individuals who were meeting the minimum national guidelines for PA for older adults were also excluded (e.g., reduced risk of chronic diseases, reduced all cause mortality fitness, prevention of weight gain; Warburton et al., 2010).

Rates of completion of each wave of measurement and flow of participants through the study from recruitment through follow-up are described previously (Chapter 3: Main Study). At baseline, these participants (n=118) ranged in age from 65 to 87 years of age (M= 72.81, SD = 5.24). The vast majority were Caucasian and had completed at least some university or college education. Eighty-eight percent of the sample reported that compared to other people their age, their health was “very good or good”.

Exercise Intervention

All study participants were asked to attend *at least* three supervised walking groups per week for four months. Each walk began with a warm up and ended with a cool down and stretching. Duration and intensity increased gradually over the course of the walking program from 15 minutes to 45 minutes or more of moderate intensity/brisk walking (not including warm up, cool down and stretching). Participants were also encouraged to walk or engage in other PA outside of the walking group in order to meet national guidelines of 150 minutes of moderate to vigorous PA per week. The intervention is described in greater detail in Chapter 2 (Main Study).

Measures

The social cognitive questionnaire was administered at baseline and included measures tapping the Theory of Planned Behaviour (TPB; 12 items) and walking habit (4 items).

TPB items

TPB constructs were measured using 7-point Likert type questions developed by Rhodes and colleagues (i.e., 150 minutes of moderate to vigorous PA per week; Canadian Society for Exercise Physiology, 2011). For the TPB questions, regular leisure-time walking was defined as "walking for at least 150 minutes per week, in bouts of 10 minutes of more, during your free time." The definition was based on Canada's recommended minimum guidelines for PA for older adults aged 65 years and over (Rhodes, Courneya, Blanchard, & Plotnikoff, 2008; Rhodes, Blanchard, Courneya, & Plotnikoff, 2009). Attitude towards regular leisure-time walking (i.e., an individual’s overall evaluation of engaging in regular leisure time walking) is comprised of two distinguishable components (i.e., affective and instrumental attitude). Three items were

used to tap instrumental attitude (i.e., useful- useless, wise-unwise, beneficial-harmful), and three items were used to tap affective attitude (i.e., enjoyable-unenjoyable, pleasant-unpleasant, exciting-boring). The response format was a series of 7-point scales (1,7 = extremely, 2,6 = moderately, 3,5 = slightly). Each scale was preceded by the phrase: "For me, regular leisure time walking over the next 4 months would be...". Internal consistency was adequate ($\alpha = 0.817$ for affective attitude and $\alpha=0.709$ for instrumental attitude).

SN was measured using items from Rhodes et al. (2009), including two items assessing the injunctive component of SN and one item tapping the descriptive component. The injunctive norm items included (1) "Most people who are important to me want me to engage in leisure-time walking over the next 4 months," and (2) "Most people whose opinions I value would approve of me engaging in leisure-time walking over the next 4 months." The items were measured on 7-point bipolar scales ranging from 1 (strongly disagree) to 7 (strongly agree) and 1 (completely disapprove) to 7 (completely approve). Internal consistency for injunctive norm was $\alpha = .652$. The descriptive component was measured with the item "Most people who are important to me will engage in regular leisure-time walking themselves over the next 4 months" which was measured on a 7-point bipolar scale ranging from 1 (completely untrue) to 7 (completely true).

PBC was measured using three items from Rhodes et al. (2007). The items were: (1) "In the next 4 months, I have complete personal control over leisure-time walking if I really wanted to do so," (2) Engaging in leisure-time walking is mostly up to me in the next 4 months if I wanted to do so," and (3) Engaging in leisure-time walking over the next 4 months if I wanted to do so would be...". The first two items were scored on a 7-

point scale ranging from 1 (strongly disagree) to 7 (strongly agree), while the third item was scored from 1 (extremely difficult) to 7 (extremely easy). An aggregate PBC measure was created using the standardized items. Internal consistency of the aggregate measure was α=0.699. Removal of the latter item, increased scale internal consistency to α=0.871.

Intention to engage in regular leisure time walking was measured with a single open frequency item: "I intend to engage in regular leisure-time walking ____ times per week over the next 4 months". The item was used to ensure scale correspondence with the measure of self-reported walking behaviour (i.e., the modified Godin Leisure Time Questionnaire (GLTQ)) as has been recommended in previous work (Courneya, 1994; Courneya & McAuley, 1994; Rhodes, Matheson, & Blanchard, 2006). It has been suggested that continuous open frequency scaling may be a better method for measuring PA intention than traditional fixed graded scaling (Rhodes et al., 2006).

Walking Habit

Walking habit (i.e., goal directed automaticity) was measured with four items from the self reported habit index developed by Verplanken and Aart (Verplankin & Aart, 1999; Bas Verplanken & Orbell, 2003) and adapted for PA (Chatzisarantis & Hagger, 2007; De Bruijn & Rhodes, 2011; Bas Verplanken & Melkevik, 2008). Items used in the current study were adapted for regular walking: (1) "Regular walking is something I do automatically"; (2) "Regular walking is something I do without having to consciously remember"; (3) "Regular walking is something I do without thinking of it"; and (4) "Regular walking is something I start doing before I realize I'm doing it". Each item was rated on a 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree). The internal consistency of the measure was excellent (α=.946).

Self-monitoring

Participants were also given a calendar to track their daily walking over the four-month walking program (See Appendix 5). At the end of the program, calendars were returned to the researcher. A dichotomized, objective measure of self-monitoring was created from the calendars (i.e., self-monitored vs. did not self-monitor).

Walking Behaviour

Both self-reported walking behaviour and attendance were examined. Self-reported moderate to vigorous walking was measured using a modified version of the Godin Leisure Time Exercise Questionnaire(GLTEQ; Godin, Jobin, & Bouillon, 1985; Godin, Jobin, & Bouillon, 1986), as in previous walking studies (e.g., Blacklock, Rhodes, & Brown, 2006; Brown & Rhodes, 2006; Rhodes, Blanchard, Courneya, & Plotnikoff, 2009; Rhodes, Brown, & McIntyre, 2006; Rhodes, Courneya, Blanchard, & Plotnikoff, 2007; Rhodes, Murray, Temple, Tuokko, & Higgins, 2012a; Rhodes, Murray, Temple, Tuokko, & Higgins, 2012b). The GLTEQ contains three open-ended questions asking participants to recall their average frequency (times/week) of mild, moderate, and strenuous physical activities during their free time in a typical week. In this study, participants were asked to recall their frequency of leisure-time *walking* (i.e., walking during free time and not during occupational and housework) in the last seven days. Mild, moderate, and strenuous physical activities from the original GLTEQ were changed to mild walking (minimal effort, no perspiration, a casual walk), moderate (not exhausting, light perspiration, a good brisk pace), and strenuous (heart beats rapidly, sweating, as fast as you could walk). Participants were also asked to report the average duration walked at each of these intensities. An aggregate index of moderate to vigorous walking was created by summing total weekly duration (frequency X duration) of moderate and

strenuous walking (minutes/week). Self-reported walking behaviour was measured at baseline and 6, 9, 12 and 16 weeks following the start of the walking program.

Attendance was measured by the walking group leaders at each walk through the four-month program. A continuous measure of weekly attendance was created by summing the number of walks attended per week (walks/week).

Data Analysis

Missingness and Multiple Imputation

To establish mechanisms of missing data using Rubin's classification system (Missing completely at random (MCAR), Missing at Random (MAR) and Missing Not at Random (MNAR; (Allison, 2002; Graham, 2012a; McKnight, McKnight, & Sidani, 2007; Schafer, 1997), missing data analysis was completed and relations between health and demographic variables and missing data across waves were examined. Patterns of missing data were examined using the SPSS MI utility as described in Graham (2012b). Patterns of missing data were scanned and no problematic patterns of missing data were identified. Reasons for missing data included dropout and inability to schedule a particular follow-up measurement wave of testing (e.g., illness, scheduling conflicts, weather). Figure 1 from Chapter 2 (Main Study) summarizes completion rates across the 5 waves and measurement tools.

To examine correlations between health and demographics and missing data, missing data at each wave was dummy coded (0=missing, 1 = completed). Significant bivariate correlations between 1) marital status (r=0.244, p=.010) and 2) living with someone full-time (r=-.217, p=0.025) and wave 4 missingness were found. In addition, self-rated overall health compared to a perfect state (r=.192, p=.045) and self-rated future health r=.277, p=.004) were significantly associated with missing data at wave 3. Sleep

quality was significantly correlated with missing data at wave 2 (r=1.98, *p*=.035) and wave 5 (r=.260, *p*=.005). Associations between *all* other demographic and health variables and missingness at each wave were non-significant (*p*>.05).

Missing data pattern analysis and examination of relations did not reveal any systematic associations; as such, it was assumed that missing data was missing at random (MAR). Given that missing data was MAR, data was imputed (n=40 imputations) using multiple imputation (fully conditional specification) following step-by-step procedures described in Graham (2012b). A multiple imputation data set was used for overall program analyses only (and not HLM analyses). Age at baseline and self-rated health were included in the imputation model as predictors only, along with total attendance and self-reported moderate to vigorous walking and social cognitive and self-regulatory variables (both dependent variables and predictors).

Primary Research Questions: TPB Analyses

Based on Ajzen's recommendations (1991) multiple regression analyses were conducted to predict intention to engage in regular leisure-time walking and overall 1) self-reported moderate to vigorous walking and 2) group attendance using the multiple imputation data set described above. First, all TPB constructs (affective attitude, instrumental attitude, PBC, injunctive norm, descriptive norm) were entered into the model simultaneously to predict intention using standard multiple regression (Equation 1a). Next, hierarchical linear regression was used to predict moderate to vigorous walking (MVW; Equation 1b-c) and group attendance (Equation 1d-e) in two blocks. First, dependent variables were regressed on intention and PBC (Model 1), followed by the remaining TPB constructs (i.e., AA, IA, DN, IN; Model 2; Ajzen, 1991). Multiple regression analyses were conducted using Statistical Package for Social Sciences (SPSS

21.0; IBM Corporation, 2012). NORM version 2.03 for Windows multi-parameter and scalar inference (Shafer, 1999) was used to combine the results from each imputation data sets.

$$Intention = b_0 + b_1(AA) + b_2(IA) + b_3(PBC) + b_4(IN) + b_4(DN) + \varepsilon_i \quad \text{(1a)}$$

$$MVW = b_0 + b_1(Intention) + b_2(PBC) + \varepsilon_i \quad \text{(1b: Model 1)}$$

$$MVW = b_0 + b_1(Intention) + b_2(PBC) + b_3(AA) + b_3(IA) + b_4(IN) + b_5(DN) + \varepsilon_i \quad \text{(1c: Model 2)}$$

$$Att = b_0 + b_1(Intention) + b_2(PBC) + \varepsilon_i \quad \text{(1d: Model 1)}$$

$$Att = b_0 + b_1(Intention) + b_2(PBC) + b_3(AA) + b_3(IA) + b_4(IN) + b_5(DN) + \varepsilon_i \quad \text{(1e: Model 2)}$$

Next, since PA intentions and patterns were expected to fluctuate over time, TPB predictors of ***change*** in 1) self-reported moderate to vigorous walking and 2) group attendance over the four-month walking program were examined using Hierarchical Linear Modeling (HLM; Raudenbush & Bryk, 2002). The multilevel models were fit using HLM 7.01 for Windows (Raudenbush, Bryk, Cheong, Fai, Congsdon, & du Toit, 2011).

Change analyses were conducted in 3 steps.

First, intercept-only models (dependent measures and no predictors) were fit to examine if variance existed at level 1 and level 2 for both moderate to vigorous walking and group attendance (Equation 1: a - d).

Level 1:	Level 2
$MVW_{ij} = \beta_{0i} + e_{ij}$ (1a)	$\beta_{0i} = \gamma_{00} + \mathrm{U}_{0i}$ (1b)
$Group\ Attendance_{ij} = \beta_{0i} + e_{ij}$ (1c)	$\beta_{0i} = \gamma_{00} + \mathrm{U}_{0i}$ (1d)

Variance components were used to calculate an ICC for each measure (ICC = between person variation (between person variation + within-person variation)).

Second, whether each of the measures displayed significant longitudinal change was tested using empty longitudinal models. A curvilinear relationship between time in

the walking program and self-reported moderate to vigorous walking and group attendance was anticipated; thus, models of change were fit by including both linear and quadratic time parameters (See equation 2a- h). The time parameters were grand mean centered to reduce multicollinearity. Specifically, moderate to vigorous walking and attendance for a given individual (i) at a given time (j) is a function of that individual's performance at the grand mean week since the start of the walking program (the intercept), plus his/her average individual linear and quadratic rates of change across weeks in walking program (the slopes), plus an error term (e_{ij}).

Level 1:

$$MVW_{ij} = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \quad (2a)$$

$$Att = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \quad (2e)$$

Level 2:

$$\beta_{0i} = \gamma_{00} + U_{0i} \quad (2b)$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \quad (2c)$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \quad (2d)$$

$$\beta_{0i} = \gamma_{00} + U_{0i} \quad (2f)$$
$$\beta_{1i} = \gamma_{10} + U_{1i} \quad (2g)$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \quad (2h)$$

Third, TBP constructs were examined as level-2 predictors of change in walking and group attendance over the 4-month program. In a similar fashion to overall program analyses, variables were entered in two blocks as per Ajzen's recommendations. Level 2 predictors were grand mean centered. The level 2 parameter estimates represented the effect of between-person differences in the TPB constructs on self-reported walking and group attendance.

Level 1:

$$MVW = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \quad (3a)$$
$$\gamma_{02}(PBC) + U_{0i} \quad (3b)$$

$$MVW = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}\ (Time\ centered\ squared) + e_{ij} \quad (3e)$$
$$\gamma_{02}(PBC) + \gamma_{03}(AA) + \gamma_{05}(IN) + \gamma_{06}(DN)\ U_{0i} \quad (3f)$$

Level 2

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(Intention) +$$

$$\beta_{1i} = \gamma_{10} + U_{1i} \quad (3c)$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \quad (3d)$$

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(Intention) + \gamma_{04}(IA) +$$

$$\beta_{1i} = \gamma_{10} + U_{1i} \quad (3g)$$
$$\beta_{2i} = \gamma_{20} + U_{2i} \quad (3h)$$

$$Att = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}(Time\ centered\ squared) + e_{ij} \quad (3i)$$
$$\gamma_{02}(PBC) + \mathrm{U}_{0i} \quad (3j)$$

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(Intention) +$$
$$\beta_{1i} = \gamma_{10} + \mathrm{U}_{1i} \quad (3k)$$
$$\beta_{2i} = \gamma_{20} + \mathrm{U}_{2i} \quad (3l)$$

$$Att = \beta_{0i} + \beta_{1i}(Time\ centered) + \beta_{2i}(Time\ centered\ squared) + e_{ij} \quad (3m)$$
$$\gamma_{02}(PBC) + \gamma_{03}(AA) +$$
$$\gamma_{05}(IN) + \gamma_{06}(DN)\ \mathrm{U}_{0i} \quad (3n)$$

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(Intention) + \gamma_{04}(IA) +$$
$$\beta_{1i} = \gamma_{10} + \mathrm{U}_{1i} \quad (3o)$$
$$\beta_{2i} = \gamma_{20} + \mathrm{U}_{2i} \quad (3p)$$

Secondary Research Questions: Action Control

To examine action control, participants were separated by intention to walk regularly over the next four months (non-intender, intender) and resulting 1) regular self-reported moderate to vigorous walking (low, high) and 2) regular group attendance over the four-month walking program. Low-high cut-points were based on 1) 150 minutes or more of average weekly minutes of moderate to vigorous walking and 2) average attendance of 3 or more walks per week. This allowed for 4 possible categories of action control for each analysis: a) non-intenders (low, low), b) non-intenders who walked (low, high), c) successful intenders (high, high) and d) unsuccessful intenders (high, low). Only 2 categories (successful intenders (SI), unsuccessful intenders (UI)) were used for subsequent logistic regression analyses because response rates of other categories were too low for meaningful analyses (See Figure 5 and 6). SPSS was used to conduct logistic regression analyses. Statistic Analysis Software version 9.3 (SAS Institute, year) and the combine chi macro version 1.0 (Alison, 2000) were used to pool the results from the SPSS logistic regression outputs.

Next, social cognitive and self-regulatory predictors of action control group membership (SI, UI) were identified based on 1) moderate to vigorous walking and 2) attendance using binary logistic regression. Antecedents of action control entered into the

model in a hierarchical fashion based on their proximity to behaviour. Odds of being a successful intender was predicted from the most proximal antecedent, habit, first (block 1), followed by habit and self-monitoring, next (block 2), and then, habit, self-monitoring, and TPB constructs, last (AA, IN, PBC; block 3; See Equations 2a, b and c).

$$odds\ of SI = b_0 + b_1(habit) + \varepsilon_i \quad (2a)$$

$$odds\ of\ SI = b_0 + b_1(habit) + b_2(SM) + \varepsilon_i \quad (2b)$$

$$odds\ of\ SI = b_0 + b_1(habit) + b_2(SM) + b_3(AA) + b_4(IA) + b_5(PBC) + \varepsilon_i \quad (2c)$$

where odds of SI= $ln(odds\ of\ SI) = ln\left(\frac{p}{1-p}\right)$

Next, we identified level 2 social cognitive and self-regulatory predictors of *change* in action control group membership (SI, UI) based on 1) moderate to vigorous walking and 2) attendance using HLM full penalized quasi-likelihood (PQL) approach. First, whether there was significant longitudinal change in action using empty longitudinal models was examined. Models of change were fit by including both linear and quadratic time parameters.

Level 1	Level 2
Block #1	
Prob ($Action\ control_{ti}$=1/π_i) = $\emptyset_{ti}$	$\pi_{0i} = \beta_{00} + U_{0j}$
$\log\left[\frac{\phi_{ti}}{(1-\phi_{ti})}\right] = \eta_{ti}$	$\pi_{1i} = \beta_{10}$
$\eta_{ti} = \pi_{0i} + \pi_{1i}(time\ centered) + \pi_{2i}(time\ centered\ squared)$	$\pi_{2i} = \beta_{20}$

Next, level 2 predictors were added to the longitudinal models. Analyses were conducted in hierarchical function in a similar fashion to the overall program analyses.

Level 1	Level 2
Block #1	

Prob ($Action\ control_{ti}$=1/π_i) = $\emptyset_{ti}$ $\pi_{0i} = \beta_{00} + \beta_{01}(Habit) + U_{0j}$

$\log\left[\frac{\phi_{ti}}{(1-\phi_{ti})}\right] = \eta_{ti}$ $\pi_{1i} = \beta_{10}$

$\eta_{ti} = \pi_{0i} + \pi_{1i}(time\ centered) + \pi_{2i}(time\ centered\ squared)$ $\pi_{2i} = \beta_{20}$

Block #2

Prob ($Action\ control_{ti}$=1/π_i) = $\emptyset_{ti}$ $\pi_{0i} = \beta_{00} + \beta_{01}(Habit) + \beta_{02}(SM) + U_{0j}$

$\log\left[\frac{\phi_{ti}}{(1-\phi_{ti})}\right] = \eta_{ti}$ $\pi_{1i} = \beta_{10}$

$\eta_{ti} = \pi_{0i} + \pi_{1i}(time\ centered) + \pi_{2i}(time\ centered\ squared)$ $\pi_{2i} = \beta_{20}$

Block #2

Prob ($Action\ control_{ti}$=1/π_i) = $\emptyset_{ti}$ $\pi_{0i} = \beta_{00} + \beta_{01}(Habit) + \beta_{02}(SM) + \beta_{03}(AA) + \beta_{04}(IA) + \beta_{05}(PBC) + U_{0j}$

$\log\left[\frac{\phi_{ti}}{(1-\phi_{ti})}\right] = \eta_{ti}$ $\pi_{1i} = \beta_{10}$

$\eta_{ti} = \pi_{0i} + \pi_{1i}(time\ centered) + \pi_{2i}(time\ centered\ squared)$ $\pi_{2i} = \beta_{20}$

Results

Theory of Planned Behaviour

Preliminary Analyses

Basic descriptive statistics and bivariate correlations of the TPB and other social cognitive constructs and the walking variables can be found in Tables 26-28 of the additional files at the end of the current chapter. Attendance was correlated significantly with habit (r=0.242, *p*=0.028) and self-monitoring (r=0.448, *p*=0.000), but did not significantly correlate with any of the TPB constructs (r<0.02, *p*>.05). Self-reported moderate to vigorous walking did not correlate significantly with any of the TPB or other social cognitive constructs (r's all <0.02, *p*>05).

Predicting Overall Moderate to Vigorous Walking and Program Attendance

First, we examined TPB predictors of intention and walking using hierarchical linear regression. Findings from the hierarchical regression analyses examining TPB

predictors of intention, self-reported walking and group attendance can be found in Table 22 at the end of this chapter. TPB constructs did not predict a significant amount of variance in intention (p=0.199). In addition, neither TPB model (model 1: proximal predictors (intention and PBC) and model 2: all TPB constructs) explained a significant amount of variance in either 1) self-reported walking (model 1: p=.470 and model 2 p=. 741) or 2) group attendance (model 1: p=.113 and model 2: p =.435).

Predicting Changes in Moderate to Vigorous Walking and Attendance over the 4 Month Walking Program

HLM analyses were conducted in 3 steps. Results of the HLM analyses are summarized in Table 23. First, to examine if variance existed at level 1 and level 2 intercept only models were run for self-reported walking and group attendance (See Equations 1: a-b). The ICC for self-reported moderate to vigorous walking was 0.237, suggesting that 23.7% of the variance in self-reported walking was at the group level and 76.3% of the variance was at the individual level. The ICC for attendance revealed that 18.9% of the variance in group attendance was at the group level and 81.1% at the individual level.

Second, we examined whether individual's self-reported walking and group attendance changed over time in the walking program by fitting empty longitudinal models (See equations 2a-2h). Significant longitudinal change was observed for both weekly moderate to vigorous walking and group attendance. Specifically, for each additional week in the walking program over the grand mean, self-reported MVW increased significantly (p<.001). In line with expectations, with each additional week in the walking program, increases in walking occurred at a decreasing rate (p<.001). Effect sizes were moderate.

Next, level 2 predictors were added to the longitudinal models of MVW and attendance. The TPB constructs were added in 2 blocks (Model 1: proximal predictors, Model 2: all TPB constructs). None of the level 2 predictors in either model of MVW or attendance were significant (p>.05; See Table 23).

Action Control

Preliminary Analyses

Based on overall program 1) attendance and 2) MVW, we classified participants in 4 quadrants of action control (a) non-intenders ((1) 1.9% and (2) 1.7%), b) non-intenders who walked ((1)<1%, (2)< 1%), c) successful intenders ((1) 3.3%, (2) 30.8%), and unsuccessful intenders ((1) 94.7%, (2) 67.3%). Frequencies across the four quadrants of action control are presented in Figure 5-6 of the additional files at the end of this chapter. For group membership using attendance data, approximately 95% of the sample were unsuccessful intenders, as such sample sizes of other groups were too small to conduct logistic regression analyses. Further *overall program* analyses with moderate to vigorous walking data were limited to 2 categories (successful intenders vs. unsuccessful intenders).

Frequency of successful intenders and unsuccessful intenders was also examined across waves of study using 1) attendance and 2) moderate to vigorous walking data. These results are summarized in Table 29 in the additional files at the end of this chapter. Frequencies of successful intenders increased from waves 2 to waves 3 ((1) 22.1% to 27.9%, and (2) 34.1% to 49.3%) and then decreased slightly across the last 2 study waves ((1) 18.8 to 16.5, and (2) 44.3 to 40.7%).

Predicting Overall Program Action Control Group Membership

Next, binary logistic regression was used to predict the odds of being a successful intender (versus unsuccessful intender) from social cognitive and self-regulatory variables. Findings from this analysis are depicted in Table 24. None of the omnibus tests of the models (model 1: habit, model 2: habit and SM, and model 3: habit, SM, and TPB) were significant (model 1: F=1.98 (1, 127.12), p=0.16; model 2: F=1.26 (2, 125.34), p =0.29, model 3: F=0.86 (5, 178.13), p=.51).

Predicting Change in Action Control Group Membership

Next, odds of being a successful intender across the five waves of measurement was predicted using Hierarchical Generalized Linear Modelling (HGLM). Results of the HGLM analyses are presented in Table 25. Analyses were conducted in 2 steps.

First, empty longitudinal models of action control were fit. The probability that an individual in the sample was a successful intender at the grand mean weeks in the program was 0.387 (log-odds = -.458, p=.094)) based on self-reported walking data and 0.224 (log-odds = -1.240, p<.001) based on attendance data. The odds of being a successful intender increased significantly with each additional week in the walking program above the grand mean (p<.001 for both self-reported walking and attendance data). Moreover, increases in the odds of being a successful intender decreased with each additional week in the walking program (p<0.001 for both self-reported walking and attendance).

Next, the probability of being a successful intender as a function of time in the walking program was examined and level 2 social cognitive and self-regulatory predictors. None of the level 2 social cognitive and self-regulatory variables were significantly associated with the odds of being a successful intender based on self-

reported walking data (*p*'s all >.05). In contrast, controlling for all other predictors, individuals who self-monitored were significantly more likely to be successful intenders (Model 2: *p*=.002 and Model 3: *p*=.005) based on attendance data. Effect sizes were moderate (Model 2 OR=4.379 and Model 3 OR=3.950) based on Chen, Cohen & Chen's (2010) recommendation for interpreting effect size estimates.

Discussion

Primary Research Questions

In the present investigation, the predictive utility of TPB (a motivational theory focused on intention information) and M-PAC (a contemporary post-intentional model of behaviour) in explaining walking behaviour was examined in a sample of inactive older adults enrolled in a four-month supervised walking program. With respect to TPB analyses, it was anticipated that TPB would significantly predict walking intentions (Hypothesis 1a), but not *overall* walking behaviour (Hypotheses 1b and c) or *change* in walking behaviour over the course of the walking program (Hypothesis 2 a-c). Contrary to expectation, none of the TPB constructs were significant predictors of walking intentions. These findings are inconsistent with existing literature in PA and a wide number of other health behaviours that has found that TPB predicts between 40-60% of the variance in intention (Armitage & Conner, 2001; Dean et al., 2007; French et al., 2005; Godin & Kok, 1996; Hagger, Chatzisarantis, & Biddle, 2002; Lucidi, Grano, Barbaranelli, & Violan, 2006; McEachan, Conner, Taylor, & Lawton, 2011; Rhodes et al., 2006). Within this body of work, both attitude and PBC, but not SN, have been moderately associated with intention (Downs & Hausenblas, 2005; McEachan et al., 2011). In the current sample, all participants were high intenders and the vast majority

reported they intended to walk three times per week resulting in very limited variance in intention in the sample.

In contrast, study hypotheses regarding TPB and walking behaviour were confirmed. As anticipated walking behaviour was significantly increased across weeks in the walking program and these improvements occurred at a decreasing rate over time. As expected, neither TPB models (model 1 (intention and PBC) and model 2 (all TPB constructs)) significantly predicted *overall program* walking behaviour or *changes* in walking behaviour. Findings were observed across both measurement types (i.e., attendance, self-reported walking). This is consistent with extensive literature on the marked discrepancy between intention and behaviour (Rhodes & de Bruijn, 2013a; Rhodes & de Bruijn, 2013b; Rhodes & Dickau, 2012; Rhodes & Dickau, 2013). As expected, although the sample had high intention to walk at the start of the walking program many participants failed to translate this behaviour into action. These results were consistent across both measures of walking behaviour. In the present study, participants were inactive at the outset. Given that existing research has identified past behaviour as one of the strongest predictors of PA behaviour (Hagger et al., 2002; McEachan et al., 2011), it is not surprising that the walking group participants failed to act on their intentions to engage in regular leisure time walking. The null findings regarding TPB and walking behaviour is suggestive that other factors, in addition to those targeting intention formation, could better explain intention-behaviour profiles (Rhodes & de Bruijn, 2013a; de Vries, Mesters, Van de Steeg, & Honing, 2005; Gollwitzer & Brandstatter, 1997; Schwarzer, 2008).

Secondary Research Questions

In this vein, the secondary analyses predicted that the sample would be comprised of only successful and unsuccessful intenders and that these intention-behaviour groupings would be significantly associated with action control constructs, especially self-monitoring, in both *overall program* and *behaviour change* analyses. Conforming to these hypotheses, the sample was high on intention and had poor overall attendance. Based on group attendance (cut-off of 3 walks per week or more), 95% of the samples were composed of unsuccessful intenders. Participants in this study were also encouraged to engage in walking and PA outside of scheduled walks in order to achieve recommended minimum PA guidelines for older adults (cut off of 150 min or more of moderate to vigorous PA). Based on self-reported walking data, the sample was comprised of about 31% successful intenders, 67% unsuccessful intenders, 2% non-intenders and <1% non-intenders who subsequently walked.

The distribution of intention-behaviour groupings resulted in 67% to 95% (self-reported vs. attendance data) of high intenders failing to translate their intentions into action; a value much greater than that found in the meta-analytic work of Rhodes & de Bruijn (2012b), where 48% of participants failed to enact their intentions. To get a better understanding of these distributions, the distribution of successful intenders across waves of the study was examined. Frequency of successful intenders was increased from baseline to wave 3, and then decreased across the final two measurement waves. At wave 3 (about 9 weeks into the study) about 50% of participants were successful intenders and this dropped to 41% by wave 5. Based on attendance data, the pattern was similar but frequencies were lower (30% and 17% were successful intenders at wave 3 and 5, respectively). Midway through the program, the findings with self-report data, but not

attendance data, were consistent with the meta-analytic work of Rhodes and colleagues. The lack of consistency across types of PA measures fits with literature on current PA guidelines that has found that based on objective measures about 15% of the adult population gets enough PA, even though self-reported estimates are generally much higher (about 50%; (Colley et al., 2011).

The final group of analyses examined habit, self-regulation and social cognitive predictors of the odds of being a successful intender based on self-reported walking and attendance. When findings from *change analyses* were examined, hypotheses were partially confirmed. The odds of being a successful intender significantly increased with each week in the walking program, and these increases occurred at a decreasing rate over time. As anticipated, it was also found that self-monitoring had significant moderate effects on odds of being a successful intender using attendance data (Model 2 (i.e., model with SM and habit): OR: 4.379), equivalent to d=0.7 and model 3 (i.e., all action control constructs): OR=3.950, equivalent to a d=0.7). Examination of behaviour change analyses using self-reported walking data revealed that none of the action control constructs significantly predicted odds of being a successful intender. However, self-monitoring did have small, non-significant positive effects on odds of being a successful intender (Model 2 (i.e., model with SM and habit): OR=2.022, equivalent to d=0.3 and Model 3 (i.e., all action control constructs): OR =1.948, equivalent to d=0.3). Affective attitude also had small, non-significant positive effects on the odds of being a successful intender (model 2 (i.e., model with habit and SM): OR=1.648, equivalent of d=0.25). Contrary to expectation, none of the action control constructs were significant predictors of action control based on *overall program* self-reported walking data. When ORs were examined one OR was practically significant: affective attitude (Model 3 (all constructs):

OR=1.590, d=0.22) had small non-significant effects on the odds of being a successful intender.

The findings regarding self-monitoring were not surprising. Self-monitoring was recorded in a weekly calendar. It was the only action control construct measured objectively. In the M-PAC model, self-regulation is viewed as particularly important when adopting new behaviours. Individuals in the current study were inactive older adults with high intentions who were in the process of adopting regular leisure time walking behaviour. Research specifically on older adults has found self-regulation to be a significant predictor of PA behaviour (McAuley et al., 2011; Umstattd & Hallam, 2007; Umstattd, Wilcox, Saunders, Watkins, & Dowda, 2008). Further, research with older samples has found that interventions targeting self-monitoring are significantly better than interventions that do not (Conn,Valentine, & Cooper, 2002).

One of the most puzzling of the findings in this study is the lack of association between perceived control and intention and behaviour across both the TPB and action control analyses. Existing literature from the perspective of both TPB and the action control framework has identified PBC as a strong predictor of PA and intention (McEachan et al., 2011; Rhodes, Fiala, & Nasuti, 2012; Rhodes & de Bruijn, 2013a). One might expect that older adults would feel limited controllability over their PA, based on age-related declines in physical functioning, reliance on others for transportation, and other more pressing obligations (e.g., medical appointments). However, time, the most commonly reported obstacle to engaging in PA (e.g., Rhodes & Kowalski, 2014), may not be as concerning for older adults as younger populations. While older adults may still have many obligations, they have more flexibility in their schedules to accommodate

their PA around their many obligations compared to college students and working adults. The bulk of current work in this area is largely restricted to these younger populations.

Moreover, walking in particular is easy to do and requires limited resources and skills. The current study was designed to increase participant's controllability over their walking. They were provided with a calendar of 11 potential weekly walks throughout town and asked to try to attend at least three. Participants had support from a group fitness instructor and personal trainer at each session to help them through the process of adopting regular leisure time walking. They were also given a coaching session and a package of self-regulatory tools at the outset of the program to help increase their perceived control over regular leisure time walking. It may be that, although PBC was poor at baseline prior to the intervention, these intervention efforts may have increased their sense of control. Given that action control constructs were measured at baseline only, it was not possible to examine whether change in PBC may have been a stronger predictor of intention-behaviour groupings over the course of the walking program.

The baseline testing occurred prior to the initial intervention (i.e., individualized coaching session, introduction to the walking program). At this time, participants may not have had a clear understanding of whether they would enjoy the program or feel in control of the program. If TPB constructs were measured both before and after the initial intervention, PBC and affective attitude may have had more predictive utility.

It was also anticipated that habit, although less so than self-monitoring, might be a significant contributor to the models. Past research has found that habit has a significant association with intention-behaviour profiles, specifically in translating behavioural adoption into maintenance (de Bruijn, Rhodes, & van Osch, 2012; Rhodes et al., 2012; Rhodes, de Bruijn, & Matheson, 2010; Rhodes & de Bruijn, 2013; van Bree et al., 2013).

In one study of older adults, van Bree et al. (2013) found that intention significantly predicted behaviour in older adults with low to medium habit strength, while intention has limited association with behaviour when habit is high. Although the findings of the current study were contrary to expectation, it could also be argued that measuring habit formation at the outset of a walking program in inactive older adults, although important to establish baseline habit strength, is of limited predictive utility for examining PA adoption (or maintenance). It is not all that surprising that habit did not significantly predict action control, given that being inactive was a requirement to be in the study. In this study, the sample was undergoing the process of translating intention into action; it is unlikely that they had reached the stage of behavioural maintenance, where reflexive action like habit and identify formation would be more strongly associated with behaviour (Rhodes & de Bruijn, 2013a).

Methodological Considerations

This study is the first study to examine PA action control from the perspective of M-PAC in older adults. Preliminary work suggests that the model has some predictive value with respect to older adult's walking behaviour. In particular, self-monitoring emerged as an important predictor of action control. Moreover, the study used both objective and self-reported walking measures to examine intention-behaviour compared to past work that has relied largely on self-report data only. However, the study also had several limitations. First, the breadth of action control constructs that were examined was limited to affective attitude, PBC, habit, and self-monitoring. Second, the study was restricted to a sample of high intenders. Third, we measured action control constructs at baseline only.

The current study and a large body of existing research suggest that even those who have high intentions to be active fail to do so. The current work was a preliminary investigation of this framework in older adults and found encouraging evidence of the role of self-regulation in the process of adopting regular leisure time walking. Future work should continue to validate the M-PAC model in older adults using a broader set of action control constructs (cross-behavioural conflict, other self-regulatory strategies outside of self-monitoring, identify formation). This work should also examine both baseline behaviour and change in action control constructs over the course of the intention-behaviour continuum using prospective observational designs with long-term follow-up. In order to further understanding of the determinants of behaviour across the intention-behaviour continuum a more varied distribution of intention-behaviour profiles should be examined (i.e., intenders and non-intenders). Research efforts into antecedents of action-control in more diverse samples (i.e., youth through older adults, not just convenient samples like university undergraduates) are also warranted.

Given the alarming, widespread rates of inactivity in our society and the associated health risks, research examining the antecedents of PA is a critical step in developing interventions to promote PA. As researchers, we turn to theoretical models to help understand and organize our findings regarding determinants of PA. Studies exploring the antecedents of PA from the perspective of theories of intention formation, like TPB, have predominated research efforts for many years. Yet, little movement has been made in our PA promotion efforts. In fact, PA rates are widespread and more problematic than ever before. Rates of inactivity are staggering across the entire lifespan and with current obesogenic lifestyles and environments it can be expected that inactivity will trouble society for years to come. Further research examining the action control

constructs that are predictive of intention-behaviour relations will help clarify the complex relations between PA intention and behaviour. Research efforts into models explaining behaviour in more varied samples across the continuum of intention behaviour from intention formation to PA adoption and maintenance are crucial for filling in the gap in how to translate high intention into behaviour. Achieving a greater understanding of PA behaviour and action control constructs as they pertain to intention formation, adoption and behavioural maintenance is an important initial step in designing interventions targeting PA behaviour at different stages of the intention-behaviour continuum.

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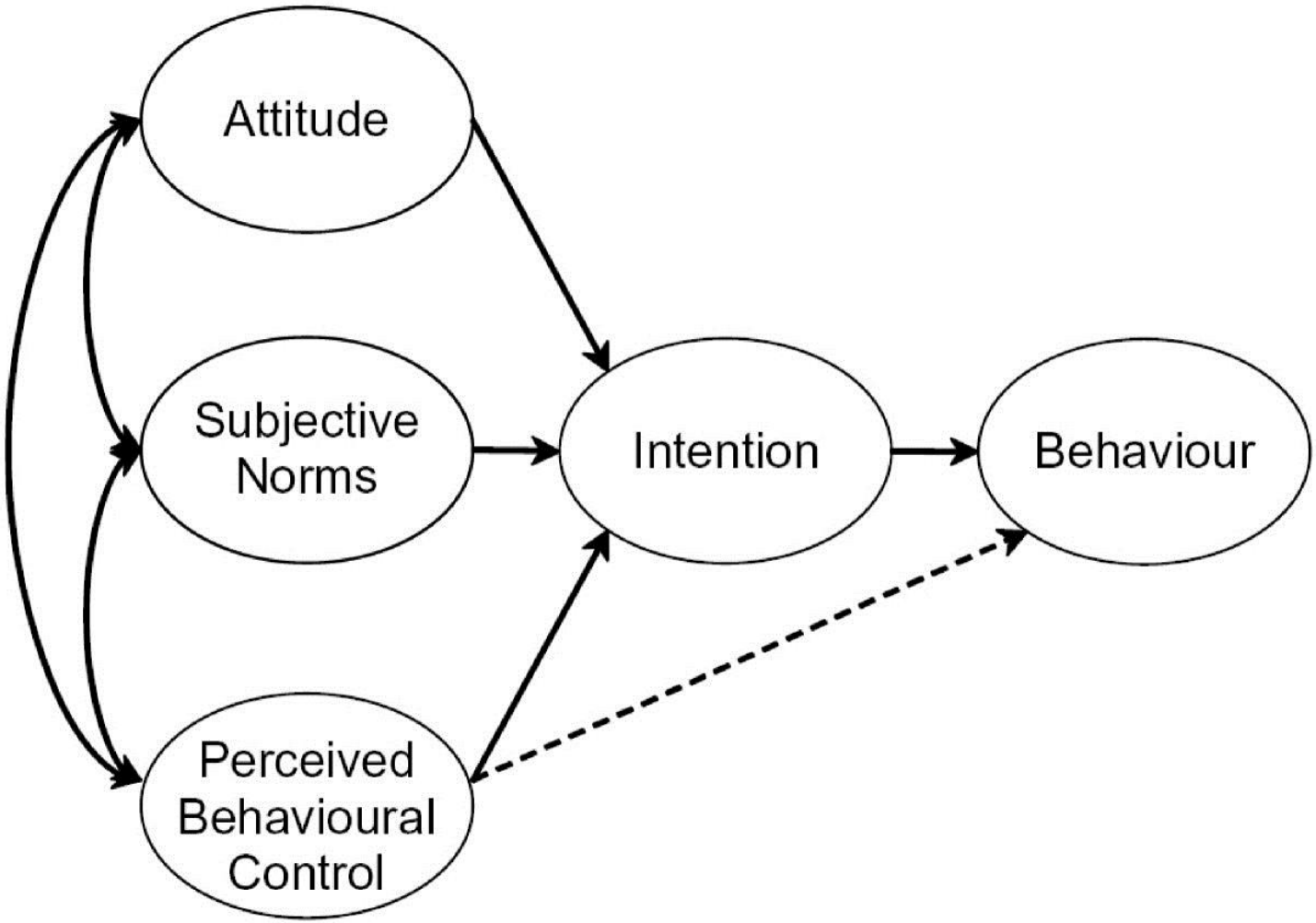
Tables and Figures

Figure 2. Schematic of the Theory of Planned Behaviour



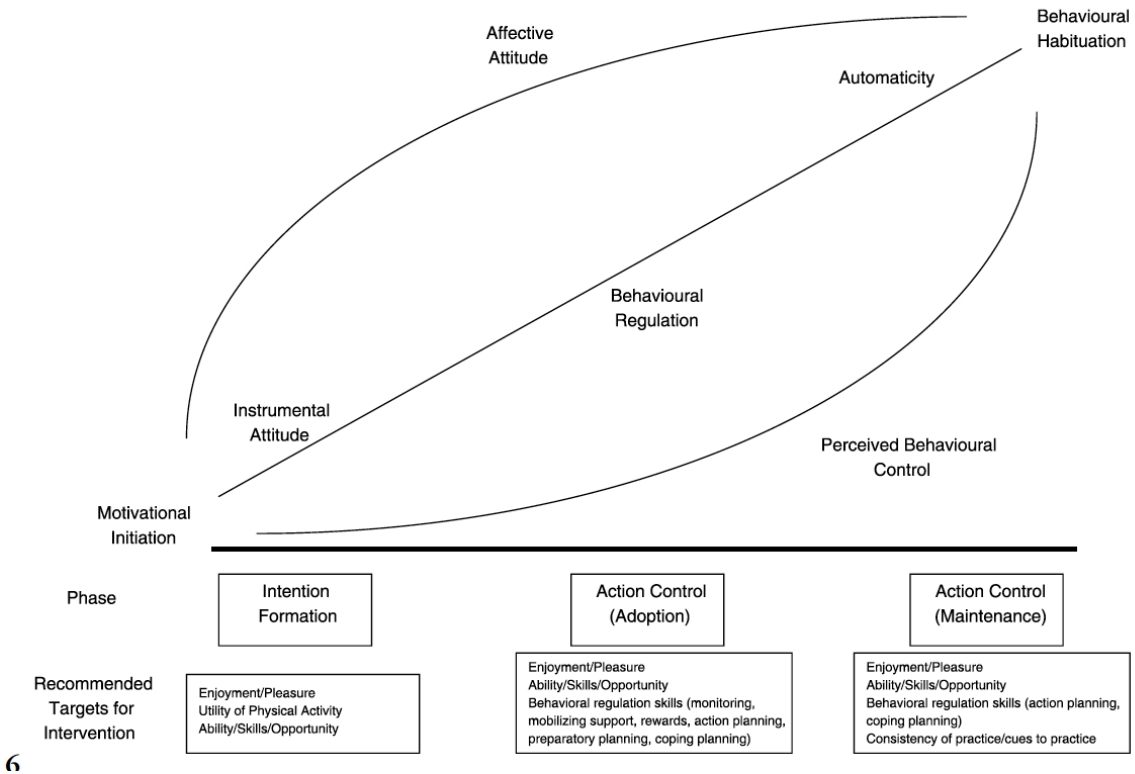


Figure 3. Schematic of the Multi-Process Action Control Model (Rhodes & de Bruijn, 2013)

Table 22. Hierarchical Regression Analysis of the Theory of Planned Behaviour Predictors of Intention and Behaviour

	B	Standard Error	T-Ratio	F	*df*	*p*
Intention						
Block #1				1.461	5, 1092	0.199
Constant	3.051	1.440	2.120	-0.880	11908	0.034
PBC	0.156	0.121	1.290	1.290	1109	0.198
Affective Attitude	-.934	0.106	0.880	0.460	2277	0.380
Instrumental Attitude	0.959	0.210	0.460	4159	4159	0.648
Injunctive Norm	0.117	0.126	0.930	2465	2465	0.353
Descriptive Norm	0.688	0.606	1.140	1360	1360	0.256
MVW						
Block #1				0.760	2, 234	0.470
Constant	147.099	208.997	2.000		115	0.048
Intention	44.856	58.466	0.770		113	0.445
PBC	49.634	61.181	0.810		138	0.419
Block #2				0.587	6, 692	0.741
Constant	37.821	24.092	1.570		1292	0.117
Intention	3.280	1.811	1.810		323	0.071
PBC	-2.104	1.888	-1.110		950	0.265
Affective Attitude	1.877	1.669	1.120		1494	0.261
Instrumental Attitude	-5.537	3.311	-1.670		1932	0.095
Injunctive Norm	3.474	2.013	1.730		1151	0.085
Descriptive Norm	0.275	0.923	0.300		1813	0.776
Attendance						
Block #1				2.183	2, 1064	0.113
Constant	12.565*	6.26206	2.010		435	0.045
Intention	3.484*	1.77001	1.970		380	0.050
PBC	-1.405	1.788804	-0.790		1268	0.432
Block #2				0.984	6, 1007	0.435
Constant	-27.821	24.092	1.570		1292	0.117
Intention	3.280	1.811	1.810		323	0.071

	B	Standard Error	T-Ratio	F	*df*	*p*
PBC	-2.104	1.888	-1.110		950	0.265
Affective Attitude	1.877	1.663	1.120		1494	0.261
Instrumental Attitude	-5.537	3.311	-1.670		1932	0.095
Injunctive Norm	3.474	2.013	1.730		1151	0.085
Descriptive Norm	0.275	0.923	0.300		1813	0.766

Notes: PBC = perceived behavioural control; df = degrees of freedom.

Table 23. Moderate to Vigorous Walking as a Function of Time in the Walking Program and Theory of Planned Behaviour Constructs

	Coefficient	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*
GLTQ										
Block #1										
Intercept, γ_{00}	134.752	8.503	15.848	104	<0.001	5.262	0.517	10.187	104	<0.001
						-0.706	0.087	-8.132	104	<0.001
Block #2										
Intercept, γ_{00}	134.993	8.477	15.924	102	<0.001	5.270	0.497	10.608	104	<0.001
Intention, γ_{01}	7.336	5.022	1.461	102	0.147	-0.707	0.083	-8.515	104	<0.001
PBC, γ_{02}	-2.904	5.554	-0.523	102	0.602					
Block #3										
Intercept, γ_{00}	135.099	8.436	16.015	98	<0.001	5.267	0.512	10.282	104	<0.001
AA, γ_{01}	7.430	6.077	1.223	98	0.224	-0.706	0.087	-8.102	104	<0.001
IA, γ_{02}	-15.728	11.866	-1.325	98	0.188					
Intention, γ_{03}	9.261	5.792	1.599	98	0.113					
IN, γ_{04}	-7.176	7.192	-0.998	98	0.321					
DN, γ_{05}	2.361	3.419	0.690	98	0.492					
PBC, γ_{06}	0.924	6.788	0.136	98	0.892					
Attendance										
Block #1										
Intercept, γ_{00}	1.430	0.109	13.146	105	<0.001	0.044	0.008	5.476	105	<0.001
						-0.015	0.002	-8.748	105	<0.001
Block #2										
Intercept, γ_{00}	1.432	0.109	13.181	103	<0.001	0.044	0.007	6.144	105	<0.001
Intention, γ_{01}	0.072	0.046	1.547	103	0.125	-0.015	0.002	-9.271	105	<0.001
PBC, γ_{02}	-0.051	0.050	-1.007	103	0.316					
Block #3										
Intercept, γ_{00}	1.431	0.107	13.378	99	<0.001	0.045	0.008	5.576	105	<0.001
AA, γ_{01}	0.060	0.077	0.781	99	0.437	-0.015	0.002	-8.702	105	<0.001
IA, γ_{02}	-0.175	0.151	-1.153	99	0.252					
Intention, γ_{03}	0.066	0.073	0.908	99	0.366					

	Coefficient	SE	*t*-ratio	*df*	*p*	Slope γ_{10}/ Slope γ_{20}	SE	*t*-ratio	*df*	*p*
IN, γ_{04}	0.071	0.090	0.787	99	0.433					
DN, γ_{05}	0.028	0.044	0.630	99	0.530					
PBC, γ_{06}	-0.065	0.086	-0.759	99	0.450					

Notes: GLTQ = Modified Godin leisure time questionnaire, CHAMPS PAQ = Community Healthy Activities Model Program for Seniors Physical Activity Questionnaire; PBC = perceived behavioural control; AA = affective attitude, IA = instrumental attitude, IN=injunctive norm, DN = descriptive norm, SE = standard error, and df = degrees of freedom; Higher scores on AA, IA, Intention, DN, and PBC reflect more positive attitudes, higher intention, greater social pressures towards, and greater perceived behavioural control towards engaging in regular leisure time walking; γ_{00} = average walking (minutes/week or sessions/week) at week =9.18 (GLTQ, CHAMPS PAQ) or 8.20 (attendance) for the grand mean of the overall sample; γ_{01} = average difference in walking (minutes/week or sessions/week) for every additional unit (score) above the grand mean affective attitude of the overall sample at baseline, holding all other variables constant, γ_{02} = average difference in walking (minutes/week or sessions/week) for every additional unit (score) above the grand mean instrumental attitude of the overall sample at baseline, holding all other variables constant, γ_{03} = average difference in walking (minutes/week or sessions/week) for every additional unit (score) above the grand mean intention of the overall sample at baseline, holding all other variables constant, γ_{04} = average difference in walking (minutes/week or sessions/week) for every additional unit (score) above the grand mean injunctive norm of the overall sample at baseline, holding all other variables constant; γ_{05} = average difference in walking (minutes/week or sessions/week) for every additional unit (score) above the grand mean descriptive norm of the overall sample at baseline, holding all other variables constant, γ_{06} = average difference in walking (minutes/week or sessions/week) for every additional unit (score) above the grand mean perceived behavioural control of the overall sample at baseline, holding all other variables constant; γ_{10} = average rate of linear change in moderate to vigorous walking (minute/week or session per week) per additional week in the study above the grand mean (9.18 weeks (GLTQ, CHAMPS PAQ) or 8.20 weeks (Attendance)); time centered), holding all other variables constant; γ_{20} = average rate of quadratic change in moderate to vigorous walking per additional week in the study above the grand mean ((9.18 weeks (GLTQ, CHAMPS PAQ) or 8.20 weeks (Attendance)); time centered and then squared), holding all other variables constant.

Table 24. Logistic Regression Analysis: Overall Program Action Control

	B	SE	*p*	OR	95% CI	
					Lower	Upper
Block # 1						
Constant	-1.792	.899	.049	.167	.028	.993
Habit	.274	.208	.190	1.315	.872	1.985
Block # 2						
Constant	-2.030	1.081	.064	.131	.015	1.125
SM	.268	.210	.204	1.307	.863	1.980
Habit	.378	.836	.653	1.459	.278	7.667
Block # 3						
Constant	-3.108	5.229	.553	.045	.000	1327.425
Affective attitude	.463	.466	.321	1.590	.634	3.984
Instrumental Attitude	-.209	.778	.789	0.811	.175	3.758
PBC	.098	.422	.816	1.103	.481	2.530
Habit	.220	.223	.327	1.246	.800	1.939
SM	.371	.849	.663	1.449	.269	7.813

Notes: GTLQ = Modified Godin Leisure Time questionnaire, PBC = perceived behavioural control, SM = self-monitoring.

Table 25. Action Control as a Function of Time in the Walking Program and Social Cognitive Constructs

	Coefficient	SE	*t*	*df*	*p*	OR	CI	γ_{10}/ γ_{20}	SE	*t*	*df*	*p*	OR	CI
MVW														
Block #1														
Intercept, γ_{00}	-0.458	0.271	-1.693	80	0.094	0.632	0.369 to 1.084	0.211	0.040	5.268	259	<.001	1.236	1.142 to 1.337
								-0.026	0.005	-4.884	*259*	<.001	0.974	0.964 to 0.984
Block #2														
Intercept, γ_{00}	-0.476	0.271	-1.760	79	0.082	0.621	0.362 to 1.065	0.212	0.040	5.281	259	<.001	1.236	1.142 to 1.337
Habit, γ_{01}	0.237	0.147	1.610	79	0.111	1.268	0.945 to 1.701	-0.026	0.005	-4.866	259	<.001	0.974	0.964 to 0.984
Block #3														
Intercept, γ_{00}	-0.952	0.437	-2.179	78	0.032	0.386	0.162 to 0.921	0.213	0.040	5.313	259	<.001	1.237	1.143 to 1.338
Habit, γ_{01}	0.209	0.148	1.405	78	0.164	1.232	0.917 to 1.655	-0.026	0.005	-4.838	259	<.001	0.974	0.964 to 0.985
SM, γ_{02}	0.704	0.502	1.403	78	0.164	2.022	0.745 to 5.491							
Block #4														
Intercept, γ_{00}	-0.942	0.441	-2.143	75	0.036	0.389	0.162 to 0.939	0.212	0.040	5.317	259	<.001	1.237	1.143 to 1.338
Habit, γ_{01}	0.151	0.157	0.961	75	0.339	1.163	0.851 to 1.590	-0.026	0.005	-4.817	259	<.001	0.974	0.964 to 0.985
SM, γ_{02}	0.664	0.511	1.299	75	0.198	1.943	0.701 to 5.384							
AA, γ_{03}	0.499	0.376	1.328	75	0.188	1.648	0.779 to 3.486							
IA, γ_{04}	-0.098	0.669	-0.147	75	0.884	0.907	0.239 to 3.437							
PBC, γ_{05}	-0.076	0.355	-0.214	75	0.831	0.927	0.457 to 1.880							
Attendance														
Block #1														
Intercept, γ_{00}	-1.240	0.228	-5.430	80	<.001	0.289	0.184 to 0.456	0.135	0.046	2.953	322	0.003	1.144	1.046 to 1.252
								-0.030	0.008	-4.039	322	<.001	0.970	0.956 to 0.985
Block #2														
Intercept, γ_{00}	-1.260	0.231	-5.451	79	<.001	0.284	0.179 to 0.449	0.120	0.046	2.599	80	0.011	1.128	1.028 to 1.236
Habit, γ_{01}	0.184	0.126	1.455	79	0.150	1.202	0.935 to 1.545	-0.028	0.008	-3.796	80	<.001	0.972	0.957 to 0.986
Block #3														
Intercept, γ_{00}	-2.294	0.421	-5.448	78	<.001	0.101	0.044 to 0.233	0.137	0.029	4.780	322	<.001	1.147	1.084 to 1.213
Habit, γ_{01}	0.153	0.129	1.185	78	0.240	1.165	0.901 to 1.505	-0.031	0.005	-6.296	322	<.001	0.970	0.960 to 0.979
SM, γ_{02}	1.477	0.459	3.214	78	0.002	4.379	1.754 to 10.932							

	Coefficient	SE	*t*	*df*	*p*	OR	CI	γ_{10}/ γ_{20}	SE	*t*	*df*	*p*	OR	CI
Block #4														
Intercept, γ_{00}	-2.229	0.422	-5.280	75	<.001	0.108	0.046 to 0.250	0.137	0.046	2.966	322	0.003	1.147	1.047 to 1.256
Habit, γ_{01}	0.114	0.137	0.837	75	0.405	1.121	0.854 to 1.472	-0.031	0.008	-4.072	322	<.001	0.969	0.955 to 0.984
SM, γ_{02}	1.374	0.474	2.897	75	0.005	3.950	1.535 to 10.163							
AA, γ_{03}	0.098	0.319	0.308	75	0.759	1.103	0.584 to 2.084							
IA, γ_{04}	-0.463	0.577	-0.803	75	0.424	0.629	0.199 to 1.987							
PBC, γ_{05}	-0.088	0.294	-0.301	75	0.765	0.915	0.509 to 1.645							

Additional Files

Table 26. Descriptive Statistics for Social Cognitive Constructs, Overall Program Self-reported Moderate to Vigorous Walking, and Group Attendance

	N	Mean
AA	116	5.5250
IA	116	6.5699
IN	116	.0499
DN	116	4.940
PBC	116	.0765
Intention	116	3.520
Habit	116	3.445
Self-Monitoring	116	n/a
Total Attendance	116	24.730
Average weekly attendance	116	1.546
Total walking	116	578.843
Avg. weekly	116	115.769

Table 27. Descriptive Statistics for Moderate to Vigorous Walking Across Study Waves

	Wave 1			Wave 2			Wave 3			Wave 4			Wave 5		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
Attendance	118	0.00	0.00	112	1.47	1.24	105	1.45	1.32	101	1.23	1.14	97	0.99	1.15
MVW	115	26.53	37.48	82	117.62	77.69	65	149.46	81.82	77	138.14	92.14	91	122.09	91.09

Notes: MVW =Moderate to vigorous walking, M = mean, SD = standard deviation

Table 28. Correlation Matrix of Overall Program Walking and Theory of Planned Behaviour Variables

	1	2	3	4	5	6	7	8	9	10	Mean
Attendance	1	**.394***	.201	.093	-.092	.159	.131	-.041	**.242***	**.448****	24.730
MVW		1	.162	-.047	.133	-.008	.058	.131	.153	.111	578.843
AA			1	**.183***	-.028	.142	.158	.131	**.248****	.056	5.525
IA				1	.096	**.375****	-.057	**.219***	-.126	-.184	6.570
Intention					1	**.188***	.142	.182	.051	.012	3.520
IN						1	**.253****	**.323****	.118	.182	0.050
DN							1	.072	.099	.169	4.940
PBC								1	.038	-.001	0.077
Habit									1	.143	3.445
SM										1	58

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

Notes: n=116.

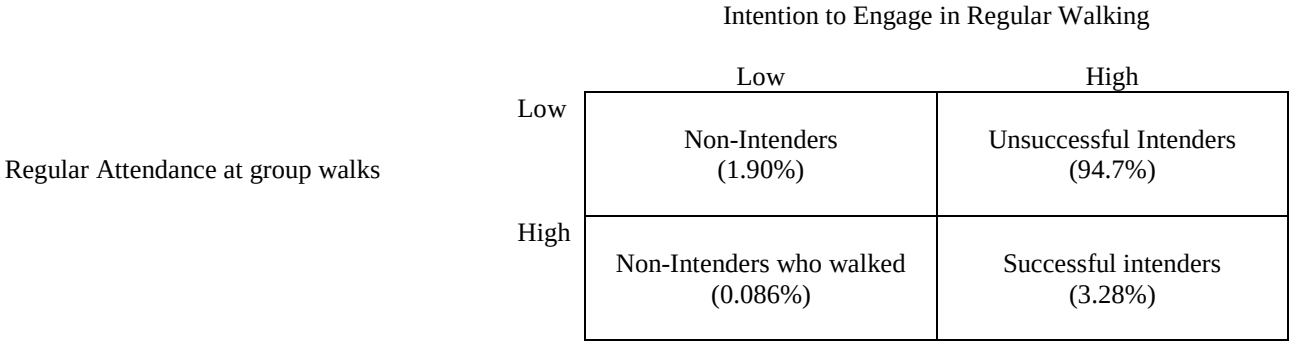


Figure 4. The Action Control Framework – Attendance

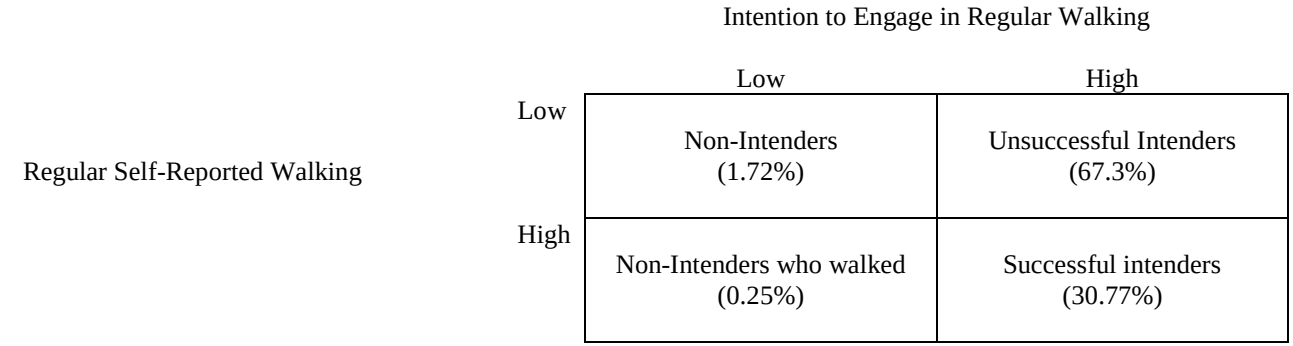


Figure 5. The Action Control Framework – Self-Reported Moderate to Vigorous Walking (modified GLTQ)

Table 29**.** Action Control Groupings

	Attendance			GLTQ		
	N	UI	SI	N	UI	SI
Wave 1	118	100.0	0.0	115	100.0	0.0
Wave 2	113	77.9	22.1	82	65.9	34.1
Wave 3	104	72.1	27.9	69	50.7	49.3
Wave 4	101	81.2	18.8	79	55.7	44.3
Wave 5	97	83.5	16.5	91	59.3	40.7

Notes: GLTQ = Modified Godin leisure time questionnaire Values are percentages; UI = unsuccessful intenders, SI=successful intenders

Chapter 5: General Conclusion

Older adults are vulnerable to age-related changes in cognitive functioning, especially executive functioning, attention and working memory, as part of both normal aging and age-related disease. With the rapid aging of the population and increased cognitive impairment and dementia in old age, it is important to ensure that while prolonging the lifespan of older adults, we are also developing strategies to maintain and promote cognitive health and maximize quality of life and years of independent functioning. Engaging in healthy lifestyle behaviours (physical activity (PA), healthy eating, intellectual stimulation, social engagement), especially PA holds promise for promoting cognitive health and preventing age-related cognitive decline.

Studies 1 and 2

Literature supporting the benefits of PA on the cognitive functioning of older adults continues to accumulate (Carvalho, Rea, Parimon, & Cusack, 2014; Gregory, Gill, & Petrella, 2013; Sofi et al., 2011). A growing body of evidence also suggests a strong cognitive contribution to walking (Amboni, Barone, & Hausdorff, 2013). Yet, a clear understanding of the within-person (i.e., fluctuations in one's own behaviour relative to their usual behaviour) and between-group effects (i.e., mean levels on behaviours between groups) of PA on cognitive performance and gait characteristics in older adults is lacking. Thus, the main study sought to distinguish the within- and between-person sources of variation of moderate to vigorous walking (MVW) and physical activity (MVPA) on cognitive functioning in a group of inactive apparently healthy older adults enrolled in a four-month supervised walking program. The secondary objective of the

main study was to examine the within-and between-person effects of healthy eating, social engagement and cognitive activity on cognition in walking group participants. Study 2 examined the relations (within- and between-person) between changes in gait, PA and cognitive function in the walking group participants.

Study 3

Greater understanding of the relations between PA, gait and cognition (Study of 1 and 2) is of limited use if older adults do not adopt or maintain a physically active lifestyle. A striking portion of the population is inactive and the prevalence increases with increasing age. Physical inactivity is associated with poorer physical and cognitive health and greater risk of chronic disease. An important public health and research agenda is to design programs to promote PA adoption and maintenance. To design effective interventions for this purpose, the antecedents of PA and walking intentions and behaviour in older adults must be better understood. In the present investigation, the predictive utility of the Theory of Planned Behaviour (TPB; a motivational theory focused on intention information) and Multi-Process Action Control model (M-PAC; a contemporary post-intentional model of behaviour) in explaining walking behaviour was examined in walking group participants.

To reach these aims, participants (n=159) were enrolled in a four-month supervised walking program and provided with materials and coaching to promote the adoption and maintenance of behaviours to enhance and maintain their cognitive health. Group participants were asked to walk *at least 3* times per week at a brisk intensity and were encouraged to get 150 minutes of MVPA per week. Social cognitive and health and demographic questionnaires were completed before the start of the walking program. At

baseline and at 6, 9, 12 and 16 weeks following the start of the walking program, participants completed 1) cognitive and diet assessments, 2) gait and fitness assessments and 3) self-report measures of PA and other health behaviours.

Significant increases in MVW were seen with each additional week in the walking program and improvements occurred at a decreasing rate over time. All gait measures and all but 1 cognitive measure (list recall) also improved significantly. A number of measures displayed similar patterns of improvement. Improvements in normal and dual task walking velocity, dual task walking stride time variability, dual costs of dual task walking on velocity and stride time variability, and select measures of executive function, attention, and working memory (i.e., category and letter fluency, maze learning, one back task) occurred at a decreasing rate over time. These similar patterns are suggestive of some association between PA, gait, executive function and working memory.

A more stringent test, time-varying covariation models of cognition and health behaviours revealed significant: 1) within-person effects of MVW and MVPA on select measures of executive functioning and 2) consistent between-group effects of cognitive activity, but not other lifestyle behaviours, on cognitive functioning. Time-varying covariation models of gait and PA exhibited consistent significant: 1) within-person effects of MVW and MVPA on gait velocity and stride time variability during dual task walking, and 2) between-person effects of MVW and MVPA on gait velocity during both dual task and normal walking, Significant within-person effects of gait on select measures of executive function and working memory were also observed. Moreover,

there was strong support of between-group effects of gait velocity and stride time variability on cognitive measures during both normal and dual task walking.

As often found in studies of PA programs in older adults, poor adherence was observed in walking group participants. In analyses looking at predictors of adherence to the walking program, the TPB did not significantly predict walking intentions, overall walking, or change in walking behaviour. The walking group participants all reported high intentions to walk; yet, a striking 67% to 95% (self-reported vs. attendance data) of high intenders failed to translate their intentions into action. Self-monitoring emerged as the only significant predictor of odds of being a successful intender.

Distinct patterns of between and within-person effects on the relations between PA, gait and cognition were observed. The findings of the present study provide convincing evidence of individual differences in the relations between gait and PA, and to a lesser extent a) PA and cognition and b) gait and cognition. Further work will need to continue to clearly elucidate the within- and between-person sources of variation in relations between PA, gait and cognition using methodologically rigorous longitudinal and experimental designs. In the existing body of literature, studies lack the use of multiple waves of measurement during and after interventions. This field of research would profoundly benefit from this type of research design. This will allow examination of the differential effects of PA on specific cognitive domains and the maintenance of these effects over time. The effects of PA on specific cognitive domains may occur at different rates. The effects of other health behaviours on the relations between PA and cognition remain to be explored.

Given the current findings and existing literature on gait, PA and cognition, the effects of cognitively stimulating PA (walking while talking or engaging in a cognitively demanding task while exercising) on cognitive functioning is an intriguing research avenue to explore. There is increasing evidence that multi-modal interventions (combined physical and cognitive interventions) are superior to either PA or cognitive activity alone (Gregory et al., 2013; Schneider & Yvon, 2013). Questions regarding the optimal activities, combination of activities, and dose-response relationships between PA and cognition need further investigation. Achieving a clearer picture of these issues and the relations between PA and cognitive function will be instrumental in the design of interventions to promote cognitive and physical health in older adults.

Meanwhile, while we continue to explore the benefits of PA on cognitive health and mobility, it is important that attention be paid to designing novel, empirically supported interventions to increase the adherence of older adults to PA programs. Given the importance of cognitive health in the maintenance of functional independence in older adults, one key motivator for increasing older adult's intentions to engage in PA may be increasing their awareness of the cognitive benefits of PA. However, greater awareness and higher intentions to be PA are only the starting point. Post-intentional models, like the M-PAC, are promising models for exploring antecedents of intention-behaviour profiles in older adults and for designing innovations to translate higher intentions into adoption and subsequent maintenance of PA behaviour in the long run.

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Appendices

Appendix 1: Expanded Literature Review

This literature review is divided into three main sections. The first focuses on the modifiable risk factors for dementia with an emphasis on the impact of physical activity (PA) on cognition (i.e., cognitive status and cognitive performance) in older adults (Main Study). Evidence from reviews, prospective/observational designs, and experimental designs is briefly reviewed. Theories of the relations between PA and cognition are discussed. The second section examines existing literature on the relations between gait and cognitive function (Study 2). The third section reviews research on social cognitive and self-regulatory predictors of intention, PA and walking behaviours in older adults (Study 3). In this section, two theoretical frameworks used to predict intention and behaviour (i.e., Theory of Planned Behaviour and Action Control Theory) are reviewed. The current chapter highlights the methodological limitations and gaps in knowledge within these three bodies of literature as it applies to the current program of research.

Section 1: Impact of Physical Activity and Other Health Behaviours on Cognitive Health

Cognitive Health Defined

Healthy cognitive aging includes language, thought, memory, executive function, judgment, attention, perception, remembered skills, and the ability to live a purposeful life (Centers for Disease Control and Prevention and the Alzheimer's Association; 2007). Healthy cognitive aging is not synonymous with absence of disease, but rather “the development and preservation of [a] multidimensional cognitive structure that allows the older adult to maintain social connectedness, and ongoing sense of purpose, and the

abilities to function independently, to recover from illness or injury, and to cope with residual deficits" (Desai, Grossberg, & Chibnall, 2010, p. 3).

Activity Engagement, Cognitive Function and Dementia Risk

Theories of cognitive enrichment, including the "use it or lose it" hypothesis, suggest that that leading an engaged lifestyle, including participating in intellectual, social, and physical activities, has a positive impact on cognitive performance throughout the lifespan (Hertzog, Kramer, Wilson, & Lindenberger, 2008) and may prevent cognitive decline by "exercising" cognitive abilities (Bielak, 2010). Likewise, theories of cognitive or brain reserve suggest that engagement in intellectual, social and physical activities enhances the cognitive reserve needed to cope with dementia-related pathology. In support of cognitive reserve, a lack of association between degree of pathology and clinical manifestations of dementia has consistently been found (Briones, 2006; Daffner, 2010; Fratiglioni, Paillard-Borg, & Winblad, 2004; Fratiglioni & Wang, 2007; Nithianantharajah & Hannan, 2009; Scarmeas, 2007).

Hertzog and colleagues view cognitive development within a lifespan perspective, where cognitive performances are seen as malleable and can be enhanced throughout the lifespan (Hertzog et al., 2008). According to their cognitive enrichment hypothesis, an individual operates at a suboptimal level within a range of cognitive functioning that is constrained by both genetics and biological aging. With advancing age, biological aging puts greater constraints on an older adult's function, yet it is not fixed. Instead, they suggest that upward or downward movement in cognitive performance can occur within these set boundaries as a result of various biological, environmental and behavioural factors. Engaging in PA, and other health behaviours (e.g., healthy eating, staying socially engaged, participating in intellectually stimulating activities) are behavioural

factors that can move an individual within their predetermined range of cognitive functioning (See figure 6; Hertzog et al., 2008).

According to a recent narrative review, diabetes mellitus, hyperlipedemia in midlife, and current tobacco use are associated with an increased risk of Alzheimer's disease, while a Mediterranean-type diet, folic acid intake, low to moderate alcohol intake, and engagement in cognitive activities and physical activities are associated with a decreased risk of Alzheimer's disease. However, current evidence for these associations is weak and high quality/methodologically rigorous research is lacking (Daviglus et al., 2011). Although modifying lifestyle behaviours, especially those associated with vascular risk factors for dementia, is a promising avenue for the prevention of dementia and the promotion of cognitive health (i.e., efforts targeting these modifiable lifestyle behaviours and preservation of cognitive functioning in aging have the potential to decrease health, societal and caregiver burden; Anderson, Logsdon, Hochhalter, & Sharkey, 2009), there is insufficient/limited evidence to advocate for such an approach at this time (Daviglus et al., 2011; Grodstein, 2007; Patterson et al., 2008). Although the relations between PA, diet, and cognitive status remain controversial, research continues to accumulate suggesting that in particular both PA and a Mediterranean-type diet offer some protective benefit against dementia (Lourida et al., 2013; Sofi et al., 2011; Sofi, Macchi, Abbate, Gensini, & Casini, 2010; Solfrizzi et al., 2011).

For instance, recent meta-analytic work of prospective studies has demonstrated that PA is significantly inversely related to cognitive impairment (Hamer & Chida, 2009; Sofi et al., 2011). Hamer and Chida (2009) restricted their meta-analysis to prospective studies of dementia risk and found that compared to the low active group, high PA offered significant protection against Alzheimer's disease (Relative Risk (RR)=0.72) and

dementia (RR= 0.55). Another recent meta-analysis of prospective studies showed that individuals who report engaging in high levels of PA (Hazard Ratio (HR) = 0.62, 95% confidence interval = 0.54–0.70; P < 0.00001) and those who report only low-moderate levels of PA (HR = 0.65, 95% confidence interval = 0.57-0.75; P < 0.00001) are both at a reduced risk (38% and 35%, respectively) of cognitive decline compared to individuals who report being sedentary (Sofi et al., 2011).

In another meta-analysis Sofi and colleagues also found that adherence to a Mediterranean diet is associated with a reduced risk of neurodegenerative disease, including mild cognitive impairment (RR = 0.87; 95% CI: 0.81-0.94; P=0.00001, 13% reduced risk; 2010). Recent work has also supported the added benefit of both PA and a Mediterranean diet on dementia risk. One prospective study found that both PA and a Mediterranean diet, as measured by self-report questionnaires, were independently associated with reduced dementia risk. Compared with individuals reporting low PA and low adherence to a Mediterranean diet (absolute AD risk, 19%), those reporting high PA and high adherence to a Mediterranean diet had a 35% to 44% relative risk reduction (absolute AD risk, 12%; Scarmeas et al., 2009).

Comprehensive reviews of the literature on engagement in healthy lifestyle behaviours and their effects on cognitive functioning have also found that mentally stimulating activities have consistent positive effects on both cognitive performance and dementia risk in older adults (e.g., Hertzog et al., 2008; La Rue, 2010; Wang, Xu, & Pei, 2012). In one recent study, Wilson and colleagues found that in a sample of older adults who rated their early life and late life cognitive activity and were followed with annual cognitive testing for a mean of 5.8 years before death, more frequent late-life cognitive

activity and early-life cognitive activity were each significantly associated with slower cognitive decline (Wilson et al., 2013).

Higher levels of social engagement and larger social networks have also been significantly associated with reduced risk of cognitive decline (Dodge, Ybarra, & Kaye, 2014; Fratiglioni et al., 2004). In comprehensive reviews of the literature, the beneficial effect of social engagement on cognitive function has generally been found, although findings are less consistent than cognitive activity and PA engagement (Hertzog et al., 2008). Findings regarding the effects of social activity on dementia risk are less researched and more equivocal (Wang et al., 2012). Moreover, social activity is hard to distinctly separate from other leisure time activities. This is in part due to the variety of means that have been used to examine social engagement (e.g., participation in social activities, size of social networks, satisfaction with social networks, loneliness).

Summary

As of yet, dementia has no cure; engaging in healthy lifestyle behaviours (i.e. PA, healthy diet, intellectual stimulation) has been associated with reduced dementia risk and better cognitive functioning in the existing research. PA, arguably, is the most promising of these lifestyle behaviours for promoting cognitive health and preventing cognitive decline. PA is a lifestyle intervention target with the potential to impact not only cognitive function and disability, but also broader aspects of the overall health and well being of older adults. Research on PA and cognition is outlined in detail next.

PA and Cognition

Benefits of PA

Engaging in PA contributes to physical and psychological well-being and quality of life. The benefits of physical activity are numerous, including reduced risk of more

than 25 chronic diseases (e.g., coronary heart disease, stroke, hypertension, breast cancer, colon cancer, type 2 diabetes, and osteoporosis), improved fitness, mobility (e.g., cardiovascular fitness, body composition, musculoskeletal strength and endurance functional capacity), psychological health (e.g., improved mood, reduced anxiety and depression), and prevention of weight gain (Colcombe & Kramer, 2003; Hautier & Bonnefoy, 2007; Paterson, Jones, & Rice, 2007; Warburton, Nicol, & Bredin, 2006).

Age, Physical Inactivity and Cognitive Decline

Despite these widespread benefits, only an estimated 15% of Canadian adults aged 20 to 79 years are getting the recommended 150 minutes of moderate to vigorous PA per week (Colley et al., 2011). Studies have shown that older adults are among the most inactive and that the prevalence of inactivity increases with advancing age (Azagba & Sharaf, 2014; Canadian Fitness & Lifestyle Research Institute, 2010; Paterson, Jones, & Rice, 2007; Shaw, Liang, Krause, Gallant, & McGeever, 2010). The alarming rate of physical inactivity in older adults is a serious public health concern. With advancing age, not only does physical inactivity increase, but so too does the prevalence of age-related cognitive impairments, such as Alzheimer's disease and related dementias (Alzheimer's Association, 2013; Alzheimer's Society of Canada, 2012; Health Canada, 2002; Desai et al., 2010; Lindsay, Sykes, McDowell, Verreault, & Laurin, 2004; World Heatlh Organization2012). To compound the problem, the risk of developing dementia is significantly associated with physical inactivity (Ahlskog, Geda, Graff-Radford, & Petersen, 2011; Fratiglioni et al., 2004; F. Sofi et al., 2011; Yunhwan et al., 2010).

Moreover, with age, older adults experience declines in cognitive function as part of the natural aging process (Beurskens & Bock, 2012; Borel & Alescio-Lautier, 2014; Glisky, 2007; Park, 2000). Age is associated with declines in a broad range of cognitive

tasks, including attention, memory, verbal reasoning and processing speed (Park, 2000). Older adults are especially vulnerable to decays in higher-level cognitive functions, including executive function (i.e., a diverse range of cognitive processes involved in the planning, organization, coordination, implementation and evaluation of non-routine activities) and working memory (i.e., monitoring incoming data and manipulating information held in focal attention; Glisky, 2007). Executive control/function is a multi-component structure involved in "virtually all aspects of cognition, allocating attentional resources among stimuli or tasks, inhibiting distracting or irrelevant information in working memory, formulating strategies for encoding and retrieval, and directing all manner of problem-solving, decision-making, and other goal-directed activities" (Glisky, 2007, p. 16). These age-related cognitive changes vary not only among individuals, but also within individuals (Borel & Alescio-Lautier, 2014; Glisky, 2007). Due to the increased prevalence of both inactivity and of cognitive impairment in old age, it is important to ensure that while prolonging lifespan of older adults, we are also developing programs to reduce age-related cognitive impairments and maximize quality of life and years of independent functioning (Hertzog et al., 2008).

Effects of PA on Cognition

There is a growing body of evidence for the beneficial effects of PA and exercise on cognitive abilities and cognitive status in older adults. This includes a variety of populations (healthy older adults, mild cognitive impairment, MCI, dementia, stroke) and research designs including meta-analyses/systematic reviews, observational, and experimental research. Considerable literature has found a beneficial effect of PA on cognitive performance, especially executive function, and cognitive status in older adults including meta-analyzes, (e.g., Colcombe & Kramer, 2003; Etnier et al., 1997; Heyn,

Abreu, & Ottenbacher, 2004), experimental/quasi-experimental (e.g., Baker et al., 2010; Cassilhas et al., 2007; Lautenschlager et al., 2009; Liu-Ambrose et al., 2010) and prospective/retrospective designs (e.g., Albert et al.,1995; Larson et al., 2006; Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001; Middleton, Barnes, Lui, & Yaffe, 2010; Middleton et al., 2011; Scarmeas, 2011; Yaffe, Barnes, Nevitt, Lui, & Covinsky,2001). There is considerable research support from cross-sectional/correlational designs, as well (Berchicci, Lucci, & Di Russo, 2013; Boucard et al., 2012; Brown et al., 2012; Farina, Tabet, & Rusted, 2014; Floel et al., 2010; Kerr et al., 2013; Newson & Kemps, 2006; Prohaska et al., 2009; Voelcker-Rehage, Godde, & Staudinger, 2010). The current review will focus mainly on meta-analyses of experimental and prospective observational designs. Results from these review papers and meta-analyses of both experimental and prospective designs are summarized in Table 30.

Effect sizes from meta-analyses of prospective observational designs and experimental designs of chronic exercise interventions have ***generally*** been small to moderate with effects sizes ranging widely from trivial/insignificant to large. Within this literature, larger estimates have been reported for higher-order cognitive functions/executive functions (ES = 0.68; Colcombe & Kramer, 2003; ES=0.459; Hindin & Zelinski, 2012; ES=0.90; Wayne et al., 2014) and cognitively impaired samples (ES=0.75; Farina, Rusted, & Tabet, 2014; ES = 0.57; Heyn et al., 2004) compared to healthy older adult samples (ES = 0.23; Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008).

Although there is considerable support for the beneficial effects of PA on cognitive health not all literature is supportive, some research has found no benefits (e.g.,

Hill, Storandt, & Malley, 1993; Kooistra et al., 2014; Okumiya et al., 1996; Podewils et al., 2005; Steinberg, Leoutsakos, Podewils, & Lyketsos, 2009; Sturman et al., 2005; J. G. Z. van Uffelen, Chinapaw, Hopman-Rock, & van Mechelen, 2009; Verghese et al., 2003; Yamada et al., 2003), while; some of the literature reporting positive effects of exercise on cognitive function have found benefits on only a select number of cognitive domains/specific tests from those which were examined (e.g., Angevaren et al., 2008; Blumenthal et al., 1991; Gates, Singh, Sachdev, & Valenzuela, 2013; Kramer et al., 1999; Snowden et al., 2011). For instance, although the meta-analysis conducted by Angaveren et al. (2008) found that aerobic physical activities had significant effects on motor function, processing speed and auditory and visual attention in healthy older adults; the authors note that the majority of the comparisons examined were non-significant. Likewise, in a meta-analysis of randomized clinical trials in individuals with mild cognitive impairment, exercise had only small significant effects on verbal fluency (ES=0.17), but none of the other cognitive measures (i.e., other measures of executive functioning, information processing or memory) under examination (Gates et al., 2013). Although limited effects of PA/exercise across cognitive domains could be viewed as a limitation, it also could mean that PA/exercise preferentially exerts its effects on certain cognitive domains or exerts its effects on cognitive domains at different rates.

It has been suggested that mixed findings are largely due to the vast heterogeneity in the methodology (e.g., type, duration, and intensity of PA, definitions of PA, length of follow-up, appropriateness of the cognitive functions under investigation, the description of the neuropsychological domains under investigation, the quality of the neurocognitive tests used in the assessment, choice of PA measures) and characteristics of the samples

(e.g., sample size, age, gender, health conditions) under investigation. Some of the methodological issues are described next.

First, many of the existing studies have small sample sizes (e.g., Amoyal & Fallon, 2012; Farina, Rusted, et al., 2014; Hertzog et al., 2008; Hindin & Zelinski, 2012). Across the literature reviewed, expert consensus has been that larger sampler samples are needed to advance our understanding of the relations between PA/exercise and cognition. To date, the majority of studies are underpowered to detect effects of PA intervention on cognitive function (Gregory, Gill, & Petrella, 2013).

Second, existing studies have received some criticism because studies frequently involve interventions that do not target at least the minimum recommended levels (intensity and duration) of PA to confer health benefits (Kruger, Buchner, & Prohaska, 2009). Current national recommended guidelines for minimum PA levels recommends that older adults engage in 150 minutes of moderate to vigorous PA per week (Canadian Society for Exercise Physiology, 2011). Current knowledge regarding the type of activities, duration, and intensity needed to achieve cognitive benefits is limited.

Although the cognitive benefits of other non-aerobic activity, such as strength training (e.g., Chang, Pan, Chen, Tsai, & Huang, 2012; Liu-Ambrose & Donaldson, 2009) and Tai Chi (Wayne et al., 2014) is accumulating, to date a larger body of evidence exists for the beneficial effects of aerobic/endurance activities, including walking, on cognition in older adults (e.g, Miller, Taler, Davidson, & Messier, 2012). Conclusions regarding dose-response relationships between PA/exercise programs and cognitive functioning are premature; however, there is some evidence that higher intensity exercise confers more benefit than lower intensity exercise (e.g., Angevaren et al., 2007; Brown et al., 2012; Kruger et al., 2009).

Walking behaviour, in particular, has had a significant inverse association with risk of cognitive decline in a number of prospective studies (Abbott et al., 2004; Weuve et al., 2004; Yaffe, Barnes, Nevitt, Lui, & Covinsky, 2001). For example, Yaffe et al. (2001) found that in a group of women the risk of developing cognitive decline over subsequent 6 to 8 years follow-up was reduced substantially in those who walked more at baseline (RR=0.66). In a classic experimental study, conducted by Kramer and colleagues (Kramer et al., 1999; Kramer et al., 2001), a group of inactive older adults were randomly assigned to an aerobic intervention (i.e., brisk walking) or an active control (i.e., stretching and toning group). The aerobic group walked 3 times per week for 6 months at a brisk pace. Findings were that older adults in the walking group performed significantly better than control subjects on cognitive tasks requiring executive control processes (i.e., monitoring, scheduling, inhibition, working memory).

More recently, Maki et al. (2012) randomly assigned older adults to an intervention, consisting of a once weekly 90 min group session (30 min of exercise, 60 minutes of group work) or a control group (educational lectures on food, nutrition, or oral care) for 12 weeks. Participants in the intervention were encouraged to engage in regular walking and to increase their daily step count gradually. The intervention group improved significantly on category fluency, but not other cognitive measures, compared to the control group. Intensity and specific walking requirements of the program were not clearly outlined.

Third, the description of neuropsychology domains under investigation and the selection of neuropsychological tests in the existing studies of exercise and cognition have been highly criticized across the literature (e.g., Etnier & Chang, 2009; Gregory et al., 2013; Miller et al., 2012; Salthouse, 2008; Tomporowski, 2009). Studies have often

examined: 1) measures of general cognitive function rather than focus on specific cognitive domains of interest, 2) tests chosen based on popularity rather than on hypothesis driven test selection, and/or 3) only a limited number of measures of cognition. In their reviews of methodological limitations in the field, Etnier & Chang (2009), Salthouse (2008), and Gregory et al. (2013) advocate for the use of multiple measures of cognition, in particular executive functioning, to advance our understanding of relations between PA and cognition. Better standardization of neuropsychological tests used in exercise research has also been recommended (Gregory et al., 2013).

Considerable research with both humans and animals suggests that PA may preferentially affect executive functioning, working memory, and attention (e.g., Colcombe & Kramer, 2003; Guiney & Machado, 2013; Hertzog et al., 2008). Although the vast majority of work suggests positive effects of PA/exercise on executive functions, the research is highly variable. Executive function is a broad category of higher order cognitive functions and more work is needed to disentangle the effects of PA on cognition and specific aspects of executive function (inhibition, task switching, fluency, etc.). Heterogeneity between studies makes comparison across studies difficult even within a single cognitive domain.

Fourth, it is also plausible that researchers in the field are missing part of the picture by focusing their research efforts almost exclusively on between-group effects of PA/exercise on cognition (e.g., high exercisers versus low exercisers, individuals who were active throughout their lives versus those who were inactive, and exercise groups versus controls), while neglecting to acknowledge the within-person differences (i.e., changes in an individual's PA levels relative to their own mean) that may contribute to the complex relations between PA/ exercise and cognitive function in older adults.

Longitudinal observational designs *with repeated measurement waves* are an optimal method to examine the relations between intra-individual changes in PA and cognition. The need for multiple waves rather than simple pre- post comparisons of cognitive performance has been recognised in the recent literature (Farina, Rusted, et al., 2014). Lifespan developmental researchers often employ multi-level models with time-varying predictors to achieve a greater understanding of the relations between variables over time. Yet, choice of models and failure to separate constant between-person sources of variation from time-specific within-person sources of variation within these multilevel models has been identified as a source of bias and can obscure results (Hoffman & Stawski, 2009; Morrell, Brant, & Ferrucci, 2009; Thorvaldsson et al., 2012).

Although the need to examine intra-individual variability on the activity-cognition relations has been highlighted in the literature (Hertzog et al., 2008; Salthouse, 2008), it has rarely been examined. To the author's knowledge, only a few studies have examined the dynamic coupling/time-varying covariation models of leisure activities, including PA and cognitive function in older adults (Lovden, Ghisletta, & Lindenberger, 2005; Small, Dixon, McArdle, & Grimm, 2012). For example, using latent change score models, Small and colleagues examined the dynamic relations between self-reported participation in social, cognitive and physical activities and changes in age-related cognitive declines in a large sample of older adults (n=952) over a 12-year period. Results indicated that reductions in cognitive activities were significantly associated with subsequent declines in verbal processing speed, episodic memory, and semantic memory and declines in cognitive abilities were significantly related to further declines in engagement leisure activities, especially social activities.

These prospective observational studies examined the dynamic relations and time lag between long-term engagement in lifestyle activities on age-related declines in cognitive skills (i.e., over the long term), rather than examining the time-varying association between PA and cognitive performance due to formal intervention (i.e., more short term). Moreover, these studies also failed to separate between- and within-person sources of variation in PA in their models, which as noted earlier can lead to biased results (Hoffman & Stawski, 2009). Based on this literature review, no studies of the effects of PA or walking programs on cognition *in older adults* that made this distinction were identified.

Summary

Controversy regarding the relations of physical activity to cognitive function is largely as a result of the many methodological limitations of current literature. To advance the field, carefully designed, high quality studies (e.g., careful selection of cognitive measures; reliance on objective rather than subjective measures of PA; when required, use of self-report measures of behaviour with established psychometrics; selection of appropriate control conditions for interventions studies; examination of potential moderators of the behaviour-cognition relationship, examination of three-way interactions between mediators, behaviour and cognition, testing rather than controlling for mediators; examination of intra-individual change over time; Ethnier, 2008; Etnier, 2009; Etnier & Chang, 2009; Spirduso, Poon, & Chodzko-Zajko, 2008a; Tomporowski, 2009) examining the relations of PA and cognitive functioning and cognitive status (i.e., early cognitive decline, dementia) are needed. Due to methodological limitations of existing studies and the many complexities of both PA

and cognition, many aspects of the relations between PA and cognition need to be unravelled.

The Public's Awareness of Modifiable Risk Factors and Cognitive Decline

It is unlikely that older engage in PA (or other health behaviours) with the specific intention to preserve or promote their cognitive health. In fact, current research examining older adult's knowledge, attitudes and beliefs, and behaviours related to preserving or promoting their cognitive health has demonstrated that older adults have limited knowledge regarding modifiable risk factors and dementia/cognitive health (e.g., Corwin et al., 2007; Gow, Hanlon, & Gilhooly, 2004; Low & Anstey, 2009; Park et al., 2008). The role of cardiovascular risk factors and dementia (Arai, Arai, & Zarit, 2008; Gow et al., 2004; Low & Anstey, 2009; Norrie et al., 2011; Park et al., 2008; Wilcox et al., 2009) and the difference between disease prevention and risk reduction (Wilcox et al., 2009) have also been highlighted as areas that the public has limited knowledge and understanding. The development of messages for older adults regarding the impact of PA and other healthy behaviours on cognitive function and other aspects of older adults' health and well-being, along with teaching skills and providing resources and support to help older sedentary adults initiate and continue to engage in these PA and other cognitive health behaviours is an important line of research. It may be that providing lay people with messages regarding the cognitive health benefits of PA could give some older adults more motivation to engage in PA than the typical message researchers and health and fitness professionals have been giving older adults for years regarding the physical health benefits of PA.

Moderators and Mediators of the Relationship between PA and Cognition

Examining the effects of PA on cognitive functioning in individuals who are at great risk at risk for cognitive decline is another fruitful avenue to explore. Individuals at risk for cognitive decline, for example those with cardiovascular risk factors or disease states (diabetes, metabolic syndrome) or those with mild cognitive impairment, may have the most room to benefit from intervention. Elucidating "how" PA/exercise exerts its effect on cognitive function in older adults is another important piece of cognitive health intervention design that requires further investigation.

The reasons why some individuals show preserved cognitive function, while others with similar disease states and risk factors for cognitive decline manifest with dementia and related cognitive impairment (i.e., for whom PA improves cognition) have also not been determined. Despite the vast literature examining PA and cognition in older adults, existing literature is plagued by methodological issues and surprisingly few of the proposed mediators and moderators of the PA/exercise-cognition relation have been put to test in either experimental or observational studies with older adults. Although the former is necessary to prove causation, the latter is useful avenue for gathering information for intervention design and choosing the target variables to be manipulated in an experimental design.

Numerous theories regarding the mechanisms underlying the positive impact of PA/exercise on cognition have been proposed and discussed in existing scientific literature. These include through improved cardiovascular fitness, by helping maintain cerebral integrity, reducing tissue loss, neuroplasticity, synaptogenesis, neurogenesis, angiogenesis, upregulating neurotrophic factors and neurotransmitters, and reducing AD related pathology (Briones, 2006; Churchill et al., 2002; Colcombe, Kramer, McAuley,

Erickson, & Scalf, 2004; Cotman, Berchtold, & Christie, 2007; Cotman & Berchtold, 2002; Cotman & Berchtold, 2007; Deslandes et al., 2009; Etnier, 2009; Jedrziewski, Lee, & Trojanowski, 2007; Kramer & Erickson, 2007; Kramer, Erickson, & Colcombe, 2006; Kramer, Bherer, Colcombe, Dong, & Greenough, 2004; Kramer et al., 2003; Kramer & Willis, 2002; Nithianantharajah & Hannan, 2009; Stranahan et al., 2009; van Praag, Shubert, Zhao, & Gage, 2005; van Praag, 2008; van Praag, 2009).

It has been proposed that PA may affect cognitive function, though its direct effects on brain structure and function, its indirect effects on other factors known to affect brain structure and function, or through a combination of indirect and direct effects (Poon, Chodzko-Zajko, & Tomporowski, 2006). According to Spirduso and colleagues (Etnier, 2008; Spirduso et al., 2008a; Spirduso, Poon, & Chodzko-Zajko, 2008b), physical resources (sleep effectiveness, energy, fatigue, appetite/nutrition, pain, drug/medication use), chronic disease states (such as hypertension, diabetes, cardiovascular disease, cerebrovascular disease, chronic obstructive pulmonary disease), and mental resources (such as chronic stress, depression, self-efficacy) mediate the relation between PA and cognition (i.e., are the causal link/mechanism driving the relationship (See Figure 7). In addition, they suggest that age, gender, education, estrogen level and genotype moderate the relationship between PA and cognition (i.e., influence the strength of the relationship; Etnier,2008; Spirduso et al., 2008a, 2008b). This model acknowledges the direct relationship between PA and cognition (e.g., improved oxygen availability and use, increased glucose regulation, up-regulation of neurotrophins), but focuses on the indirect paths between PA and cognition.

Cardiovascular Fitness and Cognition

One of the most prominent and disputed theories regarding the mechanism by which exercise improves cognition in older adults is the cardiovascular fitness theory. The cardiovascular fitness theory proposes that exercise exerts its effects on cognitive function by improving cardiovascular or aerobic fitness (e.g., Bashore, 1990; Bashore & Goddard, 1993; Busse, Gil, Santarém, & Filho, 2009; Colcombe, Kramer, McAuley, Erickson, & Scalf, 2004; Etnier, 2009; Etnier, 2009; Hall, Smith, & Keele, 2001; Hertzog et al., 2008; van Uffelen, Paw, Hopman-Rock, & van Mechelen2008). Cardiovascular fitness, which is defined as the capacity of the body to transport and utilize oxygen is typically measured using maximal oxygen uptake (VO2 max; American College of Sports Medicine, 2010). VO_2 max, the rate of oxygen consumption during maximal exercise, is the gold standard assessment of aerobic fitness, and reflects the capacity of the heart, lungs, and blood to deliver oxygen to working muscles (Heyward, 2010). Older adults experience reductions in the oxygen carrying capacity of the cardiovascular system and in the ability of the muscle to take up oxygen at the level of the muscle. Through exercise the ability of the older adults cardiovascular system to deliver oxygen to the brain can be improved (Hall, et al., 2001; Kramer, Hahn, & McAuley, 2000).

Chronic Disease and Cardiovascular Risk Factors

A number of other theories regarding how exercise improves cognition in older adults share a common element: the inclusion of cardiovascular risk factors and disease. For instance, the vascular reserve hypothesis proposes that exercise protects against cognitive decline by reducing risk factors for cardiovascular disease and stroke (Fillit et al., 2002; Fratiglioni, et al., 2004; Jedrziewski et al., 2007; Kramer & Hillman, 2006; Landi et al., 2010; Larson & Wang, 2004). The basic premise of the vascular reserve hypothesis is that since vascular risk factors are associated with dementia, if we reduce or

eliminate these risk factors than an individual will be less likely to develop dementia (Fratiglioni, et al., Andrade & Radhakrishnan, 2009; 2004). On a related note, exercise might contribute to improved cognitive function through modifying other medical co-morbidities that are known to impair cognition and contribute to cognitive decline (Bielak, 2010; Royall, 2008). For instance, exercise might modify diabetes symptoms thereby improving cognitive function (Royall, 2008). It may be that exercise modifies risk factors for diabetes (hyperglycemia, stroke, major depression), which in turn improves cognition (Royall, 2008).

Barnes, Whitmer, & Yaffe (2007) suggest that exercise reduces cognitive decline directly through improved neuronal function, and indirectly through reduced vascular risk, reduced obesity, and reduced levels of inflammatory markers. With respect to cardiovascular risk and obesity, it has been shown that individuals with metabolic syndrome (i.e., cardiovascular risk factors including abdominal obesity, high triglycerides, hyperglycemia, and hypertension, low high density lipoprotein and high inflammation) are at greater risk of cognitive impairment than individuals with metabolic syndrome and low inflammation or those without metabolic syndrome, regardless of inflammation (Barnes et al, 2007). In a similar vein, Cotman and colleagues (2007) suggest that exercise not only works to improve brain health and cognition through exercise induced growth factors cascades, but also through reducing risk factors for cognitive decline including metabolic syndrome, hypertension, and insulin resistance. They also include inflammation in their model of exercise-mediated effects on cognition. Inflammation is increased in metabolic syndrome, accelerates cognitive decline, damages growth factors and signalling cascades and is reduced by exercise (Cotman et al., 2007).

McAuley et al. (2004) further speculate that personal and environmental factors and disease states work to improve cognition indirectly, in addition to direct changes to brain structure and function that occur in response to exercise. They suggest that environmental factors, such as social support, weather, and availability of physical activity facilities, and personal factors, such as exercise history and self-efficacy influence whether and individual engages in physical activity. They further speculate that disease reduction (reducing cardiovascular disease, stroke, diabetes, hypertension) and enhanced brain structure and function (increased neurotransmitter production and efficiency, angiogenesis, synaptogenesis, and neurogenesis) may mediate the relationship between improved fitness and cognition**.**

While many theories regarding how physical activity/exercise impacts cognitive performance have been proposed and discussed, very few studies have actually examined these the indirect effects of physical activity (and exercise) on cognition. In the current literature review, few older adult intervention studies examining vascular mechanisms, (other than cardiovascular fitness) for exercises impact on cognition were identified. In one study that did, men and women who had similar gains in cardiovascular fitness following aerobic exercise differed in their cognitive performance and stress response (Baker et al., 2010). Women experienced significant gains on multiple measures of executive function, while men experienced significant gains on Trails B only. Post-intervention, women experienced improved glucoregulation, and reduced cortisol and brain derived neutrophic factor; whereas, men experienced increased cortisol levels. These findings may reflect gender difference in glucoregulation and hypothalamic-pituitary-adrenal axis response to exercise

Moderator Variables

It has also been suggested that inconsistent findings in the domain effects of exercise on cognition are in part due to the influence of moderating variables, such as age, gender, education, adherence, and genetics (Bielak, 2010; Clifford, Bandelow, & Hogervorst, 2010). Outside of demographics, adherence and genetics, it seems likely cardiovascular disease status/risk factors and midlife history of PA, for example, might moderate the strength of relations between PA and cognition. In fact, both midlife PA and cardiovascular risk have been associated with reduced risk of cognitive decline and Alzheimer's disease and related dementia in later life in existing literature (Buchman et al., 2012; de la Monte, 2014; DeFina et al., 2013; Dregan & Gulliford, 2013; Elwood et al., 2013; Feng et al., 2013; Flicker, 2010; Gallucci et al., 2013; Ku, Stevinson, & Chen, 2012; Middleton, Mitnitski, Fallah, Kirkland, & Rockwood, 2008; Morgan et al., 2012; Rockwood & Middleton, 2007; Rovio et al., 2005; Verhaeghen, Borchelt, & Smith, 2003; Yaffe et al., 2004). Cardiovascular disease (glucose intolerance, diabetes, hyperlipidemia, hypertension) are risk factor for both vascular dementia and Alzheimer's disease (Ahlskog et al., 2011; Barber, Clegg, & Young, 2012). Elucidating the factors that make an individual more responsive to the effects of exercise/PA on cognition is an important step in designing effective interventions to promote healthy cognitive aging.

Summary

Evidence for the protective function of PA/exercise on cognition function, in particular executive functions, is continuing to emerge in randomized control trials and in prospective longitudinal designs. However, while the relation between PA/exercise and improved cognitive function appears fairly robust, not all research is supportive. Few high quality randomized control trials have been conducted and studies have varied

considerably in the length, type and intensity of intervention, the cognitive functions under investigation, and the size and characteristics of the target samples. Prospective research designs have focused almost exclusively on group differences, failing to consider individual differences that may impact the relations of behaviour to cognition. The need to examine intra-individual variability on the activity-cognition relations has also been highlighted in the literature on engagement in healthy lifestyle behaviour and cognition. Prospective designs with multiple waves of measurement examining the mediators and/or moderators of the PA-cognition relation and both individual and group differences are needed. The current research program addresses some of these weaknesses and gaps in the current literature by employing adequate sample size, validated self-report measures of PA and other health behaviours, and a carefully selected battery of cognitive measures at multiple time-points. The study improves on current literature by examining both between-person and within-person sources of variability in PA and its effects on cognitive functioning in a brief single group longitudinal study.

Section 2. Gait and Cognition (Study 2)

Staying mobile, functioning independently, and living a disability-free life are key to maintaining quality of life throughout the lifespan (Brown & Flood, 2013; Paterson & Warburton, 2010). However, gait disturbances and cognitive impairment are highly prevalent among this segment of the population and can compromise both mobility and independent functioning to varying degrees. One of the most troubling consequences of both cognitive and gait impairments in older adults is falls and their related challenges (e.g., injury, hospitalization, health care costs, caregiver burden, morbidity, mortality, poor quality of life; Ambrose, Paul, & Hausdorff, 2013; Cesari et al., 2005; Holtzer,

Wang, & Verghese, 2012; Liu, Chan, & Yan, 2014; Terroso, Rosa, Marques, & Simoes, 2014).

Fall Risk

Older adults are at an increased risk of falls and the prevalence increases with increasing age (Amboni, Barone, & Hausdorff, 2013; Grundstrom, Guse, & Layde, 2012; Holtzer et al., 2012; Montero-Odasso, Verghese, Beauchet, & Hausdorff, 2012). Approximately 30 to 40% of the older adult population falls each year, and of those that fall, about 50% will be hospitalized (Ambrose et al., 2013; Liu et al., 2014; Terroso et al., 2014). Fall risk is multifactorial and among the older population certain groups have greater risk of falls (Ambrose et al., 2013; Deandrea et al., 2010; Terroso et al., 2014).

Terroso and colleagues reviewed the scientific literature on risk for falls from 1995 to 2010 and classified risk factors for falls into 5 categories, including behavioural (i.e., characteristics of the human actions, emotions, and choice), biological (i.e., related to the human body), environmental (i.e., interactions of the human body with the environment) or socio-economic (i.e., factors related to the individuals social or economic situation; Terroso et al., 2014). Of the biological factors, difficulty balancing while walking (33.3%) was the most frequently reported in the literature. Musculoskeletal and sensory degradation (26.4 %), functional dependence in the mobility (25.2 %), and cognitive impairment (24.1%) were also frequently reported causes of falling.

Both gait abnormalities and cognitive impairment (dementia and mild cognitive impairment) in the elderly have been identified as independent risks factors for falls (Amboni et al., 2013; Mirelman et al., 2012; Montero-Odasso, Verghese, et al., 2012). Although it was once thought that gait and mobility were largely unrelated to cognition,

we are becoming increasingly aware that cognitive function makes a key contribution to gait-related fall risk in the elderly.

Walking, gait and gait analysis

Walking is a method of locomotion involving the alternating use of two legs for support and propulsion. Walking and gait are often used interchangeably, though they do differ. Gait is the manner or style of walking rather than the actual act of walking itself. As such, gait analysis is the systematic study of how an individual walks (Whittle, 2007). Gait analysis involves examination of a number of spatiotemporal parameters (e.g., speed, cadence, stride length, swing time, stance time, and double support phase, stride length standard deviation (SD), and swing time SD (Bridenbaugh & Kressig, 2011; Hollman, McDade, & Petersen, 2011). These gait parameters are often used to assess mobility, fall risk and even risk of dementia. In particular, stride time variability (i.e., variability in two successive foot placements by the same foot) and gait speed (distance walked/divided ambulation time) have been examined in research on gait and cognition.

Results of a recent factor analysis grouped gait parameters into 5 spatiotemporal domains: 1) rhythm (i.e., cadence and temporal parameters such as stride time); 2) phase (i.e., parameters representing distinct divisions of the gait cycle; 3) variability (i.e., gait cycle and step variability parameters); 4) pace (i.e., speed, stride length, and step length) and 5) base of support (i.e., step width and step width variability; Hollman et al., 2011).

Gait characteristics of healthy and cognitive impaired older adults

Gait and cognitive disturbances are common in the elderly, as part of both the normal aging process and age-related disorders (e.g. dementia and other neurodegenerative diseases (Amboni et al., 2013; Borel & Alescio-Lautier, 2014; de

Melo Coelho et al., 2013; Holtzer et al., 2012; Montero-Odasso, Verghese, et al., 2012; Parihar, Mahoney, & Verghese, 2013; Verghese et al., 2006). With normal aging, gait is characterized by slower cadence, decreased stride length and swing phase, and wider base of support compared to younger adults (Haworth, 2008; Wollesen & Voelcker-Rehage, 2014). Compared to healthy older adults, gait abnormalities (e.g., slower gait speed, shorter stride length, increased step frequency, stride time variability, postural sways, poor ability to maintain stable stance during perturbations) are more frequently observed in older adults with dementia and mild cognitive impairment (Alexander & Hausdorff, 2008; Amboni et al., 2013; de Melo Coelho et al., 2013; Hageman & Thomas, 2002; Montero-Odasso, Muir, & Speechley, 2012; Parihar et al., 2013; Verghese et al., 2002). Additional evidence also suggests that gait and cognitive impairments not only co-exist, but gait abnormalities can also precede cognitive decline by many years (Alexander & Hausdorff, 2008; Parihar et al., 2013).

Considerable research has also demonstrated a strong association between specific gait characteristics (e.g., gait speed, gait instability, stride time variability) and specific cognitive functions (e.g., executive function, attention, processing speed), cognitive impairment (e.g., mild cognitive impairment, dementia; Beauchet, Allali, Launay, Herrmann, & Annweiler, 2013; Beauchet et al., 2012; Buracchio, Dodge, Howieson, Wasserman, & Kaye, 2010; Doi et al., 2014; Kearney, Harwood, Gladman, Lincoln, & Masud, 2013; Studenski et al., 2011; Verghese, Wang, Lipton, Holtzer, & Xue, 2007; Verlinden, van der Geest, Hofman, & Ikram, 2014). Findings from longitudinal and cross-sessional studies examining the relations between gait characteristics and cognitive functioning are summarized in Table 31. As can be seen in Table 31, longitudinal studies of gait and cognition have consistently found that poorer

general cognitive functioning and executive functioning at baseline is associated with declines in gait speed over follow-up periods of 2 to 5 years. In cross-sectional studies, measures of executive functioning/attention and working memory have also generally been significantly associated with both gait speed and gait variability during dual task conditions; while, an association between memory and gait characteristics is generally not found. These gait characteristics have also been linked with other important indicators of health and well-being, including mortality, mobility disability and falls (Beauchet, 2008; Brach, Studenski, Perera, VanSwearingen, & Newman, 2007; Brach, Berlin, VanSwearingen, Newman, & Studenski, 2005; Hausdorff, Rios, & Edelberg, 2001).

Gait Control and Changes in Cognitive Demands of Walking with Age

Control of locomotion and posture is largely automated. Walking has traditionally been viewed as an automated, over-learned, rhythmic movement that is "hard-wired" and mainly controlled by subcortical and spinal systems of the nervous system (Allali et al., 2007; Dubost et al., 2006; Grubaugh & Rhea, 2013; 2005; Montero-Odasso, Muir, et al., 2012). However, research on the attentional demands of walking in older adults is challenging this idea. It may be that walking is a repetitive daily activity ingrained in us at an early age; however, in the elderly walking is similar to a complex motor task, even in "routine" walking (Hausdorff et al. 2005). Moreover, in everyday life, walking is more purposeful; individuals find themselves walking in complex environments where avoiding obstacles and multi-tasking (e.g., walking when talking, walking while talking on the phone, walking while recalling a shopping list, walking when carrying groceries) can put demands on higher cognitive function (executive functions and divided attention) and sensory systems, especially in older adults (Al-Yahya et al., 2011).

Purposeful locomotion involves widespread regions of the brain including cerebellum, basal ganglia, parietal and frontal cortices (Holtzer, Epstein, Mahoney, Izzetoglu, & Blumen, 2014). This has been confirmed by a recent review of neuroimaging data, which suggests that these areas are implicated in mobility outcomes (i.e., gait, balance, fall risk). The same review also found evidence of increased recruitment of prefrontal/frontal cortical regions under both imagined walking and in dual task walking (Holtzer et al., 2014). Walking successfully in a complex environment requires executive function, attention, visual spatial function, along with motor functions of the basal ganglia and cerebellum (Buracchio et al., 2010). As part of the normal aging process and in Alzheimer's disease and related dementias, older adults experience changes in some of the same areas. As such, it seems likely that gait impairments in the elderly could be related to these cognitive processes and underlying neuropathology (Bridenbaugh & Kressig, 2011; Kearney et al., 2013; Montero-Odasso, Verghese, et al., 2012; Verghese & Holtzer, 2010). Deficits in attention and executive functioning have been proposed as the common link between gait disturbances, dementia, and subsequent fall risk.

Dual Task Paradigm, Gait Characteristics, and Cognitive Function

Until recently cognitive and gait disturbances were examined largely as separate entities; however, over the last decade their shared association has been studied extensively using variations of an experimental manipulation called the dual task paradigm. Dual task paradigms require individuals to walk while performing secondary cognitive or motor tasks in order to experimentally manipulate the attentional demands of walking (Holtzer et al., 2012; Wollesen & Voelcker-Rehage, 2014). The dual cost on gait, cognitive performance, or both is then examined.

Findings from studies examining gait parameters in healthy and cognitive impaired older adults are summarized in Table 32. As can be seen in Table 32, these dual task paradigms have generally demonstrated consistent expected changes in gait parameters (e.g., decreased speed, decreased cadence, decreased stride length, increased stride time, and increase stride time variability) during dual tasks compared to single tasks with greater cognitive and/or motor interference (i.e., dual cost) being found in the elderly compared to younger adults (Al-Yahya et al., 2011; Beurskens & Bock, 2012; Dubost et al., 2006; Li, Abbud, Fraser, & DeMont, 2012; Wollesen & Voelcker-Rehage, 2014). Dual task performance generally decreases with increasing complexity (i.e., counting backward by 1s versus counting back by 7s.). Cognitively impaired individuals generally show greater impairment, in particular on stride time variability and gait speed, while dual task walking compared to cognitively healthy older adults (Gilles Allali, van der Meulen, & Assal, 2010; Amboni et al., 2013; Beurskens & Bock, 2012). Moreover, impairments in dual task walking are associated with greater fall risk (Beauchet et al., 2008; Hall, Echt, Wolf, & Rogers, 2011; Haworth, 2008).

Gait, Cognition, and PA

The relations between 1) PA and cognition and 2) gait and cognition have been described in detail above. Based on current understanding of the link between cognition, gait and falls, it has been suggested that walking is a possible intervention target for prevention of cognitive decline and dementia, while cognitive training is a possible intervention target for prevention of gait abnormalities and fall risk (Amboni et al., 2013; Montero-Odasso, Verghese, et al., 2012). More recently, a review of thirteen dual-task training interventions (motor and cognitive tasks performed simultaneously) in older adults found that, in general, dual task training provided more cognitive and motor

benefits on motor (standing or walking) and cognitive performance than single task training. Single task training also benefited dual task walking, but not standing performance (Wollesen & Voelcker-Rehage, 2014). Research has consistently demonstrated that PA is associated with numerous physical benefits including reduced functional limitations and improved mobility (e.g., Patterson & Warburton, 2010). A recent meta-analysis demonstrated that compared to control interventions, exercise interventions significantly improved both normal and fast gait speed in frail older adults (Giné-Garriga, Roqué-Fíguls, Coll-Planas, Sitjà-Rabert, & Salvà, 2014). Moreover, PA may mitigate age-related changes in gait in older adults. Compared to younger adults, some research has demonstrated that active older adults do not show reduced walking speeds (Boyer, Andriacchi, & Beaupre, 2012).

Section 3. PA and Action Control (Study 3)

Due to the rapid aging of the population and the increasing prevalence of physical inactivity in older adults, the development of interventions to promote PA is of paramount importance. A necessary first step in designing interventions for this purpose is to gain better understanding of the antecedents of PA. Researchers in Exercise/Health Psychology often use theories of behaviour change to help make sense of and organize our understanding of these antecedents and the mechanisms through which individuals change (do not change) their PA behaviours (Baranowski, Anderson, & Carmack, 1998; Biddle & Nigg, 2000; King, Stokols, Talen, Brassington, & Killingsworth, 2002). Moreover, there is some evidence that theoretically framed interventions produce larger intervention effects than those developed without a theoretical frame (Ammerman, Lindquist, Lohr, & Hersey, 2002; Dombrowski et al., 2012; Glanz & Bishop, 2010; Michie & Johnston, 2012; Taylor, Conner, & Lawton, 2012; Webb, Joseph, Yardley, &

Michie, 2010). Many of the theories used to predict PA behaviour and develop interventions include intention as the most proximal antecedent of behaviour (Rhodes & De Bruijn, 2013a; Rhodes & Dickau, 2012). One of the most prominent, parsimonious, and well-validated of these theories is Ajzen's Theory of Planned Behaviour (1985; I. Ajzen, 1991; Symons-Downs & Hausenblas, 2005; Symons-Downs & Hausenblas, 2005; Hausenblas, Carron, & Mack, 1997; McEachan, Conner, Taylor, & Lawton, 2011; Rhodes, Blanchard, & Matheson, R. E. Rhodes, Blanchard, & Matheson, 2006).

The Theory of Reasoned Action (TRA) and the Theory of Planned Behaviour (TPB)

The TRA holds that people will engage in behaviour if they have strong intention. Intentions, in turn, are influenced by an individual's attitudes toward a behaviour (i.e., attitude) and by their beliefs that significant people in their lives want them to engage in that behaviour (i.e., subjective norm; Ajzen & Fishbein, 1980). The TRA model explains volitional behaviours and the TPB is an extension of this model that includes perceived behaviour control (PBC) to better account for non-volitional behaviours (Ajzen, 1985; Ajzen, 1991; Danielle Symons Downs & Heather A. Hausenblas, 2005; Madden, Scholder Ellen, & Ajzen, 1992; Rhodes et al., 2006).

Similar to the TRA, TPB holds that the main antecedent of behaviour is intention (Ajzen, 1991). Attitude (i.e., the overall evaluation of the behaviour), subjective norm (SN; i.e., perceived social pressure to perform the behaviour) and perceived behavioural perceived control (PBC; i.e., perceived ability to perform the behaviour; skills, opportunity, resources) are the antecedents of intention. According to the model, attitude, SN, and PBC have an indirect effect on behaviour through intention. Moreover, when the behaviour in question is not volitional, PBC has a direct effect on the non-volitional behaviour (Ajzen, 1991; Symons-Downs & Hausenblas, 2005; Madden et al., 1992).

Each of these constructs is defined in more detail next.

Constructs of the TPB

Intention: Intention refers to an individual's readiness to perform the given behaviour. In other words, how much effort or how hard an individual is willing to try in order to engage in a given behaviour (Ajzen, 1985; Ajzen, 1991; Ajzen, 2006; Rhodes et al., 2006). Intentions are assumed to be the immediate antecedent or main determinant of the behaviour. They are the motivational factors that influence a behaviour that is under volitional control. Motivational theories of behaviour, like TPB and TRA, propose that the stronger an individual's intentions towards a behaviour, the more likely that the individual will engage in a particular behaviour. The predictive utility of TPB depends on this concept. This will be discussed further below (See TPB predictive utility).

Attitude: According to TPB, attitude is "the degree to which a person has favourable or unfavourable evaluation or appraisal of the behaviour in question" (Ajzen, 1991, p. 188). Research has demonstrated two separate components within attitude construct: affective/experiential (i.e., judgements about the pleasure/displeasure, enjoyment, interest and other feeling states expected from engaging in PA) and instrumental (i.e., judgements about the outcomes of PA that do not directly related to feeling states, such as risk of chronic disease, improvements in fitness; Rhodes et al. 2006; Rhodes & Conner, 2010; Rhodes, Fiala & Conner, 2009). Of the two components of attitude, affective attitude has emerged at the stronger predictor of PA intention and behaviour (French et al., 2005; Rhodes et al., 2009).

SN: SN refers to the social pressures an individual experiences to engage or not engage in a particular behaviour (Ajzen, 1991). SN is a reflection of whether an individual believes it is important that others want them to engage in behaviour. SN has been divided into descriptive and injunctive norm in the existing literature (Rhodes et al., 2006). Injunctive norm refers to whether one believes it is important that others want them to engage in a particular behaviour and descriptive norm refers to whether people in one's social network perform the behaviour themselves.

PBC: According to the model, PBC refers to the perceived ease or difficulty of performing the behaviour (Ajzen, 1985; Ajzen, 1991; Ajzen, 2006). PBC is a result of both self-efficacy (confidence) and controllability (personal control over a behaviour; Ajzen, 2002). It is believed to reflect both past experience and anticipated obstacles.

Beliefs: Attitude, SN and PBC also have antecedents. The TPB also holds that behaviour is a product of salient beliefs about that behaviour (Ajzen, 1985, 1991, 2006). Although humans may have many beliefs toward behaviour, only some of these beliefs are salient at a specific moment in time. According to TPB, there are three types of salient beliefs: 1) behavioural beliefs, 2) normative beliefs, and 3) control beliefs.

Attitude toward a behaviour is influenced by an individual's behavioural beliefs (i.e., beliefs that the behaviour will produce a given outcome); SN is influenced by normative beliefs (i.e., beliefs about the likelihood that significant others (e.g., friends, family) approve or disapprove of the individual engaging in the behaviour); and PBC is influenced by control beliefs (i.e., beliefs about the availability of resources/opportunities/factor that may facilitate or inhibit the behaviour; Ajzen, 1991;

2006).

In sum, the TPB holds that the more favourable an individual's attitude and SN towards a behaviour and the greater their PBC, the stronger their intention to engage in the behaviour. TPB proposes that people with higher intention will be more likely to act on those intentions.

Predictive Utility of TPB

A recent meta-analysis of prospective prediction of health-related behaviours found that PA behaviour was among the best predicted by TPB; despite this, 76.1% of the variance in PA behaviour was *unexplained* by TPB (McEachan et al., 2011). After controlling for past behaviour and examining change in behaviour, TPB constructs accounted for even less variance in PA behaviour (i.e., 95% of variance in PA was *unexplained* by TPB). The authors found that of the TPB constructs and past behaviour, past behaviour was the strongest predictor of behaviour change (β=0.388), while intention (β=0.222), but not PBC (β=.074) remained significant. Likewise, past behaviour was the strongest predictor of intention (β=0.320), followed by attitude (β=0.316) and PBC (β=0.250). The meta-analysis also found that age was a significant moderator of TPB-PA relations, such that adolescent samples were better predicted by TPB than student and adult samples; however, the review did not examine older adults specifically.

TPB and PA/Exercise

The ability of the model to predict PA behaviour is centered on the relations between intention and PA. Although there is considerable research support for the ability of TPB to predict PA intentions and behaviour in a variety of populations (Symons-

Downs & Hausenblas, 2005; Hagger, Chatzisarantis, & Biddle, 2002; McEachan et al., 2011), including older adults (Benjamin, Edwards, & Bharti, 2005; Dean, 2004; Dean, Farrell, Kelley, Taylor, & Rhodes, 2007; Kosma, 2014; Lucidi, Grano, Barbaranelli, & Violani, 2006; White et al., 2012), much of this research is correlational and experimental research has generally not supported the assumptions of TPB (Sniehotta, Presseau, & Araujo-Soares, 2014).

Moreover, associations between intention and actual behaviour based on experimental evidence are weak. In fact, a recent meta-analysis of experimental research specific to PA suggests that the effect size for PA intention is moderate (*d*= .45 (95% CI .30 to .60), yet trivial for behaviour (d= .15 (95% CI .06 to .23); Rhodes & Dickau, 2012). This discordance between intention and behaviour is highly problematic for experimental researchers, given that intention is viewed as the most proximal antecedent of behaviour in models like TPB. Yet, individuals who participate in intervention research show up with positive intentions to be active in the first place (Rhodes & De Bruijn, 2013b).

In fact, evidence suggests that 48% of those high intentions fail to act on their intentions to be active (Rhodes & De Bruijn, 2013a; Rhodes & Bruijn, 2013b; Rhodes & Dickau, 2012; Rhodes & Dickau, 2013). Intentions may be necessary for PA, but they certainly are not sufficient. To help translate high intention into action, it has been suggested that researchers should incorporate other factors, in addition to those targeting intention formation, into their theoretical frameworks and research (de Vries, Mesters, Van de Steeg, & Honing, 2005; Gollwitzer & Brandstatter, 1997; Rhodes & de Bruijn, 2013a; Schwarzer, 2008).

TPB, PA and Older Adults

Cross-sectional, prospective observational, and experimental research examining the utility of TPB in older adults is described next. In the older adult population, the strongest support for the utility of TPB also comes from cross-sectional work. Benjamin et al. (2005) study, 109 physically frail Canadian older adults were categorized as either high or low actives using a cut-off of 150 minutes per week of moderate intensity PA and then compared on their responses to items tapping TPB constructs. High actives could be significantly distinguished from low actives based on intention to continue exercising, positive indirect attitudes about exercise, and doctor's advice.

In another cross-sectional design, Dean et al. (2007) examined the factors influencing participation in strength training in a sample of adults aged 55 years and over. Participants completed a self-report questionnaire including TPB constructs, PA levels, and demographics. PBC and SN, but not attitude, explained 42% of the variance in intention to participate in strength training; while, intention explained 40% of the variance in strength training behaviour. Neither gender nor current participation in strength training mediated the relationship between TPB constructs and behaviour. The finding that SN influenced intentions to exercise is in contrast to the vast majority of literature that has demonstrated a weak relationship between SN and intention to exercise. The authors suggest that this may be that social reasons for PA may be more salient for older than younger adults.

Gretebeck et al. (2007) evaluated the ability of a TPB model and a TPB plus functional ability model to predict intention and self-reported PA in retired older adults. They found that the TPB model alone explained 72% of the variance in intention, but only 24% of variance in PA behaviour. The direct effects of PBC and attitude on intention were large and significant. This is consistent with meta-analytic work

demonstrating that PBC and attitude are strong and reliable predictors of intention (McEachan et al., 2011).

Last, Courneya and colleagues (1995) examined the relationships between stage of change (i.e., pre-contemplation, contemplation, preparation, action, and maintenance) and TPB constructs in a sample of older adults aged 60 years of over. Most of the stages of change could be significantly distinguished from each other based on the TPB model. Intention, PBC and attitudes all had significant direct effects on stage of change. However, TPB constructs could not discriminate between action and maintenance stages. TPB constructs explained 63% of the variance in stages of change.

Prospective literature examining the predictive utility of TPB in explaining PA behaviour in older adult has been weaker. For example, several prospective studies examining the predictive utility of TPB in older adults have found that intentions have explained little or no variance in the exercise behaviour in older adults enrolled in an exercise program. Lucidi et al. (2006) examined whether TPB constructs and Bandura's self-efficacy significantly predicted attendance at twice-weekly exercise classes over a three-month period. In this older adult sample of 65 to 90 year olds, the model explained 55% of the variance in intention to be physically active, but this translated to only 9% of the variance in exercise class attendance (i.e., 91% of the variance in exercise behaviour was *unexplained* by TPB). In a study conducted by Brenes and colleagues, physical activity intentions did not significantly predict exercise behaviour in a group of older adults aged 53 to 84 years who were attending an exercise class (Brenes, Strube, & Storandt, 1998).

Experimental literature with older adult samples has been extremely limited. Little support for the utility of TPB was found in one intervention study with older adults

(Kelley & Abraham, 2004). In this study, the TPB model to help design health living book to promote healthy eating and increased PA in adults aged 65 years and over who were attending hospital outpatient clinics. Participants were randomly assigned to either the intervention group (received a healthy living booklet) or a control group (received a patient satisfaction questionnaire). This healthy living targeted intentions, PBC and also promoted goal setting with respect to PA and health eating. At 2-week follow-up, the intervention group had significant increases in PBC, intention, and behaviour relative to the control group, when pre-intervention scores were controlled. However, neither PBC nor intention at follow-up accounted for gains in PA in the intervention group. Goal setting emerged as a significant covariate and the authors suggested that the gains in PA in the intervention group might have been due to the small proportion that set goals for PA.

In another randomized control trial, older adults with Type II diabetes or cardiovascular disease were randomized to a TPB intervention or a wait list control (White et al., 2012). The intervention group engaged in weekly 2-hour sessions focused on TPB topics related to PA and health eating (i.e. session one explored attitudes and beliefs, session 2 explored barriers, etc.). The intervention did not significantly affect intentions or TPB constructs. Moreover, six week post-intervention the participants did not report significant maintenance of behaviour.

The Action Control Framework and the Multi-Process Action Control Model

A recent review conducted by Rhodes & Yao (2014) identified 12 post-intentional theories of behaviour change (Integrated Change Theory; de Vries et al., 2005; Information Motivation Behavioral Skills Model; Fisher & Fisher, 1992; MoVo Process Model; Fuchs, Goehner, & Seelig, 2011; Rubricon Model of Action Phases; Gollwitzer,

P.M. Gollwitzer, 1991; Integrated Behavior Change Model; Hagger & Chatzisarantis, 2014; Heckhausen, 1991; Action Control Theory; Kuhl, 1984; J. Kuhl & Beckmann, 1985; Multi-Process Action Control Model; Rhodes & de Bruijn, 2013; Health Action Process Approach; Schwarzer & Luszczynska, 2008; Triandis, 1980; PRIME; West, 2008). Of these, the action control framework/Multi-process Action Control Model (M-PAC) proposed by Rhodes and de Bruijn (2013a) is among the most validated in the physical activity domain and therefore, it was used as the conceptual model for the present study.

In the M-PAC, action control refers to intention-behaviour discordance, as originally proposed by Kuhl (1984). The intention-behaviour relationship is divided into four quadrants based on the recommended public health guidelines for PA (i.e., 150 minutes of moderate to vigorous PA per week (Canadian Society for Exercise Physiology, 2011), such that two concordant quadrants (non-intenders who are subsequently not active, successful intenders) and two discordant quadrants (unsuccessful intenders, non-intenders who are subsequently active) are created (Rhodes & de Bruijn, 2013a). A recent meta-analysis using the Action Control Framework found that approximately 36% of participants were unsuccessful intenders, 42% were successful intenders, 2% were non-intenders who performed PA and 21% were non-intenders who did not perform PA (Rhodes & de Bruijn, 2013b). These findings suggest that while intention clearly remains an important construct within this framework (i.e., a substantial proportion of intenders do act on their intentions), other social cognitive and self-regulatory constructs that may predict intention-behaviour discordance need to be explored.

According to M-PAC, action control exists along a continuum from motivation initiation to behavioural continuation. Intention choice (defined as a binary decisional choice variable rather than intention strength) is determined by instrumental attitude/outcome expectations, affective attitude/ experiential expectations and PBC (i.e., ability/skills, opportunity). Translating intention choice into PA is proposed as the product of higher affective attitude and PBC than what was required to form the initial intention, as well as self-regulatory behaviours (e.g., coping planning, enlisting support, self-monitoring). Self-regulatory behaviours are viewed as particularly important when adopting new behaviours. Maintenance of these behaviours is thought to also include more reflexive constructs such as habit and identity formation (Figure 3; Rhodes & de Bruijn, 2013a). Habit is defined as behaviour performed as the result of triggers and routinized cues (Gardner & Tang, 2014; Gardner, De Bruijn, & Lally, 2011); while identity formation is behaviour that is performed as a result of an assumed role and desire to maintain that role (Stryker & Burke, 2000). The model was developed based on a review of the literature that highlighted the above variables as significant predictors of intention-behaviour discordance (Rhodes & de Bruijn, 2013a). The summary statement in M-PAC is that action control unfolds from motivation to behavioural regulation and finally to reflexive action across the motivational initiation, adoption, and maintenance process of behaviour change, respectively.

Studies examining intention-behaviour discordance from the perspective of the Action Control Framework are emerging (Godin, Shephard, & Colantonio, 1986; Orbell & Sheeran, 1998; Rhodes, Courneya, & Jones, 2003; Rhodes, Fiala & Nasuti, 2012; Rhodes & Plotnikoff, 2006; Rhodes, de Bruijn, & Matheson, 2010; Rhodes, Blanchard, & Bellows, 2008; Rhodes, Plotnikoff, & Courneya, 2008). For example, Rhodes and

colleagues (2012) examined whether automaticity (i.e., habit) and cross-behavioural regulation (i.e., planning for other highly sought behaviours), in addition to standard social cognitive constructs significantly predicted action control in a sample of college students. In this study, affective attitude, and PBC had significant large effects on both intention and action control, while instrumental attitude had significant large effects on intention only. Automaticity and cross-behavioural regulation had significant large and medium effects on action control only. Other work by Rhodes and colleagues has also demonstrated the importance of habit in action control: in their study an additional 7% variance in action control was explained by habit, after controlling for TPB variables and intention stability (Rhodes et al., 2010). Individuals with high habit were significantly more likely to be intenders who were regularly engaging in PA (70%); while, individuals with low habit were significantly more likely to be classified as inactive non-intenders (69%) in this sample of undergraduate students.

Summary

Although there is emerging evidence for the validity of the action control framework, the literature is generally limited to college or workplace samples. The literature examining PA intention-behaviour relations in older adults from the perspective of the Action Control Framework, and the M-PAC in particular, is non-existent. The current study will examine the predictive utility of both TPB and M-PAC for predicting overall attendance and self-reported walking, and change in walking behaviour over a four-month walking program.

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Results Tables and Figures

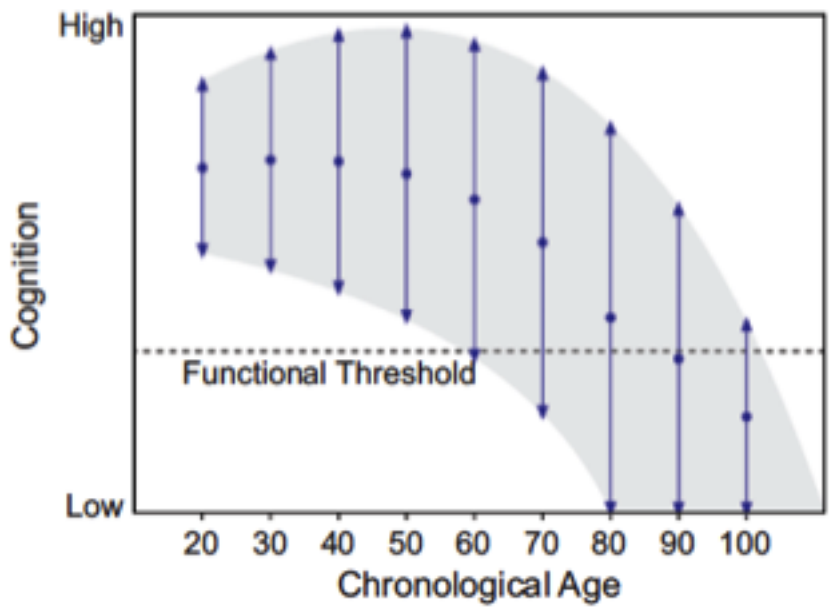

Figure 6. Depiction of the zone of possible cognitive development across adult life for a given individual (Hertzog, Kramer, & Lindenberger, 2008)

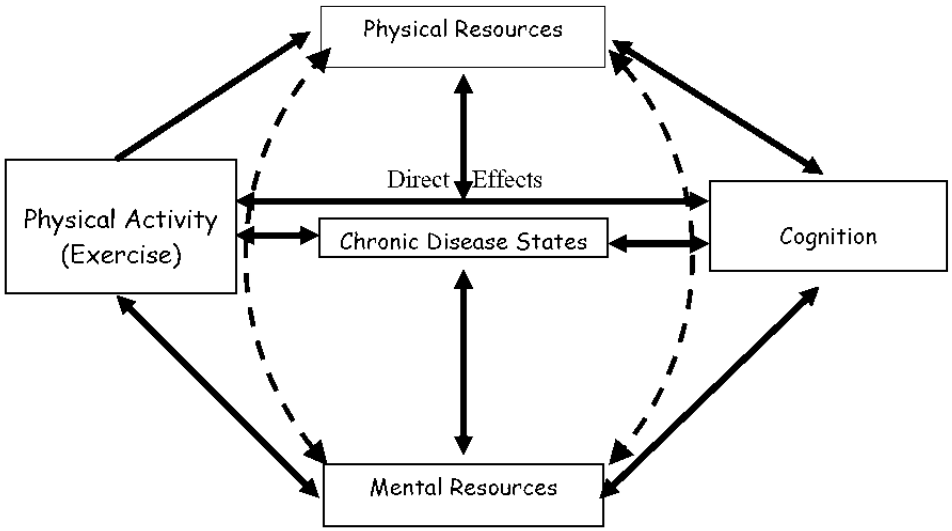

Figure 7**.** Working Model of Exercise and its Mediating Effects on Cognition (Spriduzo, Poon, Chodzko-Zajko, 2008)

Table 30. Meta-Analyzes & Systematic Reviews Examining Chronic Exercise/Physical Activity and Cognition in Older Adults

Study	N	Type	Inclusion Criteria	Findings/Effect Sizes
Angeveran (2008)	11	Meta	RCTs; cognitively unimpaired older adults ≥ 55 years of age	8 of 11 studies reported significant increase aerobic fitness & also reported improvement in cognitive function on at least 1 test.
			AE programs compared to any other intervention or no intervention	AE compared to any other intervention: Sig. "+" effects on cognitive speed (ES=0.26), visual attention (ES=0.26)
				AE compared to no intervention (wait-list, control group): Sig. + effects on auditory attention (ES=0.52) & motor function (ES=1.17)
				Improved cognitive functions varied across individual studies & most comparisons yielded insignificant effects.
Carvalho (2014)	27	Systematic review	RCTs (≥ n=30, ≥ 6 mos. long) or observational designs (≥n=100, followed for ≥ 1 year)	26 of 27 studies reported a "+" sig. association b/w E and cognition, including 9 of 10 RCTs. Identified benefits on specific domains: MMSE and inhibition
			Adults aged 60 years of age.	Unable to determine association between specific types of PA and specific cognitive domain - lack of standardization of measures and PA programs
				Differential time effect across domains: only 1 of 3 studies showed "+" of time at 12 months, 5 did at 12 months or more. "+" effects on speed and inhibition as early as 6 months (study didn't look at studies of less than 6 months)
				Only 9 of 27 studies rated "high quality", 15 of 27 "fair" and 3 of 27 "poor"; overall risk of bias was moderate.
Chang (2010)	6	Systematic review	Studies examining the effect of Tai Chi programs on cognitive performance	Limited, mixed evidence for cognitive benefits. Significant effects on executive function in those studies that those studies that examined it.
Chang (2012)	10	Systematic review	Cognitive unimpaired older adults aged 65 years or over. Resistance training compared to control group or comparable groups	2 of 3 studies examining effect of RE compared to no exercise found "+" effects between group and within groups (pre to post intervention). Results of RE compared to other activities were also mixed. Considerable discrepancies in RE interventions, description of the interventions, and in measure that were evaluated. Dose-response relationships have been found in some studies of higher quality.
Clifford (2010)	26	Systematic review	RCTs with control groups examining the effects of long-term exercise on cognitive function in middle aged-to older adults.	6 showed a clear benefit to cognition, 13 showed a benefit on select measures of those examined, and 7 showed no benefit.
				None found a negative effect
				Most support for effect of cognition on visual attention and memory but about only have of the comparisons were sig. They grouped studies by strange categories (i.e., cognitive speed, executive function, inhibition, visual attention, memory)
	4	Narrative review	RCTS of PA on cognition in individuals with existing cognitive impairment	Too few studies to compare/generalize across research – Insufficient evidence to conclude there is a clear benefit of PA to cognition in individuals with existing cognitive impairment
	13	Narrative review	observational designs examining healthy adults at baseline and ORs of dementia/staying dementia free depending on degree of PA	5 of 13 studies found reduced risk of dementia (31 to 88%), 4 found significant risk dementia for specific types of dementia only, while 4 found no effects. None found a negative effect
				Exercise may reduce risk of AD but not VaD, but this could also be due to methodological limitations of current work (great overlap between the two, control of covariates,

Study	N	Type	Inclusion Criteria	Findings/Effect Sizes
				disagreement between dementia classifications)
Colcombe (2003)	18	Meta	RCTs with control groups; supervised exercise programs with an AE component;	Regardless of cognitive function, exercise training improved cognition by 0.5 SD on average.
			Cognitively impaired & unimpaired older adults 55 years of age or older.	Large effect on executive processes (ES=0.68),
				Controlled (ES=0. 461), spatial (ES=0.461), and speed (ES=0.274) also had sig. effects.
				Combined strength & aerobic programs had stronger effect that either alone (ES=0.59 vs. 0.41).
Cumming (2012)	12	Meta	RCTs or clinical control trial examining PA/exercise on stroke	PA intervention compared to control: ES=0.20 (9 studies that had sufficient data)
				Note – cognitive measures in these studies were suboptimal and rarely the main focus of the study. 3 o the 9 studies included more comprehensive study. Studies examining individual cognitive domains were too few for ES to be calculated.
Etnier (2006)	37	Meta	Multiple designs examining the effects of cardiovascular fitness on cognition	All studies: cognition (ES=0.34) and fitness (ES=1.17)
				Results from pre-post comparisons were significant, such that smaller improvements in cardiovascular fitness (0.55) were predictive of larger improvements in cognitive functions (ES=0.25).
			All studies examining aerobic fitness using maximal, sub-maximal or composite measures of fitness.	Relations between fitness ES and cognitive ES were ns. in cross-sectional designs and post-test comparisons
Etnier (1997)	134	meta	Multiple designs examining the relationship of exercise on cognitive performance. Only those with sufficient information to calculate ES were included.	There was a significant positive, but small effect of chronic exercise on cognition (ES=0.29).
				Effect sizes decreased, as methodological rigor increased
			All age groups.	Cross-sectional designs (ES=0.53) and larger effects than for chronic exercise (ES=0.33) or acute exercise (ES=0.16)
			Chronic exercise intervention	Correlational: Mean correlation: cognition and fitness (r=0.29)
Farina (2014)	6	meta	RCTs, individual's with Alzheimer's disease of any age	ES=0.75 on global cognitive function based on only 3 of the 6 studies. The remaining 3 studies had insufficient data reported to be included in the ES calculation.
				Measures taken at baseline and endpoint only. Unable to examine trajectories.
				Insufficient studies to explore cognitive domains
Gates (2013)	14	meta	RCTS, individuals with MCI or MMSE of 24 to 28.	9 of 14 trials reported significance for at least one cognitive outcome. 12% of effects sizes were clinically relevant and only 8% were statistically significant.
				Negligible but significant effects on verbal fluency (ES=0.17).
				Other executive function measures (Stroop (ES=0.13), Trail making test B(ES=0.12)) delayed memory (ES=-0.001) and information processing (ES=0.57) were NS.
				Heterogeneous and inconclusive results of AE on cognition (n=7 studies)
				Large effects of RE on cognition (only 2 studies)
				Modest quality; under-powering for small effects was prevalent
Hamer (2009)	16	meta	Prospective epidemiological studies of physical activity and incident dementia, AD and Parkinson's disease	PA is inversely related to dementia risk. RR (pooled relative risk) of dementia in the highest physical activity category compared with the lowest was 0.72, for AD was 0.55

Study	N	Type	Inclusion Criteria	Findings/Effect Sizes
				and for Parkinson's 0.82
Heyn et al. (2004)	10	meta	Aged 65 years; dementia or related cognitive impairment; at least 1 of the following DV including health-related physical fitness, functional, cognitive, & behavioural outcomes Only those with sufficient information to calculate ES were included. Examined multiple outcomes. Only those relevant to cognition are presented in this table. Any exercise program compared control or comparison group	There was sig. medium ES (ES=0.57) of exercise compared to no-exercise on cognition. The effects on PA programs on cardiovascular fitness were also significant (ES=0.69) Effects on cognitive and fitness outcomes were not compared in relation to each other.
Hinden (2012)	42	meta	Experimental designs hypothesizing benefits on untrained cognitive domains from cognitive practice or AE were examined. Adults aged 55+	Medium effects were seen for both extended cognitive practice (ES =0.327) and aerobic fitness (ES =0.325). Cognitive practice and AE therefore had similar effects on cognition. Effect size on executive function (ES=0.459), memory (ES=0.386) and choice reaction time (ES=0.355) – including both cognitive practice and AE. Across the reviewed studies, better study quality was associated with larger ESs (0.338 vs. 0.312 for AE high vs. low quality). Studies often underpowered.
Kruger (2009)	160	meta	RCTs of 12 weeks or longer with documented outcomes of PA	Very few of the studies prescribed the recommended amount of 150 min or more per week of moderate-intensity physical activity. Insufficient body of evidence on the relationship between recommended levels of PA and cognition Some evidence that moderate-intensity physical activity had a "+" effect on cognitive health.
Law (2014)	8	Systematic review	RCTs of combined PA and cognitive training in older adult with and without cognitive impairment	Studies with cognitively healthy populations revealed significant benefits of combined cognitive and exercise interventions on general cognitive functions, memory and functional status compared to active control groups. Small literature base especially with cognitively impaired older adults. Studies need an active control
Leung (2007)	13	Systematic review	Longitudinal cohort studies of older adults and leisure activities	CA showed a more consistent beneficial effect on cognition Effects of PA and SA were more inconsistent and equivocal.
Miller (2014)	12	Systematic review	All designs examining the effects of Tai Chi on cognitive function	10 of 12 studies reported a positive effect of Tai Chi on executive function. Difficult to compare across studies due to variability in cognitive measures used and the overlap between domains.
Roig (2013)		Meta	RCTs examining the effect of acute or long-term AE on memory	Acute AE had moderate effects (ES= 0.26) and long-term AE had small effects on short-term memory (ES = 0.15) on short-term memory Acute AE had moderate to large effects (ES = 0.52) whereas long-term exercise had insignificant effects (SMD = 0.07) on long-term memory.
Schneider (2013)	6	Narrative review	RCTs of multimodal interventions combining a variety of lifestyle related factors	Promising area especially for combined PE and CA – 4 of 6 had "+" effects). Difficult to draw any conclusions of additive and synergistic effect of multimodal lifestyle interventions

Study	N	Type	Inclusion Criteria	Findings/Effect Sizes
				Limited work completed to date. 6 completed, and 8 on-going studies were identified
Smith	29		RCTs, Mean age >=18 yrs. of age; interventions were longer than >1 month included aerobic exercise Components and were supervised exercise training; Only those with sufficient information to calculate ES were included. Aerobic exercise compared to non-aerobic exercise control	Small sig. improvements in attention and processing speed (ES=0.158), executive function (ES=0.123), and memory (0.123), but not working memory (ES=0.032). Combined strength and aerobics had stronger effects on attention & working memory than aerobics alone.
Snowden (2011)			Older adults aged 50 and older, the sample of older adults was community dwelling, RCTS, quasi-experiment, or single-group interventions examining the effect of exercise intervention on cognitive outcomes.	Insufficient evidence for the effects of strength, AE, or multicomponent exercise on any cognitive domain (executive function, cognitive processing, attention, general cognition, memory, language, visual spatial). Across the cognitive domains and exercise types, the expert panel concluded that study quality was fair to good at best and they rated other areas as limited or achieved no-consensus on study quality. Insufficient evidence was due to too few studies (e.g., strength exercise and executive function) or inconclusive data (e.g., AE and executive function, multiple studies, mixed results).
Sofi (2011)	15	meta	Prospective observational designs examining the association between physical activity and cognitive decline in non-demented subjects.	Compared to engaging in low levels of PA, individuals who engaged in a high level of PA were sig. protected against cognitive decline during (HR = 0.62). Even low-to-moderate level of PA offered sig. protective effects (HR= 0.65)
Tseng (2011)	12	Systematic review	RCTs of exercise intervention on cognitive outcomes in older adults aged 65 yrs. and over.	8 of 12 studies found "+" effect on cognitive function. Small sample sizes; variations in exercise program, long term follow-up absent, diverse cognitive measures/outcomes, high dropout rates were prevalent weaknesses and limitations.
Wayne (2014)	11	meta	RCTs examining effects of Tai Chi on cognitive outcomes in individuals 60 years or over	Large effect of Tai Chi on executive function in healthy older adults when comparing Tai with non-intervention controls (ES= 0.90) and a moderate effect size when compared with active controls (ES = 0.51) Smaller but statistically significant effects on general cognition in cognitive impaired older adults when Tai Chi was compared with non-intervention controls (ES=0.35) and other active interventions (ES = 0.30).
Weih (2010)	6	meta	Cohort study of physical activity and AD	Pooled odds ratio (0.59) of high PA vs. low or no PA suggesting a inverse relationship between PA and Alzheimer disease

Table 31. Summary of Studies Examining the Relations between Gait and Cognition in Older Adults

Study (1st author, year)	Study Design	Participants characteristics	Cognitive Measure	Gait characteristic	Results
Atkinson (2007)	LS (2 yrs.)	Older adults (n=2349; mean age=75.6)	General cognition (3MS), executive function (CLOX, EXIT interview)	Gait speed	Both general cognition and executive function significantly predicted decline in gait speed over 2 years.
Atkinson (2010)	LS (6 yrs.)	Older women (n=1 739, mean age=70.3 yrs.)	General cognition (3MS)	Gait speed	Baseline general cognitive function predicted subsequent decline in gait speed and other physical measures over 6 yrs.
Beauchet (2012)	CS	Older adults (n=78, mean age = 69.9 yrs.)	Executive function (Stroop, Trail Making Test A and B) and working memory (digit span)	Gait variability (stride time variability)	Poor performance on stride time variability significantly associated with lower working memory performance
Bruce-Keller (2012)		Older adults with dementia (n=50, Controls (n=50, mean age =74.2 yrs.)	General cognitive (MMSE), executive function (clock drawing, category fluency), and processing speed (digit symbol)	Gait speed, cadence, stride length in normal and dual task walking	General cognitive function was significantly correlated with gait speed, cadence and stride length in normal and dual task walking when analyses were restricted to individuals with dementia and in all subjects, but not in controls only. Processing speed and executive functioning were significantly associated with all gait measures in analyses restricted to individuals with dementia and in all subjects. When analyses were restricted to control subjects, 1) processing speed was significantly associated with stride length and speed in dual task conditions only, 2) category fluency was significantly associated with stride length in normal and dual task walking and speed in dual task walking, and 3) clock drawing was associated with stride length in dual task walking.
Coppin (2006)	CS	Older adults (n=737, mean age = 72.7 yrs.)	Executive function/attention (Trail making Test)	Gait speed	Slower gait speed during complex dual task walking associated with poorer cognitive functioning
Donoghue (2012)	CS	Older adults 50 years and over (n=4998, mean age =62 yrs.)	General cognition (MoCA), executive function (Color Trails Test, word and letter Fluency), choice reaction time, attention (Sustained Attention to Response Task), memory (prospective memory, word recall, and picture memory).	TUG	Poorer performance on the MoCA, letter fluency, Color Trail 1, cognitive reaction time, mean sustained attention response time, and prospective memory were independently associated with slower TUG time
Duff (2008)	CS				
Hausdorff (2005)	CS	Older adults (n=43, 71.9 yrs.)	Executive function (Stroop) & memory (verbal memory).	Gait speed and variability (swing time variability)	Better catching but not tapping performance was significantly associated increased gait speed and decreased gait variability. Gait variability was also significantly inversely related to executive function
Hausdorff (2008)	CS	Older adults (n=228, mean age = 76.2 yrs.)	neuropsychological test battery (i.e., Go-No-Go, Stroop, nonverbal memory, tests of visual-spatial function, finger tapping and hand–eye coordination).	Gait speed and variability	Increased gait variability, but not decreased gait speed during dual task walking, was significantly associated with worse executive/attention performance.

Study (1st author, year)	Study Design	Participants characteristics	Cognitive Measure	Gait characteristic	Results
Herman (2010)	LS (2 yrs.)	Older adults (n=262, mean age= 76.3 yrs.)	neuropsychological test battery (i.e., Go-No-Go, Stroop, nonverbal memory, tests of visual-spatial function, finger tapping and hand–eye coordination), MMSE	Quantitative gait assessment	Baseline poorer executive function and increased gait variability during DT significantly predicted future falls over 2-year follow-up.
Holtzer (2006)	CS	Older adults (n=86, mean age = 73 yrs.)	Verbal IQ (Information, Vocabulary, Digit Span, BNT, and letter fluency), timed executive function/attention (Digit Symbol, Block design, Trail Making Test A and B) and memory (free recall from the Free and Cued Selective Reminding Test, category fluency). NOTE: tests were grouped in these 3 domains via factors analysis	Gait speed	Verbal IQ, time executive function/attention and memory all were significantly associated with gait speed in normal walking. In dual task walking, timed executive function/attention and memory were significant predictors of gait speed.
Holtzer (2012)	LS (3-7 yrs.)	Non-demented older adults (n=731, baseline mean age = 80.0)	Executive/attention (Digit Symbol Substitution Test), memory (Free and Cued Selective Reminding Test), verbal IQ (vocabulary)	Gait speed	Executive function and gait speed significantly associated with gait speed decline
Liu-Ambrose (2009)	CS	Older women aged 65 to 75 yrs. (n=140, mean age = 69.6 yrs.)	Executive functioning (set shifting (plus minus test), selective attention and inhibition (Stroop)) and working memory (digits forward and digits backward)	Time to complete 40 ft. course (i.e., 20 ft. turn and back to start)	Set shifting was significantly associated with dual task walking. None of the cognitive tests were significantly associated with normal walking
Martin (2013)	CS	Older adults (n=422, mean age = 72.0)	Executive/attention (COWAT, category fluency, Stroop, Digit Span), processing speed (symbol search, digit symbol coding) memory (Hopkins verbal learning test, RCFT delayed recall), visual-spatial (RCFT)	Quantitative gait assessment (GAITRite, speed, step time, step length, support base, double support base, gait variability)	Poorer executive functions were significantly associated with worse performance on most gait measures and increased gait variability measures; visual-spatial abilities were associated with increased double support phase variability. Memory was not associated with any of the gait measures.
McGough (2011)	CS	Sedentary older adults with MCI (n=201, mean age = 84,6 yrs.)	Executive Function (Stroop, Trail Making Test B)	Gait speed and TUG (fast pace)	Slower than usual gait speed and longer time to complete the TUG was significantly associated with poorer performance on both measures of executive function
Mielke (2013)	LS (5 yrs.)	Older adults without cognitive impairment (n=1478, mean age = 79.63 yrs.)	Memory (Logical Memory, Visual Reproduction tasks, the Auditory Verbal Learning test, language (BNT, category fluency) executive function (Trail Making test B and Digit Symbol Substitution subtest) and visual spatial skills (picture completion and block design	Gait speed	Baseline gait speed was significantly correlated with baseline cognitive performance on all cognitive domains. Gait speed and cognitive scores declined over time. Faster gait speed at baseline was associated with less decline in global cognition and all cognitive domains.
Mirelman (2012)	LS (5 yrs.)	Older adults (n=256, mean age = 76.4 yrs.)	neuropsychological test battery (i.e., Go-No-Go, Stroop, nonverbal memory, tests of visual-spatial function, finger tapping and hand–eye coordination)	Quantitative gait assessment & a falls report	Baseline executive/attention performance and gait variability under DT predicted future falls.

Study (1st author, year)	Study Design	Participants characteristics	Cognitive Measure	Gait characteristic	Results
Montero-Odasso (2009)	CS	MCI (n=55; mean age = 77.7)	General cognition (MOCA, Executive/attention (Trail making test), working memory (letter number sequencing test), psychomotor speed (digit symbol test)	Gait velocity	Working memory was associated with decreased gait speed especially during DT.
Persad (2008)	CS	MCI without EF (n=14, mean age = 72.5 yrs.); MCI with EF (n=10, mean age = 75.1 yrs.) AD (n=15, mean age = 77.5 yrs.); Controls (n=12, mean age = 70 yrs.)	Executive/attention (Map Planning and Paper Folding), memory (delayed recall from the Word List Learning Test of the Wechsler Memory Scale-III), and visual-spatial skills (Corsi Block-Task, Benton Visual Form Discrimination, Block Design)	Gait velocity	AD and MCI subjects with executive dysfunction were slower than healthy controls and individuals with MCI without executive dysfunction. Executive functioning was significantly associated with decreased gait speed during the most demanding walkway.
Sheridan (2003)	CS	AD (n=28, mean age = 77.9 yrs.)	General cognition (MMSE) Executive/attention (CLOX, verbal fluency), working memory (digit span)	gait variability	Increased gait variability and decreased gait speed during DT walking. Executive functioning and other cognitive measures were significantly associated with increased gait variability during dual task walking.
Springer (2006)	CS	Young adults (n=19, mean age = 29.4); Older adults (n=41, fallers mean age=76.1 and nonfallers mean age = 71.0 yrs.)	neuropsychological test battery (i.e., Go-No-Go, Stroop, nonverbal memory, tests of visual-spatial function, finger tapping and hand–eye coordination)	Quantitative gait assessment	Gait variability measures increased during DT only in the fallers. Increased gait variability measures were associated with worse executive function.
van Iersel et al.51 (2008)	CS	Older adults (n=100, mean age = 80.6 yrs.)	Executive/attention (Trail making test, Stroop), memory CANTAB) subtests)	Quantitative gait assessment	Executive functions were associated with increased gait variability measures during the DT (animal naming not serial 7s). Memory was not associated with dual task performance.
Verghese (2007)	LS (5 yrs.)	Older adults (n=427, mean age = 77.4 yrs.)	Executive/attention (Digit Symbol Substitution18 and Letter Fluency Tests, digit span), memory (Free and Cued Selective Reminding Test), general cognition (Blessed Information– Memory–Concentration Test)	Quantitative gait assessment (spatiotemporal domains grouped by factors of rhythm, pace, variability)	Baseline rhythm factor was associated with memory decline; baseline pace factor was associated with decline in executive function; both baseline rhythm and variability factor were associated with later dementia.
Verlinden (2014)	CS	Older adults (n=1232, mean age	Memory (a 15 word verbal learning task – immediate and delayed), information processing speed (Stroop reading, Stroop naming, Letter Digit	Quantitative gait assessment (GAITRite) - Rhythm, Variability,	Information processing speed was significantly associated with rhythm, fine motor with Tandem, and executive function with Pace (stride length and gait velocity) in bonferonni adjusted analyses.

Study (1st author, year)	Study Design	Participants characteristics	Cognitive Measure	Gait characteristic	Results
		= 66.3 yrs.)	Substitution Task), fine motor speed (Purdue Pegboard), and executive function (Stroop interference, Verbal Fluency, Letter Digit Substitution Task) and general cognition (all tasks).	Phases, Pace, Tandem (heal to toe walking), Turning, and Base of Support)	When using conventional p values, memory became significantly associated with Phases and Pace, information processing speed with Turning, and fine motor speed and executive function with Variability.
Watson et al. (2010)	LS (5 yrs.)	Older adults (n=909, mean age = 75.2 yrs.)	Executive/attention (EXIT interview), memory (Buschke Selective Reminding Test), global cognition (MMSE), psychomotor speed (Boxes and Digit Copying tests), perceptual speed (Pattern and Letter Comparison)	Gait speed	Baseline poorer performance in global cognitive function, verbal memory and executive function were significantly associated with greater gait speed decline over 5 years

Table 32. Summary of Dual Task Findings in Healthy and Cognitive Impaired Older Adults

Study	Design	Participants characteristics	Gait Measures	Dual Task Conditions	Findings
Allali (2007)	CS	1) Demented older adults (n=16; mean age =83.6 yrs.)	Quantitative gait Assessment (GAITRite)	1) counting forward 2) counting backward	Increased gait variability during dual task walking (forward and backward counting) relative to normal walking. Backward counting associated with increased gait variability compared to forward counting. Cognitive performance did not differ between normal and dual task walking, but more numbers were recited during forward counting than backward counting.
Bloem (2001)	CS	1) Young adults (n=50, mean age 27.0 yrs.); 2) Older adults (n=13; mean age 62.0 yrs.)	Time taken to complete each of 11 tasks	11 motor tasks of increasing difficulty while walking (e.g., 1 - standing up, undisturbed walking, 2 - turning around and sitting down. standing up, undisturbed walking while answering every day questions).	Increased motor errors associated with DT complexity especially in older adults. Young adults gave preference to motor over cognitive tasks.
Camicioli (1997)	CS	1) Healthy older adults (n=43) including n=20 old-old (mean age =86 yrs.) & n=23 young-old (mean age =72 yrs.) 2) AD (n=15, mean age = 74 yrs.) .	Time and steps taken to walk 30 ft.	Verbal fluency task	Decreased walking speed in AD patients versus older adults during DT
Donohue (2013)	CS	Older adults (n=1307, mean age 71.3, including no FOF, FOF, FOF with activity restriction)	Quantitative gait assessment (GAITRite)	Reciting alternative letters of the alphabet (i.e., A-C-E)	FOF was associated with reduced gait speed and stride length and increased double support phase and step width in normal and dual task conditions. Most pronounced in FOF with activity restrictions
Hausdorff (2008)	CS	Older adults (n=228; mean age =76.2)	Quantitative gait assessment (GAITRite)	Serial 3s and 7s Phoneme monitoring (listened to story and counted the number of times two predetermined words occurred)	Increased gait speed and swing time and decreased gait variability during all DT. Gait variability under DT was sig. associated with executive function (i.e., Go-No-Go and the Stroop tests).
Hollman et al. (2007)	CS	1) older adults (n=20, mean age=81 yrs.); 2) middle-aged adults (n=20, mean age = 48 yrs.); 3) young adults (n=20, 25 yrs.)	Quantitative gait assessment (GAITRite)	Spelling 5-letter words backwards	Increased gait variability and decreased walking speed, and poorer dual task performance in older versus middle-aged and young adults during DT.
Lamouth (2008)		1) dementia (n=13, 82.6 yrs.) 2) older adults (n=13, 79.4	Distance walked in 3 minutes along a 40 minute corridor	Verbal fluency (“R” or “G”)	Dual tasking significantly decreased walking speed, stride time variability increased, and stability and regularity of lateral trunk accelerations decreased. Stride time variability was greater in

		yrs.)			individual with dementia compared to healthy older adults.
Lindenberger (2000)	CS	1) young adults (n=47, mean age=24 yrs.); 2) middle-aged adults (n=45, 45 yrs. of age); 3) older adults (n=48, mean age =65 yrs.)	Time taken to walk on a two oval tracks	Memorization	Decreased speed during DT & poorer memorization performance with increased age
Montero-Odasso (2009)	CS	MCI (n=55, mean age=77.7 yrs.)	Time to walk 6m walk	Counting backwards and Category fluency (animals)	Gait velocity decreased under dual task conditions. Slow gait was associated with working memory.
Montero-Odasso (2009)	CS	MCI (n=11, mean age =76.6 yrs.)	Quantitative gait assessment (GAITRite) - 2 sessions	Counting backwards	Gait velocity decreased and gait variability (stride time, step time, and double support time) increased during dual task conditions. High reliability between the 2 sessions on the gait mat.
Montero-Odasso (2012)	CS	MCI (n=43, mean age = 75.1 yrs.) Controls (n=25, mean age = 71.5 yrs.)	Quantitative gait Assessment (GAITRite)	Serial 7s and category fluency (animals)	Increased gait variability and decreased walking speed in MCI compared to control subjects. Increased with increasing DT complexity.
Muir (2012)	CS	AD (n=23, mean age =77.5 yrs); MCI (n=29, mean age= 73.6); Controls (n=22, mean age =71.0 yrs.);	Quantitative gait assessment (GAITRite)	Semantic fluency task; counting backwards, serial 7s	Increased gait variability and decreased walking speed in AD and MCI versus controls during DT. This increased with increasing DT complexity.
Plummer-D'Amato (2011)	CS	Young adults (n=21, mean age =22.0 yrs.74.7 yrs) Older adults (n=23, mean age=74.7 yrs)	Walk for 60 second around an oval track	Stroop, spontaneous speech task	Walking while talking decreased gait speed in both young and older adults. Older adults, and not younger adults, also experienced significant cognitive-motor interference during the Stroop task. Stride duration variability increased and gait asymmetry increased during dual task in older adults.
Sheridan (2003)	CS	AD (n=28, mean age =77. 7 yrs.)	Quantitative gait assessment (laps around oval track wearing force-sensitive insoles)	Forward digit span	Decreased gait variability and increased walking speed during DT. Executive function (CLOX, verbal fluency) associated with increased gait variability during DT
Theil (2011)	CS	Older adults (n=711, mean age= 77.2	Quantitative gait assessment (GAITRite)	Counting back by 2s, verbal fluency	Decreased gait velocity and poorer performance on serial counting but not semantic fluency during dual tasking. Cognitively impaired greater decreases in gait velocity but not cognitive performance during dual tasking walking than cognitively healthy participants
Verghese et al.	CS	Older adults (n=189, mean age	Quantitative gait assessment	Reciting alternate letter of the alphabet	Decreased speed during cognitive task prioritization as compared to prioritizing both. Performance on the alternating alphabet did

(2007)	=80.2 yrs.)	(GAITRite) Examined effect of prioritization	not differ between conditions

Appendix 2: Screening Materials

1. Telephone Screen
2. Case Record Form
3. Telephone Interview for Cognitive Status
4. PAR-Q+

Healthy Bodies, Healthy Minds – A Supervised Walking Program for Older Adults

Initial Contact and Telephone Screening Instructions

Participants will be recruited through physician referral and advertisements in local media. Thus, in most cases, they will be calling the Healthy Bodies, Healthy Minds program to get more information and to volunteer. At this first informal telephone interview, the researcher will have two goals:

1. To obtain some basic information from the person that enables us to determine whether they meet basic criteria for potential inclusion in the study; in particular that they do not possess any of the characteristics that would exclude them from participating.
2. To provide the person with basic information about the study and what they will be asked to do so they can make an initial informed judgment about whether they wish to volunteer to participate.

The information below is a guideline for the informal interview. The researcher will make the conversation as natural as possible rather than reading the information in a stilted manner. In some cases, she will have to change what she says to accommodate the situation. For example, if she is returning a call following a phone message, it makes no sense to ask for their name or phone number. But in some cases, you may wish to confirm the spelling of their name.

Information provided by each person should be recorded on the Contact Record Form and in the Master Participants File (Password protected Excel file).

Telephone Protocol

Introduction

Hi, my name is Kristina Kowalski. I am the primary researcher and certified personal trainer working on the Healthy Bodies, Healthy Minds Program and a research assistant at the Behavioural Medicine Laboratory and Centre on Aging at the University of Victoria. I am running a walking program for older adults aimed at promoting cognitive and physical health. I am doing so as part of my degree requirements for obtaining my PhD in Exercise Science and Neuropsychology at the University of Victoria. The Healthy Bodies, Healthy Minds supervised walking program is being run by myself under the supervision of Drs. Rhodes, Tuokko, Naylor and MacDonald and a certified exercise physiologist. Thank you for your call and your interest in learning more about the Healthy Body, Healthy Minds Supervised Walking Program for Older Adults. The program is very exciting and I'm looking forward to tell you all about it.

Study Description:

The study involves a walking program that is 4 months long. The group meets 3 times a week for 30-45 minutes. The intensity and duration of the walking builds up slowly starting from 15 minutes. After the walk, the group snacks and refreshments will be available.

You can attend walking groups at the University of Victoria, Dallas Road, Elk Lake and other walking locations around town. The locations and times of groups you attend are up to you. Biweekly, there will be themed walking groups. These will be the same as regular walking groups except that the group also discusses a selected topic while going for a walk for these sessions. The topics will include hot topics for older adults like successful aging, staying mentally sharp and mobility. There will be selected articles to read before these groups. Reading them is optional. If you enjoy reading and want to become more active, these sessions could be fun for you. Research has demonstrated that added benefit of exercising and keeping an active mind. You are welcome to read and participate in the discussion or just attend the walking groups to walk.

Again, attending the walking groups is completely up to you.

- If you are interested in joining the 4 month program you will be asked to fill out health and demographic questionnaires, questions about your readiness to exercise and your thoughts and beliefs about walking. Only those people screened as safe to exercise by the PAR-Q+/e-PAR-med-X and/or their doctor will be permitted to participate. At the time of the first appointment, if permission from your doctors was necessary, you will required to present a copy of the final page of the PAR-Q-med-X+ signed by your physician to qualify for the study. This will only be necessary when your responses on the PAR-Q+ and PAR-Q-Med X+ indicate that it is necessary for you to seek medical advice before exercising. If your doctor's permission is needed and obtaining this medical advice and signature is associated with a fee, you will be reimbursed for this fee.
- Then you will be scheduled for a group testing session, where you will complete test of your fitness (height, weight, blood pressure, heart rate, waist circumference, and a walking test) and a gait assessment. You will also fill out a questionnaire about your history of physical activity.
- Then you will be asked to monitor your physical activity for 1 week using an objective measure of physical activity – a motion sensor. The motion sensor is a 'smart' pedometer that works like the lights used in yards and carports. Like these lights, the motion sensor is always on, but is activated by movement. The motion sensor will give us an idea of your typical physical activity patterns. The motion sensor is safe, non-invasive, and is only attached to the body by the belt worn around the waist. We would like you to begin wearing the motion sensor when you get out of bed in the morning, until you go back to bed at night; continuously for 7 days (i.e. 7 days straight), starting the morning after I give it to you. You will also keep a log of you physical activity. At the end of a week you fill out a quick questionnaire on your physical activity and other activities.
- Then I will come to your home for an appointment where we will talk about your diet, your medical conditions and medications. You will complete a short computer test of your memory and thinking abilities. It is okay if you don't have a computer or aren't used to using one. I will be there to help explain the test and all I ask is you do your best!
- Immediately after these tests or on another date if you prefer, you will participate in an information session about healthy behaviours and your cognitive health.

During this session you will learn about things you can do to promote your cognitive and physical health. You will receive tools to help you stay active & eat well and you will be introduced to the supervised walking program.

- Additional cognitive, fitness, and diet assessments will occur in your home at 6, 9, 12 & 16 weeks. Following each of these appointments you will monitor your activity for 1 week using an accelerometer and activity log after. Additional gait assessments and walking tests will also occur; however, the gait mat is large (16 ft long) and cannot be easily transported to your home. Prior to the walking groups on these weeks, we will have several participants complete the gait assessments walking tests, ideally at the University.

Any questions?

You might be wondering about the time commitment. The program has a large time commitment. At the beginning of the study participants will participate in a group testing and an in-home testing session each requiring approximately 2 hours and 1.5 hours of the participant's time, respectively. The information and personalized coaching session takes 1.5 hours. Over the four-month period participants will engage testing session of 1 hour each at 6 weeks, 9 weeks, and 12 weeks and 16 weeks. They monitor their physical activity for 1 week at each of these time periods. If any of these appointments are too long I am flexible and can return to your home for multiple shorter appointments if necessary.

The walking group meets three times a week, but it is up to you if you attend all the sessions. It is completely voluntary.

There is a lot involved in the program but there are many benefits.

- Become more physically active!
- Get free personal training & lifestyle coaching!
- Be part of a fun & motivating group!
- Potential to win monthly raffle prizes!
- Be entered into a draw for a 1 year regional pass to all the recreation centres in Greater Victoria!
- Learn about your cognitive health and how to lead a healthier lifestyle.

Verbal Consent:

Now before we proceed further, I want to ask you some basic questions to make sure you are eligible for the study. This information will be used for screening purposes only and will not be used for future data analysis. If it okay with you, I will also keep track of the numbers of individuals who are interested and eligible for the study, those who decide not to participate, and those who are ineligible and the reasons why. Is that ok? (Obtain consent and record that verbal consent was received on the Case Record and Contact Form)?

Eligibility Criteria:

1. <u>Name and Geographic Location</u>

First, let me get (confirm) some information. Can you give me your full name? (Record). And what is your phone number? (Record). (If you are calling them, confirm these items). Can you also give me your address, please (Record; If you don't know roughly where the address is located ask the person to identify the area or general location.

If the address is outside of the core area [e.g., Malahat, Gulf Islands] tell the person they will have to come to the University for all testing and information/coaching sessions, explaining it is too far for me to drive and still test and see everyone).

2. Age: What is your age? (Record).
   If under age 65: I am sorry to say we are looking for volunteers who are at least 65 years old for this particular study. However, if you wish I can keep your name on file in the event that another of our studies involves younger persons such as yourself. Would you like to leave your name on file? (Record). Thank you very much for your interest in the project. (Goodbye).

3. Health Problems:
   Have you been diagnosed by a physician with a serious aliment such as dementia, Parkinson's disease, heart disease, cancer, alcoholism, or a psychiatric illness; or have you had a recent illness that made you go to hospital, or that has significantly affected your daily activities? (Record; Probe to determine if the problem is currently active and potentially serious).

   If a significant health problem that might influence cognition (e.g., Parkinson's, brain tumor, head injury, recent stroke or heart attack): I am sorry to say we are looking for volunteers who have not had any major recent illnesses. However, if you wish I can keep your name on file in the event that another of our studies involves persons such as yourself. Would you like to leave your name on file? (Record). Thank you very much for your interest in the project. (Goodbye).

4. Cognitive Screen
   If participant scores <28, inform them that based on their score on this test, they are ineligible for the study. However, if you wish I can keep your name on file in the event that another of our studies involves persons such as yourself. Would you like to leave your name on file? (Record). Thank you very much for your interest in the project. (Goodbye).

5. Language:
   Do you speak, read and write fluently in English? (Record).
   If no, I am sorry to say, but to participate in this study you must be able to easily and fluently communicate, orally and in writing, and read and understand English.

6. Sensory Impairment:
   Do you have any trouble seeing, hearing, or writing? That is, do you have difficulty reading newspaper-size print? (Record). Do you have trouble hearing a

normal spoken conversation? (Record). Do you have arthritis or other problems with your hands so that writing or pressing a key on a keyboard is difficult? (Record). (In each case, probe to determine the extent of the problem).

If a significant problem (e.g., can't read even with glasses; can't hear normal conversation even with hearing aid; severe arthritis or other motor problem resulting in great difficulty moving hands): I am sorry to say, to participate you must be able to see newspaper-size print easily, hear a normal conversation easily, and write easily. However, if you wish I can keep your name on file in the event that another of our studies involves persons such as yourself. Would you like to leave your name on file? (Record). Thank you very much for your interest in the project. (Goodbye).

7. Physical Activity Level: Are you currently getting 150 minutes of moderate to vigorous physical activity per week in bouts of 10 minutes or more?

If yes, I am sorry to say, to participate you must be getting less than 150 minutes of moderate to vigorous physical activity per week. However, if you wish I can keep your name on file in the event that another of our studies involves persons such as yourself. Would you like to leave your name on file? (Record). Thank you very much for your interest in the project. (Goodbye).

Eligible for Study?

Yes/No (Record on contact sheet) IF NO DESTROY DATA. KEEP TRACK OF NUMBERS OF PEOPLE WHO ARE INELIGIBLE AND WHY (i.e., X participants were ineligible to participate because they did not speak English)

If yes, check of interest and schedule appointments using procedures below:

Interest and Scheduling

Do you have any other questions at this time about the Healthy Bodies, Healthy Minds Program or what it will require of you? Do you think you would like to participate in the study? (Record)

If yes: (Positive expression: Very good, wonderful, etc.). We appreciate your willingness to participate in the Healthy Bodies, Healthy Minds Program and help me with my research.

Can I get your address? I will mail you the consent forms and the initial questionnaire for you to complete prior to the first appointment.

What I would like to do then, is set up an appointment for the initial session. As I mentioned, the first session will be conducted in small groups at the university or a recreation centre. We will send you a map and parking instructions. Would you prefer to receive this information via email or would you like a hard copy in the mail (Record preference and address). Now, I have several possible appointment times (Schedule and record appointment in Study Calendar)

If no, that’s fine. Thank you for taking the time to learn more about the program and your initial interest in the project. I wish you all the best with physical activity and healthy living goals. Goodbye!

IF NOT INTERESTED DESTROY SCREENING DATA, BUT KEEP TALLY OF NUMBER OF INDIVIDUALS WHO WERE NOT INTERESTED

Healthy Bodies, Healthy Minds – A Supervised Walking Program for Older Adults

Case Record Form

Telephone Screen

Refer to questions in telephone script when filling out this section of the case record form.

1. Initial Telephone Contact: _____ (dd/mm/yyyy)
2. Verbal Consent for Screening (Yes/No)**:** _____
3. Inclusion Criteria (Circle Y or N):
    i. **Name and Geographic Location:**

Full Name:	
Phone Number:	
Email:	
Address with Postal Code: **Note: - must be community dwelling**	
Geographic Location	

Eligible: Yes/No (Must live in Greater Victoria)

ii. **Age:**

Age & DOB	

Eligible: Yes/No (Must be 65+)

iii. **Serious Health Conditions:**

Must not influence cognition or significantly impair ADLs:

List	Describe

Eligible: Yes/No

iv. **Cognitive Screen (TICS) Score: _____**

Eligible: Yes/No (28 or higher to be eligible)

v. **Language:**

	Yes/No
Speak English fluently:	
Read English fluently:	
Write English fluently:	

Eligible: Yes/No

vi. **Sensory Impairment:**

	Yes/No
Trouble seeing:	
Trouble hearing:	
Trouble writing:	

Eligible: Yes/No

vii. **Physical Activity:**

	Yes/No
150 minutes of MVPA?:	

Eligible: Yes/No

4. **Verbal consent to mail out package?** **Y N**

If Yes, mail out consents, PAR-Q, & preliminary instructions for fitness testing, and the initial questionnaire so the participant can review and fill them out before the first session.

Date package mailed out: _____ (dd/mm/yyyy)

5. **Availability:**

Best time to call _____

Availability for appointments _____

_____

_____

6. **Scheduling:**

	Date	**Time**	**Location**
Group			
Individual			
Information Session			

7. **Equipment Log & Follow-Up Appointment Scheduling:**

Timing	**Accelerometer Number**	**Date of Appointment**	**Date Returned**	**Data Uploaded**
Baseline				
6 weeks				
9 weeks				
12 weeks				
16 weeks				

8. **Follow-Up Gait and Walk Test:**

Timing	**Date of Appointment**	**Data Uploaded**
Baseline		
6 weeks		
9 weeks		
12 weeks		
16 weeks		

9. **On-Going Support**

Month 1: _____ to _____
Bi-Weekly Phone Call: _____
Bi-Weely Phone Call _____
Month 2: _____ to _____
Bi-Weekly Phone Call: _____
Bi-Weely Phone Call: _____
Month 3: _____ to _____
Bi-Weekly Phone Call: _____
Bi-Weely Phone Call: _____
Month 4: _____ to _____
Bi-Weekly Phone Call: _____

Healthy Bodies, Healthy Minds – A Supervised Walking Program for Older Adults

Telephone Interview for Cognitive Status

Date: _____

Participant ID: _____

Question	Scoring Criteria	Points Awarded
1. Please tell me your full name?	1 pt. for first name and 1 pt. for last name. **2 pts**	
2. What is today's date?	1 pt. for month, date, year, day of week, and season (if incomplete, ask for specifics – e.g., What is the month? What is the season?) **5 pts.**	
3. What is your age? What is your phone number?	1 pt. for correct age. 1 pt for correct phone number including area code. **2 pts.**	
4. Count backwards from 20 to 1	2 pts. if completely correct on 1st trial, 1 pt. if completely correct on 2nd trial, 0 points for anything else. **2 pts.**	
5. I am going to read you a list of 10 words. Please listen carefully and try to remember them. When I am done, tell me as many words as you can, in any order. The words are: 1. Cabin 2. Pipe 3. Chest, 4. Elephant 5. Silk 6. Theatre 7. Watch 8. Whip 9. Pillow 10. Giant Now, tell me all the words you can remember.	1 pt. for each correct response. No penalty for intrusions or repetitions. **10 pts.**	
6. 100 minus 7 equals what? And 7 from that?.... Now continue to subtract 7	Stop at 5 serial subtractions. 1 pt. for each correct subtraction. Do not inform the participant of incorrect	

from what you have left over until I ask you to stop.	subtractions, but allow for subtractions to be made from his/her last response. **5 pts.**	
7. What do people usually use to cut paper? How many things are in a dozen? What do you call the prickly green plant that grows in the desert? What animal does wool come from?	1 pt. for scissors or shears only. 1 pt. for 12 1 pt. for cactus 1 pt. for sheep or lamb **4 pts.**	
8. Say this "No ifs, ands or buts" Say this "Methodist Episcopal"	1 pt. for each if exactly right. **2 pts.**	
9. What is the Prime Minister's name? 10. What is the name of the premier of BC?	2 pt. for Steven Harper. 2 pt. for Christy Clarke. **4 pts.**	
10. With your finger, tap 5 times on the part of the phone you speak into	2 pts. if 5 taps heard, 1 pt. if participant taps more or less than 5 times. **2 pts.**	
11. I'm going to give you a word and I want you to give me its opposite. For example, the opposite of hot is cold. What is the opposite of West? What is the opposite of generous?	1 pt. for east. 1 pt. for selfish, greedy, stingy, cheap, tight, mean, meager, skimpy, or other good antonym. **2 pts.**	
12. Please repeat the list of words I read earlier	1 pt. for each correct response. **10 points.**	
	Total	

Physical Activity Readiness Questionnaire for Everyone (PAR-Q+)

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition **OR** high blood pressure?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition?	☐	☐
6) Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer **NO** if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Canada's Physical Activity Guidelines for your age (www.csep.ca/guidelines).
- You may take part in a health and fitness appraisal.
- If you have any further questions, contact a qualified exercise professional such as a Canadian Society for Exercise Physiology - Certified Exercise Physiologist® (CSEP-CEP) or a CSEP Certified Personal Trainer® (CSEP-CPT).
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional (CSEP-CEP) before engaging in this intensity of activity.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever - wait until you feel better
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the **ePARmed-X+ at www.eparmedx.com** before becoming more physically active
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity program.

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PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have Heart Disease or Cardiovascular Disease? *This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm*

If the above condition(s) is/are present, answer questions 3a-3e If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐
3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you have any Metabolic Conditions? *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes*

If the above condition(s) is/are present, answer questions 4a-4c If **NO** ☐ go to question 5

4a.	Is your blood sugar often above 13.0 mmol/L? (Answer **YES** if you are not sure)	YES ☐ NO ☐
4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?	YES ☐ NO ☐
4c.	Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?	YES ☐ NO ☐

5. Do you have any Mental Health Problems or Learning Difficulties? *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)*

If the above condition(s) is/are present, answer questions 5a-5b If **NO** ☐ go to question 6

5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
5b.	Do you **ALSO** have back problems affecting nerves or muscles?	YES ☐ NO ☐

PAR-Q+

6. Do you have a Respiratory Disease? *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 6a-6d — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

7. Do you have a Spinal Cord Injury? *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 7a-7c — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

8. Have you had a Stroke? *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

9. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 9a-9c — If **NO** ☐ read the Page 4 recommendations

9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
9c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20-60 min of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional (CSEP-CEP) before engaging in this intensity of activity.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional (CSEP-CEP) to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever - wait until you feel better
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the **ePARmed-X+ at www.eparmedx.com** before becoming more physically active
- Your health changes - talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The PAR-Q+ Collaboration, the Canadian Society for Exercise Physiology, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- Please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact

www.eparmedx.com or
Canadian Society for Exercise Physiology
www.csep.ca

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration.
The Physical Activity Readiness Questionnaire (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

Key References
1. Jamnik VJ, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation: background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance: Consensus Document. APNM 36(S1):S266-s298, 2011.

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Appendix 3: Recruitment Materials

1. Recruitment poster
2. Notice of research
3. Newspaper advertisement
4. Brochure

Recruitment Poster

Do you want to become more physically active ?

Behavioural Medicine Laboratory UVic

Healthy Bodies, Healthy Minds—A Supervised Walking Program for Older Adults is looking for Participants!

What is Involved?
Participate in a four month program involving walking groups that meet 3 times a week. Learn about healthy behaviours that can promote your cognitive and physical health! Learn valuable tools to help you begin and maintain a physical activity program. Call Kristina to learn more about the study and walking program.

Who Can Participate?
Adults (65+) who engage in less than 150 min of moderate to vigorous intensity physical activity per week.

Keep your mind and body active! Stay socially engaged!

HAVE FUN!

For more information, contact:
Kristina Kowalski
250-472-5288
kkowalsk@uvic.ca

Notice of Research

Notice of Research

We are inviting you to participate in a study titled **"Healthy Bodies, Healthy Minds – The Impact of a Supervised Walking Program on the Cognitive and Physical Health of Older Adults"**

The study is being conducted by Kristina Kowalski, a PhD candidate from the School of Exercise Science, Physical and Health Education and the Department of Psychology and research assistant in the Behavioural Medicine Lab and the Centre on Aging at the University of Victoria.

For this research, we are looking for individuals who would like to become more physically active. Are you over 65 years of age? Are you trying to maintain your physical and cognitive health as you age? The Healthy Bodies Healthy Minds Supervised Walking Program could be for you!

Why should you participate?

Through the walking program, the researcher aims to help you engage in a healthy lifestyle and to educate and encourage you to maintain your cognitive and physical health as you age. The objective of the research program is to examine the relations of physical activity (and other health behaviours—diet, social engagement, intellectual stimulation) to cognitive and physical health. Ultimately, the goal of the program of research is to inform the development of an intervention to preserve cognitive health, promote quality of life, and reduce the risk of dementia in older adults.

What is involved?

If you chose to participate, you will:

- Receive a package of consent forms, and a questionnaire about your readiness to exercise, background demographics and health, and walking. Only those people screened as safe to exercise by the PAR-Q+/e-PAR-med-X and/or their doctor will be permitted to participate. At the time of the first appointment, if permission from your doctors was necessary, you will be required to present a copy of the final page of the e-PAR-Q-med-X+ signed by your physician to qualify for the study. This will only be necessary when your responses on the PAR-Q+ and e-PAR-Q-med X+ indicate that it is necessary for you to seek medical advice before exercising. If your doctor's permission is needed and obtaining this medical advice and signature is associated with a fee, you will be reimbursed for this fee.
- Attend a group testing session for a gait and fitness assessment
- Monitor your activity for 1 week using an accelerometer and activity log
- Complete in-home testing where you will be interviewed about your diet, medical conditions, and you will complete cognitive testing
- Attend a walking program. The walking program includes:
    - An information session on behaviours to help maintain your cognitive health.
    - Personalized coaching and tools to help you become active and maintain a healthy lifestyle.
    - Walking groups that meet 3 times a week for 4 months and walk at a moderate to vigorous intensity.
    - Your choice of participating in walking sessions at the University, along Dallas Road, Elk

Lake, and other great walking locations around town. You can come to the same location and times each week or mix it up. You will be given a schedule of times and locations for each month.

- Bi-weekly themed discussions at walks. The themes will be hot topics for older adults including successful aging, staying mentally sharp and mobility. You will be given several articles to read prior to the walks and the group will discuss these important topics while we walk. Reading the articles and participating in the themed discussion is optional.

- Additional cognitive, fitness, and diet assessments in the home at 6, 9, 12 & 16 weeks.
- Monitor your activity for 1 week using an accelerometer and activity log after each of these appointments.
- Also complete gait assessments and walking tests at 6, 9, 12, and 16 weeks. The gait mat used for these assessments is large and not easily transported to your home. As such, the assessments will occur before group walking sessions at the University or a local recreation centre.

Why is this research important?

Your involvement in this research is very important! Due to the rapid aging of our population and the increased prevalence of Alzheimer's disease and related dementias with advancing age, strategies aimed at preventing cognitive decline and promoting healthy aging are important research and public health priorities The focus needs to be on methodologically rigorous research examining the relations of modifiable risk factors (e.g., physical activity, diet) to cognitive functioning and other aspects of health and well-being in older adults. The focus of this body of research should also be on the development and evaluation of programs supporting the adoption and maintenance of attitudes, beliefs and behaviours believed to promote healthy cognitive aging and to prevent disease and disability in the older adult population. Despite the known benefits of physical activity, over half of Canadians are not active enough to reap these benefits and the prevalence increases with age. Developing methods to increasing the physical activity levels and other health behaviours of older adults can benefit many aspects of health and well-being. Ultimately, the goal of this program of research is to inform the development of an intervention to preserve cognitive health and reduce the risk of dementia in older adults.

What is in it for you?

- Become more physically active!
- Get free personal training & lifestyle coaching
- Be part of a fun & motivating group
- Be entered into monthly raffle prizes
- Be entered into a draw for a 1 year regional pass to all the recreation centres in Greater Victoria!

Should you choose to participate, it is important for you to know that you can withdraw at anytime without explanation or consequence. Thank you very much for your time, and please feel free to contact Kristina at the Behavioural Medicine Lab at 250-472-5288 for further information.

Newspaper Advertisement

Healthy Bodies, Healthy Minds – A Supervised Walking Program for Older Adults

Are you 65+? Do you want to become more physically active?

Participate in the Healthy Bodies, Healthy Minds Supervised Walking Program for older adults. The four month research study involves walking groups that meet 3 times a week. Learn about healthy behaviours that can promote your cognitive health! Learn valuable tools to help you begin and maintain a physical activity program. Contact Kristina from the UVic's Behavioural Medicine Lab at 250-472-5288 to learn more about the what is involved in this exciting research study and walking program for older adults!

Brochure

DO YOU WANT TO BECOME MORE PHYSICALLY ACTIVE?

Are you trying to maintain your physical and cognitive health as you age? Join my 4 month supervised walking program. This program includes:

- An information session on behaviours to help maintain your cognitive and physical health.
- Personalized coaching & tools to help you become active & maintain a healthy lifestyle
- A walking group that meets 3 times a week for 30-45 min.

Call Kristina at 250-472-5288 to learn more about this exciting walking program and associated research!

Behavioural Medicine Laboratory UVic

Healthy Bodies Healthy Minds

Behavioural Medicine Laboratory (MacLaurin Building D013)
Faculty of Education
University of Victoria
PO Box 3010 STN CSC

Phone: 250-472-5288
Fax: 250-721-6601
E-mail: kkowalsk@uvic.ca

Healthy Bodies Healthy Minds

Keep your mind & body active!
Eat well! Be socially engaged!

A Supervised Walking Program for Older Adults

Tel: 250-472-5288
Email: kkowalsk@uvic.ca

Healthy Bodies, Healthy Minds — A Supervised Walking Program for Adults Aged 65+

Who am I?

- My name is Kristina Kowalski and I am a certified personal trainer and a PhD Candidate in the School of Exercise Science, Physical and Health Education and the Department of Psychology.
- As part of my research, I am running a supervised walking program for older adults. Below, please find more information to help you decide if you want to participate.

Why participate?

- Through the walking program, I aim to help you engage in a healthy lifestyle and to educate and encourage you to maintain your cognitive and physical health as you age.
- The objective of my research program is to examine the relations between physical activity (and other health behaviours—diet, social engagement, intellectual stimulation) and cognitive and physical health.
- Ultimately, the goal of my research program is to inform the development of an intervention to preserve cognitive and physical health, promote quality of life, and reduce the risk of dementia in older adults.

Who is eligible?

- You must be 65+ & live in Victoria
- You must speak, read & write fluently in English
- You must be getting < 150 min of moderate to vigorous physical activity per week

Contact Kristina to compete a further screen for your appropriateness for the Healthy Minds, Healthy Bodies program.

What is involved?

- You will receive a package with consent forms, a questionnaire about your readiness to exercise, demographics & health, & walking.
- You will attend a group testing session for a gait & fitness assessment.
- You will monitor your activity for 1 week using an accelerometer and activity log.
- You will be interviewed about your diet, medical conditions & complete cognitive testing in your home.
- You will participate in an information session about your cognitive health. During this session you will learn about things you can do to promote your cognitive and physical health.
- You will receive tools to help you stay active & eat well.

- You will be introduced to and participate in the supervised walking program.

What is the walking program?

- Attend three 30-45 min, building up gradually starting from 15 min! Flexibility to choose walking locations & times that work for you.
- Walking groups will meet at various locations around town including the University of Victoria, Elk Lake, & along Dallas Road.
- Twice a month, there will be themed discussions during the walks. Group participants will be invited to discuss topics important to older adults, including successful aging, staying mentally sharp, & mobility.

If you want to be more active & social, these walking groups are for you!

What else?

- Additional cognitive, gait, fitness, & diet assessments at 6, 9, 12 & 16 weeks
- Self-monitoring of your activity for 1 week following each assessment using an accelerometer and activity log

How will it benefit you?

- Opportunity to become more active!
- Free personal training & lifestyle coaching
- Participation in a fun & motivating group
- Monthly raffle prizes
- Entry into a draw for a 1 year regional pass to Greater Victoria recreation centres!
- Opportunity to learn about your cognitive health and how to lead a healthier lifestyle

Kristina Kowalski

Phone: 250-472-5288
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E-mail: kkowalsk@uvic.ca

Appendix 4: Informed Consent

1. Informed consent

University of Victoria | British Columbia Canada

Participant Consent Form

"Healthy Bodies, Healthy Minds – The Impact of A Supervised Walking Program on the Cognitive and Physical Health of Older Adults"

You are being invited to participate in a study entitled **"Healthy Bodies, Healthy Minds – The Impact of a Supervised Walking Program on the Cognitive and Physical Health of Older Adults"** that is being conducted by Kristina Kowalski at the Behavioural Medicine Laboratory and the Centre on Aging at the University of Victoria. As a graduate student, Kristina is required to conduct research as part of the requirements for an interdisciplinary PhD in the School of Exercise Science, Physical and Health Education and the Department of Psychology. You may contact her if you have further questions by email at kkowalsk@uvic.ca or by phone at (250)472-5288. Her research is being conducted under the supervision of Dr. Rhodes and Dr. Holly Tuokko. You may contact them at:

	Email:	**Phone:**
Ryan Rhodes	rhodes@uvic.ca	(250)721-8384.
Holly Tuokko	htuokko@uvic.ca	(250)721-6350.

This project is being funded by the **Sara Spencer Foundation.**

WHAT ARE THE OBJECTIVES OF THIS STUDY?

A supervised walking program, involving personalized coaching and on-going support, will be used to promote physical activity and cognitive and physical health in older adults. The walking program will also include an information session that is designed to educate older adults about the cognitive benefits of staying active, eating a healthy diet, staying socially engaged, and keeping the mind active. The research objectives of the supervised walking program and study are:

- To examine the impact of a supervised walking program on the cognitive and physical health of older adults.
- To examine the interrelations of gait, physical activity, and cognitive function in older adults.
- To examine the impact of other health behaviours (i.e., diet, social engagement, and intellectual stimulation/cognitive activity) on the relations between physical activity and cognitive function.
- To examine personal and environmental factors that may influence adherence to a supervised walking program for older adults.

WHY IS THIS RESEARCH IMPORTANT?

Physical activity is one target for intervention with the potential to impact not only cognitive health, but also many other aspects of the health and well being (e.g., functional fitness, quality of life) of older adults. Despite the many benefits of physical activity, the vast majority of older adults are physically inactive and the prevalence increases with advancing age. Moreover, it is unlikely that older adults engage in physical activity with the specific intention to preserve or promote their cognitive health. The current walking and research program is designed to educate older adults about health behaviours and reducing the risk of dementia with

age.

A growing body of literature supports the link between healthy lifestyle behaviours and cognitive health. Of the modifiable risk factors for dementia that could be targeted in an intervention promoting cognitive health, support for the beneficial influence of physical activity on cognition in older adults is most promising. Unfortunately, scientific literature within the field of physical activity and cognition is plagued with methodological problems. The current study aims to advance the field by investigating the link between healthy lifestyle behaviours and cognitive health with stronger research methods.

Ultimately, the goal of this program of research is to inform the development of an intervention to preserve cognitive and physical health and reduce the risk of dementia in older adults. Developing interventions targeting older adults' cognitive health is a promising avenue for dementia risk reduction and given the rapid aging of our population, this type of intervention could have far reaching effects on society.

WHY ARE YOU BEING ASKED TO PARTICIPATE?

You are being asked to participate in the study because you are 65 years and over and you are NOT meeting Canada's Physical Activity Guidelines for Older Adults (i.e., you are NOT accumulating 150 minutes of moderate to vigorous aerobic physical activity per week).

WHAT DO PARTICIPANTS HAVE TO DO?

If you volunteer to participate, you will:

- Receive a package of consent forms and a questionnaire about your readiness to exercise, background demographics and health, and walking in the mail.
- Complete this package prior to your first appointment. This questionnaire should take approximately 30 minutes. Take your time to complete it at your own pace. You may complete it over several occasions, if needed.
- Attend a group session at the University or local recreation centre for an assessment of your gait and fitness. This appointment will take approximately 45 minutes.
    - The fitness testing will involve an assessment of your resting blood pressure and heart rate, your cardiovascular fitness (a brief walking test), and body composition (body mass index, waist girth).
    - The gait assessment will require you to walk across a pressure sensitive mat at normal walking speed to measure characteristics of your gait including stride length, stride width, swing time, stance time, normalized velocity, cadence (step rate), and gait variability.
    - You will answer questions about your lifetime history of physical activity.
    - You will be given a package with instructions for next appointment and questions about your current engagement in physical, social and intellectual activities. You will return this questionnaire at your next appointment.
- Complete a testing session where you will be interviewed about your diet and medical conditions. At this appointment, you will also complete a short computer battery of cognitive tests. If available, participants are asked to give the researcher a copy of recent blood work results to further clarify their health and medical conditions. This appointment will take about 1.5 hours. **Note:** You do not need to own a computer or be experienced with computers for this testing.

- Participate in a 1-1.5 hour information session about your cognitive health. During this session you will learn about things you can do to promote your cognitive and physical health. You will receive tools to help you stay active and eat well. You will also be introduced to the supervised walking program. Two types of walking sessions are available:
  1—Weekly walking groups at great walking locations around town (e.g., University of Victoria, local recreation centres, Dallas Road, Lochside Drive, the Gorge).
  2—Bi-weekly themed walking groups. These will be the same as regular walking groups except that the group also discusses a selected topic while going for a walk. The topics will include hot topics for older adults (e.g., successful aging, staying mentally sharp and mobility). There will be selected articles to read before these groups. Reading them is optional. If you enjoy reading and want to become more active, these sessions could be fun for you. Research has demonstrated the added cognitive benefit of exercising and keeping an active mind. You are welcome to read and participate in the discussion or just attend the themed walking groups to enjoy a walk.
- Come to 3 group walking sessions per week for 30-45 minutes for 4 months. You will build up gradually in intensity of physical activity starting at 15 minutes! All sessions will be followed by snacks and refreshments.

WHAT ELSE IS INVOLVED IN THE 4 MONTH PROGRAM?

- Additional cognitive, fitness and diet assessments will take place at 6, 9, 12 & 16 weeks. These appointments will take 1 hour. Again, you will be asked to answer questions about your engagement in physical, social and intellectual activities.
- Gait assessments and a brief 6 minute walk test at 6, 9, 12 & 16 weeks, as well. These brief assessments will also at the University or local recreation centres.
- Regular follow-up calls from a personal trainer who will help monitor your physical activity and progress.
- Access to on-going support from a personal trainer.

WHAT ARE THE INCONVENIENCES ASSOCIATED WITH PARTICIPATING?

The major inconvenience in this study is time. The time commitment includes:

1) Questionnaire completion lasting approximately 30 minutes.
2) A baseline group testing session lasting 45 minutes.
3) A baseline individual testing session lasting 1.5 hours.
4) At the beginning of the walking program, an information session and personal training/coaching session lasting 1-1.5 hours.
5) A walking program that meets 3 times a week for 30-45 minutes followed by snacks and refreshments. Your attendance at these sessions is voluntary and you can choose to not attend the sessions whenever you wish. There will be more than 3 scheduled per week so you can pick and choose dates, times and locations that work for you.
6) Follow-up testing sessions lasting 1 hour at 6 weeks, 9 weeks, 12 weeks and 16 weeks.

Additional inconveniences include possible fees that may be incurred by participants when requesting information from physicians (e.g., signatures if e-PAR-med-X is required, requests for blood work). In the event the physician charges you for these services, provide the researcher with a copy of your receipt and you will be reimbursed.

WHAT ARE THE RISKS OF PARTICIPATING?

There are some potential risks to you by participating in this research and they include physical risk, such as fatigue or stress as a result of physical exertion. The potential risks are unlikely and there are a number of steps that are being taken to prevent physical risk. These include:

- The PAR-Q+ will be administered prior to the fitness assessment to ensure that it will be safe for you to become more physically active. Your medical doctor will be consulted based on your responses to the PAR-Q+ if required. Only those people screened as safe to exercise by the PAR-Q+/e-PAR-med-X and/or their doctor will be permitted to participate. At the time of the first appointment, if permission from your doctors was necessary, you will be required to present a copy of the final page of the e-PAR-Q-med-X+ signed by your physician to qualify for the study. This will only be necessary when your responses on the PAR-Q+ and e-PAR-Q-med-X+ indicate that it is necessary for you to seek medical advice before exercising. If your doctor's permission is needed and obtaining this medical advice and signature is associated with a fee, you will be reimbursed for this fee.
- The researcher and her colleagues from the University of Victoria's Behavioural Medicine Laboratory who will be assisting her with the walking program are certified personal trainers or group fitness leaders who are experienced with administering protocols with a variety of populations including older adults. The fitness testing protocols are being administered under the supervision and guidance of a certified exercise physiologist. The researcher will also have the assistance of undergraduate volunteers. All involved are certified in first aid and CPR.
- When out walking or at participant's homes, the researcher will have her cell phone on her at all times so that she can call campus security (if on campus) and/or 911 in the unlikely event that risk occurs. The researcher will also have a contact list with emergency numbers on her person at all times. This list will also have an emergency contact list for all current participants. She will also carry a fanny pack/back pack with a complete first aid kit, water, and ice to be used for small injuries and discomfort. Advanced emergency personnel will be called when needed.
- Participants will begin walking 15 minutes per session and will increase this gradually by several minutes per week. The personal trainer will ensure that the walking group participants do not engage in a dose of exercise, right away, that would be harmful. When someone becomes more physically active, they should begin slowly and build up the exercise dose. The researcher, a certified personal trainer, will be leading the walking program and in attendance at each walking group session to maximize safety.

WHAT ARE THE BENEFITS OF PARTICIPATING?

- Contribute to an exciting research study focused on the impact of physical activity and healthy living on cognitive and physical health of older adults
- Become more physically active in a supportive and safe environment
- Get free personal training, healthy lifestyle coaching and on-going support throughout the four month program
- Learn tools to help you begin and maintain an exercise program
- Learn about methods to help maintain your cognitive health as you age
- Receive feedback about your diet, activity levels, and your fitness
- Be part of a fun and motivating group
- Be entered into a draw for monthly raffle prizes
- Be entered into a draw for a 1 year regional pass to Greater Victoria recreation centres!

Voluntary Participation. Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your data will used only if you grant us permission. If you chose to withdraw, you will not be eligible for raffle prizes drawn after you leave the program. Any prizes you won while in the program are yours to keep.

On-going Consent. To make sure that you continue to consent to participate throughout the 4 month program, at each additional follow-up session (e.g., 6, 9, 12 & 16 weeks) the researcher will ask you if you would like to continue and you will provide on-going consent by signing the consent form at each additional appointment.

Anonymity & Confidentiality. In terms of protecting your anonymity, all participants will be assigned an identification number, and will be identified by this number on all forms with data. All results produced will be from group data, and no individuals will be identified. The confidentiality of your data will be protected. The master list which pairs identification numbers with participant names will be stored in a password protected computer in the Behavioural Medicine Lab. All other data will be stored in a secure and locked location in the Behavioural Medicine Lab, as well as on password-protected computers. Only lab personnel associated with the study will have access to this information and data.

Due to the group nature of the study, there are limits to confidentiality. The results from the group testing sessions will be kept private and not shared with other participants. Results will not be identified by name, however, because we will be meeting in groups for the group testing sessions and the weekly walking groups, participants will not be anonymous to the researcher and other walking group members. Anything shared of a personal nature is to be maintained confidential by the researcher and other group members. The group testing sessions and the walking groups are not meant to gather information regarding anything of a personal/sensitive nature. In the event that a participant chooses to share information of this nature (i.e., while chatting during the walking groups), the group members will be encouraged to keep anything shared between group members.

Dissemination of Results. It is anticipated that the results of this study will be shared with others in the form of published articles and conference presentations.

Disposal of Data. Data from this study will be destroyed after five years. Electronic files will be deleted and paper copies will be shredded.

Contacts. You can request further information regarding this study by contacting Kristina Kowalski at (250)472-5288. In addition to being able to contact the researcher at the above phone number and email, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Board at the University of Victoria ((250)472-4545).

Consent. Your signature below indicates that you understand the above conditions of the participation in this study, and that you have had the opportunity to have your questions answered by the researchers.

Name of Participant	Signature	Date

Please sign and return ONE signed copy and keep one copy for yourself.

Appendix 5: Questionnaires and Data Collection Forms

1. Health and demographics questionnaire
2. Social cognitive questionnaire
3. Medications list
4. Expanded CIRS
5. Diet Interview
6. Fitness testing summary sheet
7. Gait assessment instructions
8. Emergency contact form
9. Modified Lifetime Physical Activity Questionnaire
10. CHAMPS Questionnaire
11. Modified Godin Leisure Time Questionnaire

Health and Demographics Questionnaire

Participant ID:_____
Date: _____

Healthy Bodies, Healthy Minds – Supervised Walking Program

Health and Demographics Questionnaire

In order to better understand the results of our study and to provide you with a personalized supervised walking program, we need to know a few things about you and your background. We will use this information for research and program purposes only, and it will be kept strictly confidential. You will note that we do not ask for your name on the form. Please respond to the following items completely. Please note that you are not obligated to answer any of the questions.

1. My sex is: ***(please circle)*** **Male** **Female**

2. My birth date is: _____

(Day) **(Month)** **(Year)**

3. What is your native language?

- ✎ English
- ✎ French:
- ✎ Other ***(please specify)*** _____

4. What is your citizenship?

- ✎ Canadian
- ✎ Other: ***(please specify)*** _____

5. What is your ethnic background? Please check the appropriate alternative.

- ✎ **Indigenous Origin** (A person having origins in any of the original peoples of North America, and who maintains a cultural identification through tribal or band affiliation or community recognition)
- ✎ **Asian or Pacific Islander** (A person having origins in any of the original peoples of the Far East, Southeast Asia, the Indian subcontinent, or the Pacific Islands. This area includes, for example, China, India, Pakistan, Japan, Korea, the Philippine Islands, and Samoa.)
- ✎ **Black**, not of Hispanic origin (A person having origins in any of the black racial groups of Africa)
- ✎ **Hispanic** (A person of Mexican, Puerto Rican, Cuban, Central or South American, or other Spanish culture or origin, regardless of race)
- ✎ **White (Caucasian)**, not of Hispanic origin (A person having origins in any of original peoples of Europe, North Africa, or the Middle East)
- ✎ **Other** (please explain)

_____
_____ _____
_____

6. Currently, I am: ***(please circle one)***

- ✎ married
- ✎ single
- ✎ widowed
- ✎ divorced
- ✎ separated
- ✎ common-law

7. How long have you lived in the municipal region of Victoria? _____

8. What type of dwelling do you live in? **(*Please circle one*)**

- ✎ single family home
- ✎ duplex/townhouse
- ✎ apartment or condominium
- ✎ retirement home
- ✎ senior assisted care facility
- ✎ other (*please specify below*) _____

9.

a. How many people **other than yourself** live in your personal room, apartment, or home on a permanent basis? _____

i. How are they related to you? **(*Please circle ALL that apply*)**

- ✎ husband/wife/common-law partner
- ✎ mother/father
- ✎ daughter/son
- ✎ brother/sister
- ✎ friend
- ✎ other (*please specify below*) _____

b. How many people **other than yourself** live in your personal room, apartment, or home on a part-time basis (i.e., occasional renter, intern student, etc.)? _____

i. How are they related to you? **(*Please circle ALL that apply*)**

- ✎ husband/wife/ common-law partner
- ✎ mother/father
- ✎ daughter/son
- ✎ brother/sister
- ✎ friend
- ✎ other (*please specify below*) _____

10. Have you taken part in any other studies at the University of Victoria?

- ✎ Yes
- ✎ No

If YES, please specify which project:

- ✎ Project MIND
- ✎ Victoria Longitudinal Study
- ✎ The Adams Project
- ✎ Other (*please specify)*_____

11. Which academic diplomas or degrees or certificates have you obtained? (***Please circle ALL that apply***).

- no degree/diploma/certificate
- high school diploma
- technical/trade school or community college (e.g. apprentice, LPN, etc.)
- Bachelor's (e.g., BA, BSc, BComm.)
- Master's (e.g., MA, MSc, MEd, LLM)
- Bachelor's of Law (LLB)
- Medical degree (MD)
- PhD or other doctoral degree
- Other or additional degrees/diplomas/certificates (e.g. nurse, etc. - *Please specify below*):
  _____
  _____

12. For **EACH** of the following levels of education, **PLEASE CIRCLE** the highest grade or years of full-time attendance you have **COMPLETED.** Do not include part-time or extension courses taken for interest.

a) **Grade/Intermediate School**

Grade 1 Grade 2 Grade 3 Grade 4
Grade 5 Grade 6 Grade 7 Grade 8

b) **Secondary/High School**

None Grade 9 Grade 10 Grade 11
Grade 12 Grade 13

c) **Technical, Trade, Nursing or Business School, or Community College**

None 1 year 2 years 3 years
4 years 5+ years

d) **University** (Bachelor's Level)

None 1st year 2nd year 3rd year
4th year 5+ years

e) **Post-Graduate School** (e.g., LLB, Master's, MD, PhD)

None 1 year 2 years 3 years
4 years 5+ years

Now we would like to ask you some questions about your health.

13. Compared to a perfect state of health, I believe my overall health to be (***please circle one***):

- very good
- good
- fair
- poor
- very poor

14. Compared to other people my age, I believe my overall health to be (***please circle one***):

- very good
- good
- fair
- poor
- very poor

15. Compared to other people my age, I believe my eyesight to be (***please circle one***):

- very good
- good
- fair
- poor
- very poor

16. Compared to other people my age, I believe my hearing to be (***please circle one***):

- very good
- good
- fair
- poor
- very poor

17. Compared to other people my age, I believe my memory to be (***please circle one***):

- very good
- good
- fair
- poor
- very poor

18. Considering everything, I believe my future overall health will be (***please circle one***):

- very good
- good
- fair
- poor
- very poor

19. In the past 24 hours, how many cigarettes did you smoke (1 pack = 20 cigarettes) _____

20. How many hours did you sleep last night? _____

21. How many hours per night do you usually sleep? _____

22. How well do you usually sleep?

- Awful
- Not so good
- Average
- Pretty good
- Great

23. Do you have a family history of the following? Please an X in the appropriate box.

	Mother	Father	Sister	Brother	Grandmother	Grandfather
Dementia/Severe Memory Loss						
Other Cognitive Problems						

Social Cognitive Questionnaire

Participant ID:_____
Date:_____

Regular Leisure-Time Walking

The following questions ask you to rate how you feel about regular leisure-time walking. We define regular leisure-time walking as walking for at least 150 minutes per week, in bouts of 10 minutes of more, during your free time. Pay careful attention to the words at each end of the scales and circle the number that best represents how you feel about regular leisure-time walking.

For me, regular leisure-time walking over the next 4 months would be:

	1	2	3	4	5	6	7
1.	extremely enjoyable	quite enjoyable	slightly enjoyable	neutral	slightly unenjoyable	quite unenjoyable	extremely unenjoyable
2.	extremely useful	quite useful	slightly useful	neutral	slightly useless	quite useless	extremely useless
3.	extremely pleasant	quite pleasant	slightly pleasant	neutral	slightly unpleasant	quite unpleasant	extremely unpleasant
4.	extremely wise	quite wise	slightly wise	neutral	slightly unwise	quite unwise	extremely unwise
5.	extremely boring	quite boring	slightly boring	neutral	slightly exciting	quite exciting	extremely exciting
6.	extremely harmful	quite harmful	slightly harmful	neutral	slightly beneficial	quite beneficial	extremely beneficial

Participant ID:_____
Date:_____

For these questions, we would like to ask you more specific questions about regular leisure-time walking. Please answer the questions by writing the number that best represents your belief in each space provided. Please use the following numerical scale as a yardstick:

1	2	3	4	5	6	7
extremely unlikely	quite unlikely	slightly unlikely	neutral	slightly likely	quite likely	extremely likely

For me, regular walking over the next 4 months would….

1. Make me feel good _____
2. Take too much of my free time _____
3. Increase my physical fitness _____
4. Improve my physical appearance _____
5. Reduce my chances of disease _____
6. Help relieve my stress _____

PART 2: Social Aspects of Regular Leisure-Time Walking

The next questions ask you about what other people in your social network (e.g., friends, family) think about you engaging in regular leisure-time walking. Please respond to each statement using the following scale by circling a number between 1 and 7 at the end of each statement. Please answer these questions thinking only about the people in your social network.

1. Most people who are important to me want me to engage in leisure-time walking over the next 4 months.

1	2	3	4	5	6	7
strongly disagree	moderately disagree	slightly disagree	neutral	slightly agree	moderately agree	strongly agree

2. Most people whose opinions I value would approve of me engaging in leisure-time walking over the next 4 months.

1	2	3	4	5	6	7
completely disapprove	moderately disapprove	slightly disapprove	neutral	slightly approve	moderately approve	completely approve

3. Most people who are important to me will engage in regular leisure-time walking themselves over the next 4 months.

1	2	3	4	5	6	7
completely untrue	quite untrue	slightly untrue	neutral	slightly true	quite true	completely true

Medications list

Healthy Bodies, Healthy Minds – A Supervised Walking Program for Older Adults

To Be Completed by the Researcher during the first appointment

Name of Drug, Vitamin or Supplement	Daily Dosage	Notes/Comments

Expanded CIRS - Selected Sections

Disease/condition	No Problem	Current Mild or Past Significant	Moderate problem that requires first-line therapy	Severe Problem	Extremely Severe
	0	1	2	3	4
Have you ever had or experienced or been diagnosed with any of the following?					
B. Vascular					
1. Any circulatory problem.	○	○	○	○	○
2. High blood pressure	○	○	○	○	○
3. High cholesterol	○	○	○	○	○
C. Blood Problems					
1. Anemia, leukemia, clotting problems OR any problem affecting the blood cells, spleen or lymphatic system	○	○	○	○	○
D. Respiratory					
Any respiratory problem (asthma, emphysema, bronchitis, pneumonia, pulmonary embolism)	○	○	○	○	○
Smoking (pack years)	○	○	○	○	○

Disease/condition	**No Problem**	**Current Mild or Past Significant**	**Moderate problem that requires first-line therapy**	**Severe Problem**	**Extremely Severe**
	0	1	2	3	4
Have you ever had or experienced or been diagnosed with any of the following?					
I. Neurological					
1. Stroke, mini-stroke, TIA	○	○	○	○	○
2. Headaches/ migraines	○	○	○	○	○
3. Epilepsy, seizures	○	○	○	○	○
4. Parkinson's disease	○	○	○	○	○
5. Tremors	○	○	○	○	○
6. Neuropathy	○	○	○	○	○
m. Endocrine, Metabolic					
Diabetic: 1 or 2	○	○	○	○	○
Diabetic Retinopathy	○	○	○	○	○
Thyroid Problems	○	○	○	○	○
Hypoglycemic episodes (low blood sugar)	○	○	○	○	○
Obesity	○	○	○	○	○

Healthy Bodies, Healthy Minds – A Supervised Walking Program

Diet Interview

Think about your current diet. Reflecting on the last 7 days, answer the following questions about your average daily intake.

	Question	Response	Criteria	Score
1	Do you use olive oil as the principal source of fat for cooking?		Yes = 1 point	
2	How much olive oil do you consume per day (including that used in frying, salads, meals eaten away from home, etc.)? **1 serving = 1 tsp**		≥4 Tbsp = 1 point	
3	How many servings of vegetables do you consume per day? **1 serving = 1 piece (e.g., 1 medium carrot), 1 cup of salad or raw leafy veggies, ½ cup of other veggies (e.g., 4 stalks of broccoli) or ½ cup of vegetable juice.**		≥ 2 = 1 point	
4	How many servings of fruit (including fresh-squeezed juice) do you consume per day? **1 serving = 1 medium sized piece or ½ cup or about the size of a baseball (e.g., a small apple). ½ cup of fruit juice.**		≥ 3= 1 point	
5	How many servings of red meat, hamburger, or sausages do you consume per day? **1 serving = 75 grams, 2.5 ounces, roughly the size of a deck of cards or the palm of your hand**		<1 = 1 point	
6	How many servings (12 g) of butter, margarine, or cream do you consume per day? **1 serving of cream = 1 tbsp/15 ml of cream or cream substitute 1 serving of butter or margarine = 1 tsp (5ml) or 1 pat of butter (1tsp or 5 ml)**		<1 = 1 point	

	Question	Response	Criteria	Score
7	How many carbonated and/or sugar-sweetened beverages do you consume per day? **1 can = 355ml, 1 bottle = 590 ml,**		<1 = 1 point	
8	Do you drink wine? How much do you consume per week? **Standard serving of wine is about 5 ounces?**		≥ 7 cups (1 cup of wine = 100 ml)	
9	How many servings (150 g) of beans & legumes do you consume per week? **1 serving = ¾ cup cooked beans, peas or lentils**		≥ 3	
10	How many servings of fish/seafood do you consume per week? **1 serving = 75 grams, 2.5 ounces, roughly the size of a deck of cards or the palm of your hand**		≥ 3	
11	How many times do you consume commercial (not homemade) pastry such as cookies or cake per week?		<2	
12	How many times do you consume nuts per week? (1 serving = 30 g)		≥ 3	
13	Do you prefer to eat chicken, turkey or rabbit instead of beef, pork, hamburgers, or sausages?		Yes = 1 point	
14	How many times per week do you consume boiled vegetables, pasta, rice, or other dishes with a sauce of tomato, garlic, onion, or leeks sautéed in olive oil?		≥ 2 = 1 point	
15	How many serving of white bread and rice per day? **1 serving of bread = 1 slice of bread. 1 serving of rice = ½ cup cooked rice (125 ml)**		< 1	
16	How many serving of whole grain bread do you consume per week?		> 5	

Adherence to the Canadian Food Guide

Reflecting on the last 7 days…

	Question	Amount	Item	
1	How many daily Food Guide Servings of fruit and veggies did you consume? Remember: **1 FGS = 1 piece (e.g., 1 medium carrot), 1 cup of salad or raw leafy veggies, ½ cup of other veggies (e.g., 4 stalks of broccoli) or ½ cup of vegetable juice. 1 serving = 1 medium sized piece or ½ cup or about the size of a baseball (e.g., a small apple). ½ cup of fruit juice.**		≥ 7 = 1 point	
2	How many daily Food Guide Servings of meat and alternatives did you consume? **1 FGS = 75 grams, 2.5 ounces, roughly the size of a deck of cards or the palm of your hand**		≥ 3 = 1 point	
3	How many daily Food Guide Servings of grains did you consume? **1 FGS = 1 slice of bread, ½ a bagel, 1/2 cup of pasta or 3/4 cup of cereal)?**		≥ 7 for men and 6 for women = 1 point	
4	How many daily Food Guide Servings of milk and alternatives did you consume? **1 FGS = 1 cup milk, 2 slices/ 50g or 1 ounce of cheese (two 1 inch square blocks), or 3/4 cup of yogurt)?**		≥ 3 = 1 point	

Summary of Fitness Testing Results **ID #:_____**

	Baseline	6 weeks	9 weeks	12 Weeks	16 week
Date					
Age (yrs)					
Pre test Heart Rate (bpm)					
Pre test Blood Pressure (mmHg)					
Body Composition					
Height (cm)					
Weight (kg)					
Body Mass Index (kg/m^2)					
Waist Girth (cm)					
Aerobic Fitness					
Distance walked in 6 minutes					
Predicted VO_2max (mL/kg/min)					
Post-test HR (bpm) & BP(mmHg) 1 min					
Post-test HR(bpm) & BP(mmHg) 3 min					
Post-test HR(bpm) & BP(mmHg) 5 min					

Healthy Minds, Healthy Bodies – A Supervised Walking Program for Older Adults

Instructions for Administering the GaitRite

1. Enter the participant's personal information in the program. In order for the FAP to be calculated you must enter:
    a. Subject Number in the First Name box (with Trial ID (i.e., "a,b,c")
    b. Date of Testing in the Last Name box
    c. Date of Birth
    d. Gender
    e. Left and Right length measurements (cm)
2. Ask participants to stand directly in front of chair (chair is located 5 feet from the beginning of the mat)
3. *** Explain an overview of the tasks to be completed***

"I will be asking you to complete several tasks that will require you to walk back and forth several times on this matt. Each task will have a separate set of instructions"
Task 1 – Walking Only Condition:

SAY:

For the initial task, I would like you to walk down the mat to the chair that is placed at the far end of the mat. I would like you to walk at a pace with which you are comfortable – as quickly and as safely as possible. When I say the word "BEGIN" you can start walking. When you reach the chair, I would like you to turn around and wait. When I say the word "BEGIN", I will ask you to come back, again walking down the middle of the mat. You will complete this task three times (there, back, there, back, there, back).

Do you have any questions?

"BEGIN"
****Tester Note: It is beneficial to use a hand gesture motioning them forward as you say the word BEGIN****

END OF TASK 1

SAY:
For the following tasks, I would like to stress that many people have difficulty with some tasks. As researchers we are looking to understand the various abilities in adults over the age of 65 years. Even if you do make mistakes we ask that you continue walking and doing the task.

TASK 2 – Cognitive Load:
SAY:

For the next task, I would like you to walk down the middle of the mat to the chair placed at the far end of the mat. I would like you to walk at a pace with which you are comfortable – as quickly and as safely as possible. I will be asking you to repeatedly subtract 7's from a given starting number, out loud. When I give you the number you will immediately begin walking. When you reach the mast you will immediately begin to subtract 7's staring from this number, out loud. When you reach the chair, I would like you to turn around and wait. I will give you a different number. You will begin walking and when you reach the mat you will immediately begin subtracting by 7s out loud as you walk. You will complete this task 3 times (there, back, there, back, there, back).

**TESTER – brief demo as needed. Only if necessary do you need to replicate the entire demo. Most important to reiterate is that the person begins walking immediately and begins subtracting by 7 when they reach the mat.*

****TESTER – Give NUMBER******

If a trial doesn't work due to human error or computer error, make note of it in the provided notebook. You may have to do additional trials and those with errors will be removed during the data recovery phase. However, notes are extremely important for the person that is removing the data.

Optimally you will collect 6 passes across the mat for each trial (walk only, cognitive trial). You should be confident that all 6 passes for each trial are congruent with the protocol.

Healthy Bodies, Healthy Minds – A Supervised Walking Program for Older Adults

Emergency Contact Form

Physical activity is safe for most people! However, in the unlikely event that you are injured or hurt while in this program please provide the following emergency contact information:

Your Physician

Name:	Address	Phone number

Emergency Contact:

Name:	Relationship to you	Phone number

Modified Lifetime Physical Activity Questionnaire

STEP 1: Please place a check mark in the first column next to each activity that you have ever every participated in more than 10 times during your lifetime

STEP 2: For those activities that you have checked, proceed to the right answering the questions in the columns above.

		During ages 51-65 years (a 15-year span)			During aged 35-50 years (a 15-year span)			During ages 20-34 (a 15-year span)		
Have you ever participated in any of the following (see leisure activities below)?		**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**	**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**	**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**
→ Check if "Yes"										
Leisure Activities										
Walking for exercise (outdoor, indoor at mall, treadmill)										
Walking up hill or hiking uphill										
Stair –climbing machine										
Jogging or running (outdoor/treadmill)										
Bicycling (stationary/outdoor)										
Horseback riding										
Dancing (such as square, fold, line, ballet)										
Gymnastics										
Light calisthenics or chair exercises										

		During ages 51-65 years (a 15-year span)			During aged 35-50 years (a 15-year span)			During ages 20-34 (a 15-year span)		
Have you ever participated in any of the following (see leisure activities below)?		**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**	**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**	**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**
Check if → "Yes"										
Leisure Activities										
X-Country skiing/skiing machine										
Skating (ice, rolling, in-line)										
Singles Tennis										
Doubles Tennis										
Other racquet sports										
Softball/baseball										
Golf (riding a cart)										
Golf (walking, carrying and pulling your equipment)										
Volleyball										
Basketball										
Bowling										
Soccer										
Other Physical Activity (specify)										
Other Physical Activity (specify)										

		During ages 51-65 years (a 15-year span)			During aged 35-50 years (a 15-year span)			During ages 20-34 (a 15-year span)		
Have you ever participated in any of the following (see leisure activities below)?		**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**	**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**	**# of years**	**Typical # of months/ year**	**Typical # of hours/ week**
Check if → "Yes"										
Household Activities										
Heavy Gardening/Yard work (spading, raking)										
Light Gardening (watering plants)										
Work on your car, truck, lawn mower, or other machinery										
Grooming and feeding children										
Playing with children (walk/run with them)										
Light household cleaning (sweeping, dusting)										
Heavy household cleaning (scrub floors, vacuum)										
Heavy work around the house (washing windows, cleaning gutters)										

CHAMPS Activities Questionnaire for Older Adults

This questionnaire is about activities that you may have done in the past 4 weeks. The questions on the following pages are similar to the example shown below.

INSTRUCTIONS

If you DID the activity in the past 4 weeks:

Step #1 **Check the YES box.**

Step #2 **Think about <u>how many</u> TIMES <u>a week</u> you usually did it, and write your response in the space provided.**

Step #3 **Circle how many TOTAL HOURS <u>in a typical week</u> you did the activity.**

Here is an example of how Mrs. Jones would answer question #1: Mrs. Jones usually visits her friends Maria and Olga <u>twice a week</u>. She usually spends <u>one</u> hour on Monday with Maria and <u>two</u> hours on Wednesday with Olga. Therefore, the total hours a week that she visits with friends is <u>3</u> hours a week.

In a typical week during the past 4 weeks, did you…							
1. Visit with friends or family (other than those you live with)? ☒ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	(5-6½ hours)	7-8½ hours	9 or more hours

If you DID NOT do the activity:

- **Check the NO box and move to the next question**

In a typical week during the past 4 weeks, did you …							
1. Visit with friends or family (other than those you live with)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
1. Go to the senior center? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
3. Do volunteer work? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
4. Attend church or take part in church activities? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
5. Attend other club or group meetings? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
6. Use a computer? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
7. Dance (such as square, folk, line, ballroom) (do not count aerobic dance here)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
8. Do woodworking, needlework, drawing, or other arts or crafts? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
9. Play golf, carrying or pulling your equipment (count walking time only)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
10. Play golf, riding a cart (count walking time only)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
11. Attend a concert, movie, lecture, or sport event? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
12. Play cards, bingo, or board games with other people? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
13. Shoot pool or billiards? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
14. Play singles tennis (do not count doubles)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
15. Play doubles tennis (do not count singles)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
16. Skate (ice, roller, in-line)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
17. Play a musical instrument? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
18. Read? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
19. Do heavy work around the house (such as washing windows, cleaning gutters)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
20. Do light work around the house (such as sweeping or vacuuming)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
21. Do heavy gardening (such as spading, raking)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
22. Do light gardening (such as watering plants)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
23. Work on your car, truck, lawn mower, or other machinery? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
****Please note: For the following questions about running and walking, include use of a treadmill.**							
24. Jog or run? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
25. Walk uphill or hike uphill (count only uphill part)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
26. Walk fast or briskly for exercise (do not count walking leisurely or uphill)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
27. Walk to do errands (such as to/from a store or to take children to school (count walk time only)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
28. Walk leisurely for exercise or pleasure? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
29. Ride a bicycle or stationary cycle? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
30. Do other aerobic machines such as rowing, or step machines (do not count treadmill or stationary cycle)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
31. Do water exercises (do not count other swimming)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
32. Swim moderately or fast? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
33. Swim gently? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
34. Do stretching or flexibility exercises (do <u>not</u> count yoga or Tai-chi)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
35. Do yoga or Tai-chi? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
36. Do aerobics or aerobic dancing? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
37. Do moderate to heavy strength training (such as hand-held weights of <u>more than 5 lbs</u>., weight machines, or push-ups)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
38. Do light strength training (such as hand-held weights of 5 lbs. or less or elastic bands)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
39. Do general conditioning exercises, such as light calisthenics or chair exercises (do not count strength training)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
40. Play basketball, soccer, or racquetball (do not count time on sidelines)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
41. Do other types of physical activity not previously mentioned (please specify)? _____ ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

Modified Godin Leisure Time Questionnaire

We would also like you to recall your average weekly leisure-time walking over the past 7 days. Specifically, on average, how many times per week did you walk over the past 7 days and what was the duration of these walks? **When answering these questions please**

- ✓ only count walking that was done during free time (i.e., not occupation or housework).
- ✓ note that the main difference between the three categories is the intensity of the walking.
- ✓ write the average frequency on the first line and the average duration on the second line.

Activity	**Times Per Week**	**Average Minutes**
a. STRENUOUS WALKING (Heart beats rapidly, sweating, as fast as you could walk)	_____	_____
b. MODERATE WALKING (Not exhausting, light perspiration, a good brisk pace)	_____	_____
c. MILD WALKING (Minimal effort, no perspiration, a casual walk)	_____	_____

Appendix 6: Intervention Materials

1. Group walk schedule
2. Walking group handbook
3. Canadian Guidelines for Physical Activity for Older Adults
4. Canada's Food Guide
5. Heads up for Healthier Brains
6. Self-monitoring calendar

Group Walk Schedule

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
9:00 am – Gordon Head Recreation Centre	10:30 am – Beacon Hill	9:00 am – Gordon Head Recreation Centre	10:30 am Beacon Hill	9:00 am – University of Victoria	10:30 am Willows Beach	
1:00 pm – Lochside Park	1:00 pm – Gorge Waterway	1:00 pm – Lochside Park	1:00 pm – Gorge Waterway	1:00 pm – Lochside Park	1:00 pm – Gorge Waterway (	

Welcome to "Healthy Bodies, Healthy Minds—A Supervised Walking Program for Older Adults"

Congratulations on taking the first steps to becoming more physically active and maintaining your physical and cognitive health as you age! Becoming more active is a challenge. Joining this research study and walking program is a great starting point. Through the program you will incorporate walking into your life within a fun and supportive environment.

The program will provide you with the tools and on-going support needed to help you begin and maintain a walking program and lead a healthier lifestyle. The program is flexible and will be individualized to meet your personal physical activity and walking needs.

The Walking Program

Physical Activity Guidelines

In line with the Canadian Physical Activity Guidelines for Older Adults, the Healthy Bodies, Healthy Minds –Supervised Walking Program for Older Adults recommends that you aim to engage in **at least** 150 minutes of moderate to vigorous intensity physical activity per week, in bouts of 10 minutes or more.

To achieve greater physical and cognitive health benefits, **more physical activity is needed!**

How Much Should You Walk?

Engaging in regular leisure-time walking is an easy and fun way to meet these physical activity guidelines. Although the amount of walking you should engage in varies somewhat by your age and fitness level, according to the British Columbia Recreation and Parks Association, individuals should walk at a brisk pace, 4 to 7 days a week, for at least 30 minutes (30-60 minutes)[1].

This may sound like a lot. Don't worry! You do not need to start at 30 minutes! You will begin by walking for 10-15 minutes and build up your duration gradually to 30 minutes or more as you become more fit. The program will support you through the process.

1 British Columbia Recreation and Parks (2006). BCRPA Walking Handbook. Retrieved from http://www.bcrpa.bc.ca/walking/documents/BCRPA_Walking_Handbook.pdf

The Walking Groups

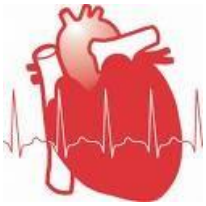
To help you engage in regular leisure-time walking the **Healthy Bodies, Healthy Minds – Supervised Walking Program for Older Adults** will be running group walks at locations throughout Victoria, including the University of Victoria, Dallas Road, and Elk/ Beaver lake.

You are being asked to join the walking group for **at least 3 sessions** per week. At the beginning of the program we will walk for 15 minutes at a mild intensity, and then we will build up gradually to 30-45 minutes per walk at a moderate to vigorous intensity. Each session will be followed by snacks and refreshments.

Remember to achieve health benefits you need to be engage in at least 150 minutes of moderate to vigorous physical activity per week. We suggest you get more physical activity by joining the group for more walks, walking with a friend, or scheduling an additional walk with Kristina, the walking group leader. You will work with Kristina to develop a walking schedule that works for you (See My 4 Month Walking Program).

How Do You Judge Your Intensity When Walking?

You should walk briskly (i.e., walk fast without overexerting yourself). You should be able to carry a conversation with other group members while walking. This is called the Talk Test. We will also monitor our heart rates at the walking groups to help keep track of how intensely we are walking. Over the beginning weeks of the program and the first information session, you will learn how to monitor your walking intensity using your heart rate and ratings of perceived exertion.



Rating of Perceived Exertion:

rating	description
6	NO EXERTION AT ALL
7	EXTREMELY LIGHT
8	
9	VERY LIGHT
10	
11	LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD (HEAVY)
16	
17	VERY HARD
18	
19	EXTREMELY HARD
20	MAXIMAL EXERTION

Canadian Physical Activity Guidelines

Canadian Physical Activity Guidelines

FOR OLDER ADULTS - 65 YEARS & OLDER

Guidelines

To achieve health benefits, and improve functional abilities, adults aged 65 years and older should accumulate at least 150 minutes of moderate- to vigorous-intensity aerobic physical activity per week, in bouts of 10 minutes or more.

It is also beneficial to add muscle and bone strengthening activities using major muscle groups, at least 2 days per week.

Those with poor mobility should perform physical activities to enhance balance and prevent falls.

More physical activity provides greater health benefits.

Let's Talk Intensity!

Moderate-intensity physical activities will cause older adults to sweat a little and to breathe harder. Activities like:

- Brisk walking
- Bicycling

Vigorous-intensity physical activities will cause older adults to sweat and be 'out of breath'. Activities like:

- Cross-country skiing
- Swimming

Being active for at least **150 minutes** per week can help reduce the risk of:

- Chronic disease (such as high blood pressure and heart disease) and,
- Premature death

And also help to:

- Maintain functional independence
- Maintain mobility
- Improve fitness
- Improve or maintain body weight
- Maintain bone health and,
- Maintain mental health and feel better

Pick a time. Pick a place. Make a plan and move more!

- ☑ Join a community urban poling or mall walking group.
- ☑ Go for a brisk walk around the block after lunch.
- ☑ Take a dance class in the afternoon.
- ☑ Train for and participate in a run or walk for charity!
- ☑ Take up a favourite sport again.
- ☑ Be active with the family! Plan to have "active reunions".
- ☑ Go for a nature hike on the weekend.
- ☑ Take the dog for a walk after dinner.

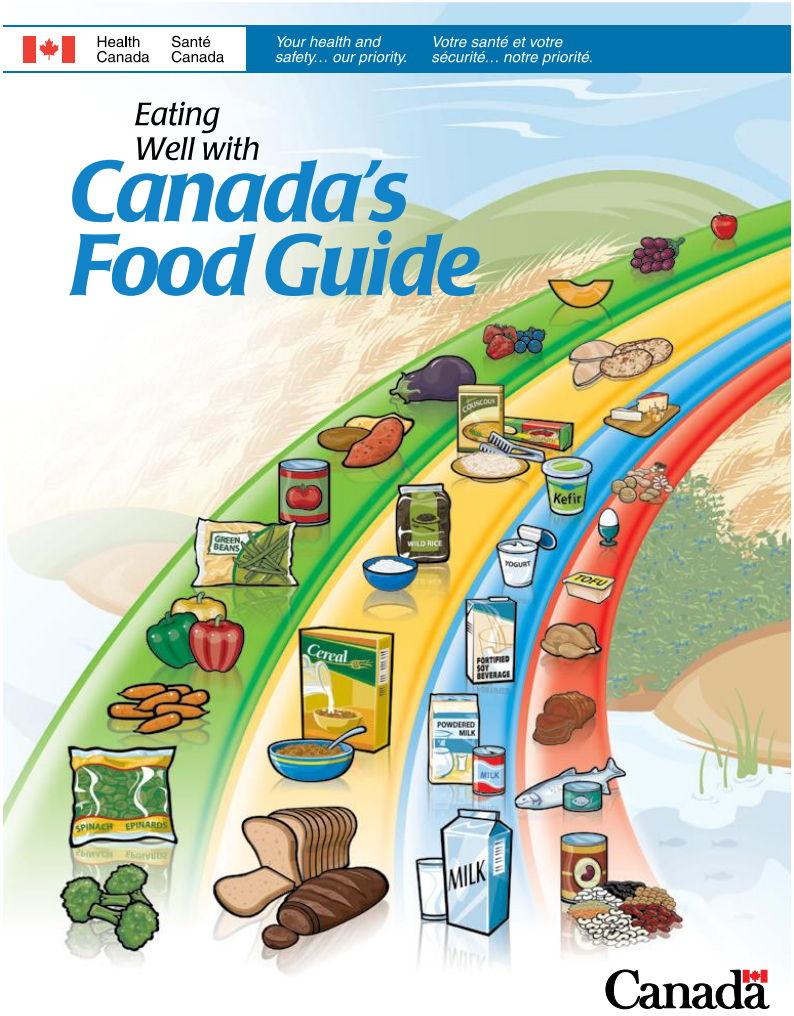
Now is the time. Walk, run, or wheel, and embrace life.

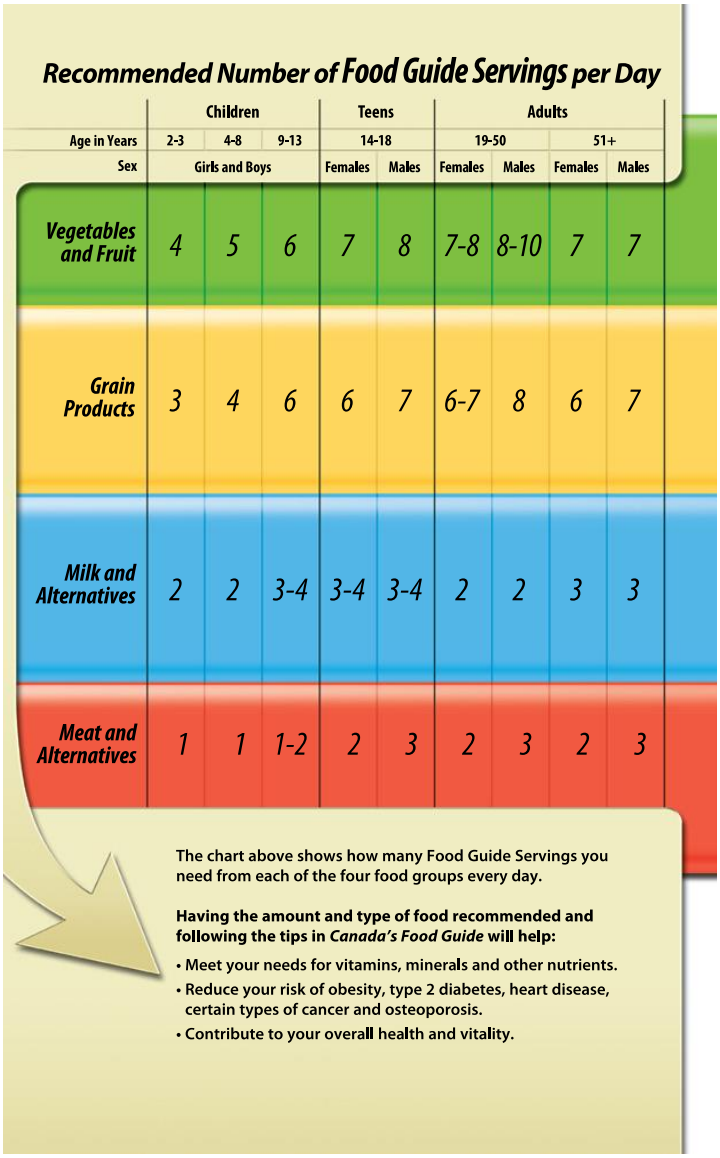
ParticipACTION

CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

www.csep.ca/guidelines

Canada's Food Guide





Recommended Number of Food Guide Servings per Day

	Children			Teens		Adults			
Age in Years	2-3	4-8	9-13	14-18		19-50		51+	
Sex	Girls and Boys			Females	Males	Females	Males	Females	Males
Vegetables and Fruit	4	5	6	7	8	7-8	8-10	7	7
Grain Products	3	4	6	6	7	6-7	8	6	7
Milk and Alternatives	2	2	3-4	3-4	3-4	2	2	3	3
Meat and Alternatives	1	1	1-2	2	3	2	3	2	3

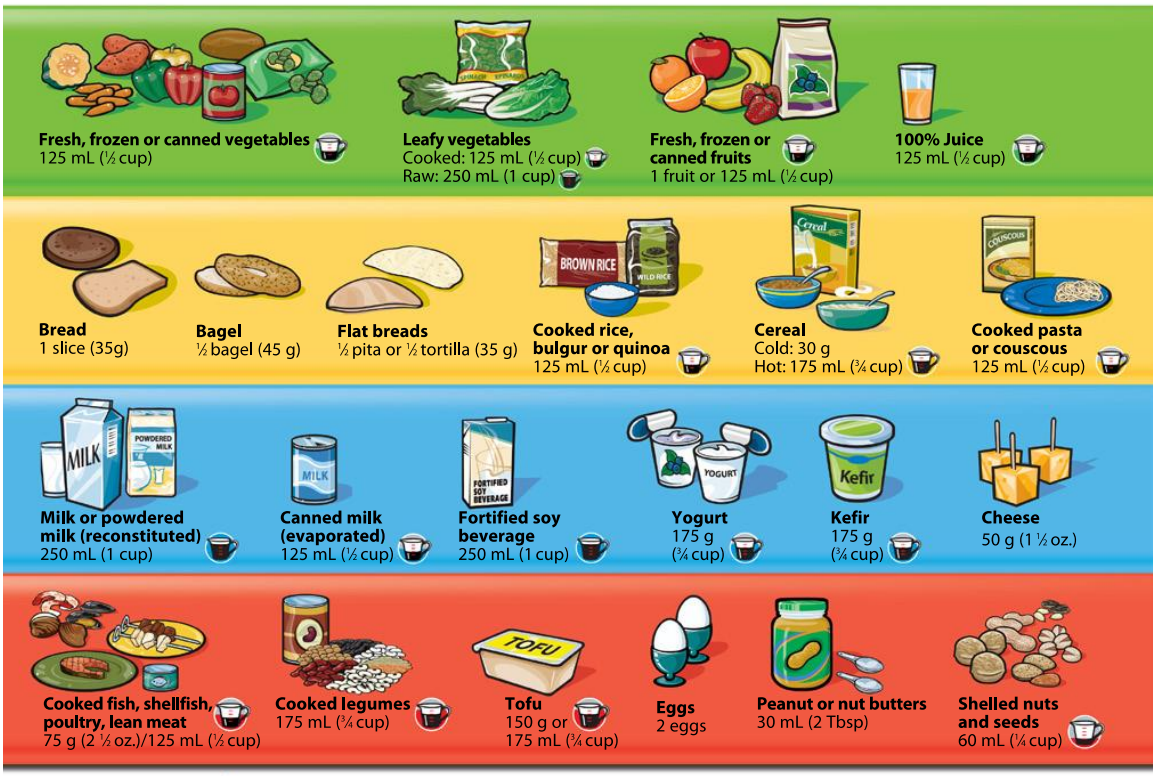
The chart above shows how many Food Guide Servings you need from each of the four food groups every day.

Having the amount and type of food recommended and following the tips in *Canada's Food Guide* will help:

- Meet your needs for vitamins, minerals and other nutrients.
- Reduce your risk of obesity, type 2 diabetes, heart disease, certain types of cancer and osteoporosis.
- Contribute to your overall health and vitality.

What is One Food Guide Serving?

Look at the examples below.



Oils and Fats

- Include a small amount – 30 to 45 mL (2 to 3 Tbsp) – of unsaturated fat each day. This includes oil used for cooking, salad dressings, margarine and mayonnaise.
- Use vegetable oils such as canola, olive and soybean.
- Choose soft margarines that are low in saturated and trans fats.
- Limit butter, hard margarine, lard and shortening.

Make each Food Guide Serving count…

wherever you are – at home, at school, at work or when eating out!

Eat at least one dark green and one orange vegetable each day.
- Go for dark green vegetables such as broccoli, romaine lettuce and spinach.
- Go for orange vegetables such as carrots, sweet potatoes and winter squash.

Choose vegetables and fruit prepared with little or no added fat, sugar or salt.
- Enjoy vegetables steamed, baked or stir-fried instead of deep-fried.

Have vegetables and fruit more often than juice.

Make at least half of your grain products whole grain each day.
- Eat a variety of whole grains such as barley, brown rice, oats, quinoa and wild rice.
- Enjoy whole grain breads, oatmeal or whole wheat pasta.

Choose grain products that are lower in fat, sugar or salt.
- Compare the Nutrition Facts table on labels to make wise choices.
- Enjoy the true taste of grain products. When adding sauces or spreads, use small amounts.

Drink skim, 1%, or 2% milk each day.
- Have 500 mL (2 cups) of milk every day for adequate vitamin D.
- Drink fortified soy beverages if you do not drink milk.

Select lower fat milk alternatives.
- Compare the Nutrition Facts table on yogurts or cheeses to make wise choices.

Have meat alternatives such as beans, lentils and tofu often.

Eat at least two Food Guide Servings of fish each week.*
- Choose fish such as char, herring, mackerel, salmon, sardines and trout.

Select lean meat and alternatives prepared with little or no added fat or salt.
- Trim the visible fat from meats. Remove the skin on poultry.
- Use cooking methods such as roasting, baking or poaching that require little or no added fat.
- If you eat luncheon meats, sausages or prepackaged meats, choose those lower in salt (sodium) and fat.

Enjoy a variety of foods from the four food groups.

Satisfy your thirst with water!

Drink water regularly. It's a calorie-free way to quench your thirst. Drink more water in hot weather or when you are very active.

* Health Canada provides advice for limiting exposure to mercury from certain types of fish. Refer to www.healthcanada.gc.ca for the latest information.

Eat well and be active today and every day!

The benefits of eating well and being active include:

- Better overall health.
- Lower risk of disease.
- A healthy body weight.
- Feeling and looking better.
- More energy.
- Stronger muscles and bones.

Be active

To be active every day is a step towards better health and a healthy body weight.

It is recommended that adults accumulate at least 2 ½ hours of moderate to vigorous physical activity each week and that children and youth accumulate at least 60 minutes per day. You don't have to do it all at once. Choose a variety of activities spread throughout the week.

Start slowly and build up.

Eat well

Another important step towards better health and a healthy body weight is to follow *Canada's Food Guide* by:

- Eating the recommended amount and type of food each day.
- Limiting foods and beverages high in calories, fat, sugar or salt (sodium) such as cakes and pastries, chocolate and candies, cookies and granola bars, doughnuts and muffins, ice cream and frozen desserts, french fries, potato chips, nachos and other salty snacks, alcohol, fruit flavoured drinks, soft drinks, sports and energy drinks, and sweetened hot or cold drinks.

Read the label

- Compare the Nutrition Facts table on food labels to choose products that contain less fat, saturated fat, trans fat, sugar and sodium.
- Keep in mind that the calories and nutrients listed are for the amount of food found at the top of the Nutrition Facts table.

Nutrition Facts

Per 0 mL (0 g)

Amount		% Daily Value
Calories 0		
Fat 0 g		**0** %
Saturates 0 g		**0** %
+ Trans 0 g		
Cholesterol 0 mg		
Sodium 0 mg		**0** %
Carbohydrate 0 g		**0** %
Fibre 0 g		**0** %
Sugars 0 g		
Protein 0 g		
Vitamin A 0 %	Vitamin C	0 %
Calcium 0 %	Iron	0 %

Limit trans fat

When a Nutrition Facts table is not available, ask for nutrition information to choose foods lower in trans and saturated fats.

Take a step today…

- ✓ Have breakfast every day. It may help control your hunger later in the day.
- ✓ Walk wherever you can – get off the bus early, use the stairs.
- ✓ Benefit from eating vegetables and fruit at all meals and as snacks.
- ✓ Spend less time being inactive such as watching TV or playing computer games.
- ✓ Request nutrition information about menu items when eating out to help you make healthier choices.
- ✓ Enjoy eating with family and friends!
- ✓ Take time to eat and savour every bite!

For more information, interactive tools, or additional copies visit Canada's Food Guide on-line at:
www.healthcanada.gc.ca/foodguide

or contact:

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Également disponible en français sous le titre : Bien manger avec le Guide alimentaire canadien

This publication can be made available on request on diskette, large print, audio-cassette and braille.

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Advice for different ages and stages…

Children

Following *Canada's Food Guide* helps children grow and thrive.

Young children have small appetites and need calories for growth and development.

- Serve small nutritious meals and snacks each day.
- Do not restrict nutritious foods because of their fat content. Offer a variety of foods from the four food groups.
- Most of all... be a good role model.

Women of childbearing age

All women who could become pregnant and those who are pregnant or breastfeeding need a multivitamin containing **folic acid** every day. Pregnant women need to ensure that their multivitamin also contains **iron**. A health care professional can help you find the multivitamin that's right for you.

Pregnant and breastfeeding women need more calories. Include an extra 2 to 3 Food Guide Servings each day.

Here are two examples:

- Have fruit and yogurt for a snack, or
- Have an extra slice of toast at breakfast and an extra glass of milk at supper.

Men and women over 50

The need for **vitamin D** increases after the age of 50.

In addition to following *Canada's Food Guide*, everyone over the age of 50 should take a daily vitamin D supplement of 10 µg (400 IU).

How do I count Food Guide Servings in a meal?

Here is an example:

Vegetable and beef stir-fry with rice, a glass of milk and an apple for dessert		
250 mL (1 cup) mixed broccoli, carrot and sweet red pepper	=	2 **Vegetables and Fruit** Food Guide Servings
75 g (2 ½ oz.) lean beef	=	1 **Meat and Alternatives** Food Guide Serving
250 mL (1 cup) brown rice	=	2 **Grain Products** Food Guide Servings
5 mL (1 tsp) canola oil	=	part of your **Oils and Fats** intake for the day
250 mL (1 cup) 1% milk	=	1 **Milk and Alternatives** Food Guide Serving
1 apple	=	1 **Vegetables and Fruit** Food Guide Serving

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Sodium 0 mg		**0** %
Carbohydrate 0 g		**0** %
Fibre 0 g		**0** %
Sugars 0 g		
Protein 0 g		
Vitamin A 0 %	Vitamin C	0 %
Calcium 0 %	Iron	0 %

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Heads Up for Healthier Brains

Genetics and Aging

There are two risk factors that you can't control: genetics and aging.

The Genetic Component

There is no doubt that genetics play a role in the disease. Yet, only a small percentage of cases are associated with the specific genes that cause the inherited form of the disease. The majority of cases may have genetic links but it only slightly increases your risk of getting the disease if a family member had/has Alzheimer's disease.

Aging

Age is the most significant known risk factor for Alzheimer's disease. Even with other risk factors present, Alzheimer's disease never sets in until mid to late adulthood. However, researchers believe that the disease process starts years before symptoms appear.

Additional Materials or References:

- www.alzheimer.ca
- *Heads Up for Healthier Living* brochure (for people with the disease and their caregivers) – Alzheimer Society of Canada
- Canadian Standards Association (CSA) for information on helmet safety and suppliers. www.csa.ca
- Canada's Food Guide to Healthy Eating. www.hc-sc.gc.ca (Food and Nutrition)
- Canada's Physical Activity Guide to Healthy Active Living. www.hc-sc.gc.ca (Healthy Living)

Give someone you care about a *Heads Up* today:

It's never too soon, or too late to make the lifestyle changes necessary to help improve your brain health, changes that may also help to reduce your risk for Alzheimer's disease.

If you are living with Alzheimer's disease, taking care of your brain health may also improve your quality of life and even help slow the progression of the disease. (see Heads Up for Healthier Living brochure)

What is Alzheimer's disease?

Alzheimer's disease is a progressive, degenerative disease that destroys vital brain cells. It affects a person's ability to think, remember, speak and even perform simple tasks. Alzheimer's disease is not a normal part of aging.

The Alzheimer Society works nationwide to improve the quality of life for Canadians affected by Alzheimer's and related diseases, and to advance the search for a cure. It is a leading funder of Alzheimer research in Canada.

Help for today. Hope for tomorrow...

Heads Up for Healthier Brains

Help for today. Hope for tomorrow...

The Heads Up for Healthier Brains Awareness Campaign was made possible in part through the generosity of Pfizer Canada, Lundbeck Canada Inc., BMO Financial Group and Medicine Shoppe Canada. Support in-kind was provided by Transcontinental Media and Burnbrae Farms Ltd.

Find out more - www.alzheimer.ca
or contact your local Society.

Alzheimer Society

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What everyone should know about brain health and Alzheimer's disease

Alzheimer Society

Your Brain & Good Health

Make the Connection

The brain is one of your most vital organs, playing a role in every action and every thought, and just like the rest of your body it needs to be looked after.

It's never too soon, or too late to make changes that will maintain or improve your brain health, changes that may also help reduce your risk of developing Alzheimer's disease.

Reducing Your Risk

Alzheimer's disease develops when the risk factors for the disease combine and reach a level that overwhelms the brain's ability to maintain and repair itself. So reducing as many of the risk factors that you can makes good sense. By making healthy lifestyle choices, you may be able to reduce your risk and improve your brain's ability to sustain long-term health.

There are some risk factors that you can't control – your genetic makeup and growing older, but there is a lot you can do that may help reduce your risk of getting the disease. The suggestions that follow provide practical action steps, based on current research, that you can take to improve your brain health.

Will healthy lifestyle choices prevent Alzheimer's disease? There are no guarantees but evidence suggests that healthy lifestyles help the brain maintain connections and even build new ones. That means that a healthy brain can withstand illness better. So take action today.

Take Action for a Healthier Brain

Here are things that you can do to maintain or improve your brain health:

Challenge Your Brain

Keep your brain active every day. Studies show that regularly challenging your brain may reduce your likelihood of developing Alzheimer's disease, so it is important to give your brain a regular work out. Try something new or change the way you usually do a task -- such as brushing your hair with your less dominant hand. Here are some ideas to help you challenge your brain every day:

- Play games to challenge your mind - chess, cards, word or number puzzles, jigsaws, crosswords, and memory games
- Pursue a new interest, learn a language, take up a musical instrument, take a course, go to a museum, enjoy hobbies

Be Socially Active

Staying connected socially helps you stay connected mentally. Social interaction appears to have a protective effect against Alzheimer's disease. So pick up the phone, stay connected to family and friends, get together with your neighbours. Spend time with people who have a positive outlook. The more engaged you are the better, so here are a few ideas for enhancing your social interactions:

- Enjoy events with family and friends
- Stay active in the workforce or become a volunteer
- Join a club or hobby group or take a class

Choose a Healthy Lifestyle

A healthy lifestyle is as important to brain health as it is to the rest of your body. Diabetes, hypertension, high cholesterol and obesity are all risk factors for Alzheimer's disease. There are many simple lifestyle choices you can make to improve your brain health.

- Make healthy food choices: eat a varied diet rich in dark-coloured fruits and vegetables, including foods rich in anti-oxidants, such as blueberries and spinach; and omega 3 oils found in fish and canola oils.
- Be active: regular moderate physical activity helps maintain cardiovascular health and can significantly reduce the risk of heart attacks, stroke and diabetes.
- Track your numbers: keep your blood pressure, cholesterol, blood sugar and weight within recommended ranges. If you have diabetes, it is important to manage it well.
- Reduce stress: practice relaxation, meditation or other stress reduction techniques.
- Choose wisely: avoid smoking and excessive alcohol consumption.

Protect Your Head

Brain injuries, especially repeated concussions, are risk factors for the later development of Alzheimer's disease. By protecting your head you are caring for your brain today and in the future.

- Wear an approved helmet when engaging in sporting activities such as skating, skiing, skateboarding, rollerblading and cycling.
- Protect against concussions by using safety features like handrails to avoid falls.
- Drive safely and wear a seatbelt.
- See your doctor regularly: both for check ups and any specific health concerns. Your doctor is an important partner in maintaining your health.

Self-Monitoring Calendar