

The Mediating Effect of Functional Social Support in the Pathway between Memory and Depressive Symptoms: A Longitudinal Mediation Analysis of the Canadian Longitudinal Study on Aging

by

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Author's Declaration

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

Abstract

Background: Cognitive function and emotional wellbeing are essential for healthy aging. Cognitive impairment and depressive symptoms can lead to severe morbidity and mortality in aging adults. Strong, positive associations exist between memory impairment – memory is a subdomain of cognition – and depressive symptoms. Evidence also suggests one’s perceived level of functional social support (FSS) may affect the emergence of depressive symptoms in aging adults with memory impairment. However, few studies have explored whether FSS mediates the association between memory and depressive symptoms.

Methods: This research utilized an analytical sample drawn from 21,241 participants between the ages of 45 and 85 years who were enrolled in the Tracking Cohort of the Canadian Longitudinal Study on Aging (CLSA) at baseline. The thesis examined three aims: the association between memory and depressive symptoms across three time points of data (baseline, three-year follow-up, and six-year follow-up), controlling for health, lifestyle, and sociodemographic covariates; the potential mediation effect of FSS on this association; and whether moderated mediation was present by age group and sex.

Results: Overall, memory function was inversely associated with depressive symptoms ($\hat{\beta} = -0.08$; 95% confidence interval [CI]: -0.11, -0.04). The indirect (mediated) effect of memory on depressive symptoms through FSS was statistically significant, though minimal ($\hat{\beta} = -0.02$; 95% CI: -0.02, -0.01), and most of the effect was direct ($\hat{\beta} = -0.07$; 95% CI: -0.10, -0.04). No evidence existed for statistically significant moderated mediation by age group or sex.

Contribution: This novel research suggested that functional social support may mediate the association between memory and depressive symptoms. Further research is required to advise health practitioners who deal with memory-impaired individuals as to whether interventions promoting functional social support (e.g., social prescribing) can help minimize symptoms of depression.

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List of Abbreviations

ADL – Activities of daily living

AMT – Abbreviated Mental Test

CCHS-HA – Canadian Community Health Survey- Healthy Aging

CESD-10 – Center for Epidemiologic Studies Depression Scale

CHD – Coronary heart disease

CHMS – Canadian Health Measures Survey

CLSA – Canadian Longitudinal Study on Aging

COPD – Chronic obstructive pulmonary disease

CTUMS – Canadian Tobacco Use Monitoring Survey

CI – Confidence interval

DSM-5 – Diagnostic and Statistical Manual of Mental Disorders

ESSI – ENRICH Social Support Instrument

FCS – Full conditional specification

FSS – Functional social support

GDS – Geriatric Depression Scale

HALST – Healthy Aging Longitudinal Study

HPA – Hypothalamic-pituitary-adrenal

IADL – Instrumental activities of daily living

ICD – International Classification of Diseases

MADRS – Montgomery-Asberg Depression Rating Scale

MAR – Missing at Random

MCAR – Missing completely at random

MMSE – Mini-mental State Examination

MoCA – Montréal Cognitive Assessment

MOS – SSS – Medical Outcomes Study-Social Support Survey

MPSP – Multidimensional Scale of Perceived Social Support

OARS – Older Americans Resources and Services

OSS-3 – Oslo-3 Social Support Scale

PM – Proportion mediated

RAVLT – Rey Auditory Verbal Learning Test

WHO – World Health Organization

WMS-IV – Wechsler Memory Scale

1. INTRODUCTION

As people age, they experience changes in their biological, psychological, behavioral, and social processes¹. Physiological deterioration in aging adults over time contributes to declines in cognitive and physical ability, lower emotional wellbeing, increased risk of chronic illness, and death^{1,2}. Age-related cognitive decline can adversely affect learning and memory, perceptual-motor function, executive function, social cognition, language, and complex attention³. Aging does not have equivalent effects across these areas^{4,5} and one of the main cognitive complaints among aging adults is difficulties with memory. Memory impairment has been shown to have strong inverse associations with quality of life and independence in daily functioning^{6,7}. Memory decline has also been identified as the hallmark of many age-related neurodegenerative diseases, especially Alzheimer's disease^{8,9}.

Depression is a mood disorder that is prevalent among aging adults^{10,11}. A number of factors, including impaired brain functioning and structural changes in some brain regions, have been implicated in the pathophysiology of depression¹². Depression is characterized by symptoms such as poor sleep and appetite loss, extreme sadness, and persistent feelings of guilt and hopelessness. The number and severity of these symptoms are linked to suicidal thoughts¹³. Depressive symptoms impose additional functional limitations on aging populations and contribute substantially to increased morbidity and mortality in these populations¹⁴⁻¹⁶.

Among aging adults, depressive symptoms and cognitive dysfunction often co-exist¹⁷⁻¹⁹, with many studies reporting bidirectional associations between these two conditions¹⁷⁻²⁰. Research has shown strong positive linkages between depressive symptoms as a risk factor and memory impairment as the outcome^{2,21-25}, with other studies finding memory decline to be a risk factor for depressive symptoms²⁶⁻²⁸. Some research suggests depressive symptoms are an early prodromal

feature of memory impairment^{17,29–32}, while other studies regard them as a response to the negative effects of memory decline on an individual's health and quality of life^{33,34}. People with coexisting memory decline and depressive symptoms may be at higher risk of suicidal thoughts and behaviour, worse antidepressant responses, increased disability, worsening cognitive impairment, depression relapse, and mortality than people with depressive symptoms alone^{35–37}.

Research has shown that functional social support (FSS) is positively associated with memory function which may be attributed to the necessity of memory function for building and maintaining FSS^{38–42}. FSS is the extent to which one believes they will receive help from members of their social network in times of need⁴³. FSS protects against depressive symptoms by reducing stress responses^{26,44} and may buffer the relationship between cognition and depressive symptoms^{24,45}. However, few studies have specifically explored the mediating effects of FSS in the longitudinal pathway between memory and depressive symptoms.

Given the complex nature of the intertwined association between memory and depressive symptoms, an assessment of the potential mediating role of FSS is key to expanding our knowledge about the interplay between these two constructs. As such, this thesis involved a mediation analysis to explore whether the effect of memory on depressive symptoms is mediated by FSS. Minimizing the impact of memory impairment on depressive symptoms – by emphasizing the development of functional social support – could lessen depressive symptoms and help promote healthier aging in older adult populations.

2. LITERATURE REVIEW

2.1. Memory

Memory is a complex neurological process whereby the brain encodes, consolidates, and retrieves information⁴⁶. A recent systematic review and meta-analysis by Salari et.al showed the global prevalence of mild cognitive impairment to be 23.7% in the geriatric population (65 years or older)⁴⁷. In Canada, the prevalence of dementia in persons aged over 65 years in 2024 was 8.7%⁴⁸.

Episodic memory, implicit memory, semantic memory, and working memory are the clinically important memory systems in individuals⁴⁹. Episodic memory is the capacity to remember information about previous personal experiences, such as recalling what one had for breakfast⁵⁰. Implicit memory involves the unconscious and effortless recall of saved information like remembering how to read a book⁵¹. Semantic memory involves remembering general facts and knowledge gained over the years, and it is the type of memory one would use to complete something like a crossword puzzle⁵². Working memory is the ability to recall temporarily-stored information that is needed to perform an immediate and successive cognitive task, such as recalling the name of a person mentioned in a sentence when intending to use that name in the next sentence⁵². Episodic and working memory are severely affected by aging. However, episodic memory is most susceptible to the neurochemical, neurophysiological, and neuroanatomical changes associated with aging^{53–55}; it is the earliest marker of neurocognitive disorders^{56,57}. Semantic and implicit memory are often preserved in aging adults⁵. This thesis will focus on episodic memory in a sample of middle-aged and older adults.

2.1.1. Measures of Memory

Psychometric tests such as the Mini Wechsler Memory Scale-IV (WMS-IV)⁵⁸ and the Rey Auditory Verbal Learning Test (RAVLT)⁵⁹, among others, can be used to evaluate memory function. The basic idea behind these tests is that memory retrieval or remembering can happen in response to both internal signals (free recall) or external prompts (cued recall)^{60,61}. In free recall tests, participants are evaluated on their ability to remember items – usually word lists – based on their own memory; in cued recall tests, participants' ability to remember is prompted by an instruction, such as being told to say the word 'dog' after hearing the word 'canine'. In this thesis, episodic memory based on free recall was measured using the modified Rey Auditory Verbal Learning Test (RAVLT) (see Section 4.2.1 below).

2.1.2. Primary Factors Associated with Memory

Consistent evidence has shown that age^{62,63}, sex^{63,64}, and chronic diseases^{64,65} are associated with memory. Previous works suggest that age and sex could modify the association between memory and depressive symptoms^{66,67}. These known associations led to the inclusion of these variables as confounders in the thesis. Age and sex were additionally explored as potential moderators of the mediation pathway described in Chapter 1 above.

Age is the primary risk factor for memory decline^{62,63}. Decreases in the pathophysiological components of the brain over time, e.g., volume of grey and white matter, neuronal numbers, and size and concentrations of neurotransmitters, have been implicated as the mechanisms leading to age-associated memory decline^{56,68}. Medical illnesses, psychological factors, and sensory deficits such as vision and hearing impairment – all exacerbated as people age – can accelerate age-related memory decline⁶⁹.

Disparities between females and males exist in relation to memory^{63,64}. Females appear to have an advantage in episodic memory, performing better than men on immediate and delayed recall tasks^{70,71}. One explanation in existing literature is that this difference may be attributed to sex variations⁷² in brain structures that make women less vulnerable to negative, age-related changes in cognition⁷³. However, some studies have not found sex-specific variations in memory decline among aging adults^{74,75}.

Chronic diseases (e.g., stroke, coronary heart disease [CHD], chronic obstructive pulmonary disease [COPD]) and other health conditions (e.g., hearing loss, depression, disability) have been recognized as independent risk factors for memory decline in aging individuals⁶⁴. The co-occurrence of chronic diseases, especially cerebrovascular disease, alongside memory decline in aging adults can also accelerate damage to the cerebral cortex and lead to further losses of brain function and memory^{64,65}.

2.2. Functional Social Support

FSS refers to a person's perception of the extent to which they can depend on other people in their social network for assistance in times of need^{43,45}. FSS has different subtypes, including tangible/instrumental, affectionate, emotional, informational, and positive support^{42,43}. Tangible/instrumental support involves receipt of physical help to carry out duties or tasks; affectionate support is the availability of someone to give outward expressions or feelings of love; emotional support is being cared for through the provision of empathy, compassion, and nurturing; informational support involves receiving advice, feedback, or guidance; positive support is being able to make one feel comforted and at ease as a result of social interaction^{42,43}. Some studies include one or more subtypes of FSS and others look solely at 'overall FSS'^{38,76–81}. The receipt of high levels of FSS has been observed to protect against cognitive decline (including memory

decline) and major neurocognitive disorders^{42,82}, as well as depressive symptoms^{26,44,83}. Reasons for these protective effects on depressive symptoms are discussed in Section 2.4.3.

2.2.1. Measures of Functional Social Support

Given the multiple subtypes of FSS and the absence of a gold standard means of measuring FSS in research, an assortment of tools exists to operationalize the construct. These tools – some of which are validated – ask respondents to rate their perceived levels of FSS on one or more subtypes, ultimately leading to the generation of subtype specific and overall FSS scores. One validated measure of FSS is the self-administered Medical Outcomes Study-Social Support Survey (MOS-SSS)⁴³, which was employed in this thesis to measure overall FSS^{42,84}. More information about the MOS-SSS is provided in Section 4.2.2 below.

2.2.2. Primary Factors Associated with Functional Social Support

Age^{66,85} and sex^{82,86} are consistently associated with FSS. Older adults tend to report greater relationship satisfaction⁸⁷ and happier interactions with members of their social networks⁸⁸ compared to younger adults, but their FSS may decrease over time as their contemporary social contacts become less capable of providing support due to functional limitations and chronic illnesses^{66,85}. In some, FSS remains stable because they seek out greater support from a small number of remaining social network members^{89,90} who bring value-added benefits to relationships, while simultaneously eliminating members who cause stress (e.g., “gossipers”, “drama queens”, or “complainers”)^{89,90}.

Females and males report different experiences with FSS⁸². FSS tends to be higher in females compared to males because females maintain more extensive social networks and possess a greater willingness to seek assistance when needed. Indeed, older females show a greater capacity than males to maintain and even expand their FSS through family and community

links^{66,85}. Males, on the other hand, generally rely on smaller-sized networks for FSS and may underuse existing resources, leaving them more vulnerable during times of stress^{82,86,91,92}. Further, emotional support has been demonstrated to be more important for women in the context of maintaining cognitive function^{93,94}, as women are better able to recognize unmet emotional support needs compared to men and are more adept at tapping into available FSS.

2.3. Depressive Symptoms

Depression is a common psychiatric disorder that affects the way an individual feels and thinks about themselves and the world around them^{77,95}. Abnormalities with neurotransmitter functionality and structural changes in the mid-brain and amygdala have been implicated in the development of depressive symptoms^{12,96}. According to the WHO, an estimated 3.8% of the population, including 5% of all adults over 40 years of age and 5.7% of adults older than 60 years of age, experience depressive symptoms globally⁹⁷. The global prevalence of depressive symptoms in older adults, measured using screening tools like the 10-item Center for Epidemiologic Studies Depression Scale (CESD-10)⁹⁸ or Geriatric Depression Scale (GDS)⁹⁹, varies broadly from 8.2% to 63%¹⁰⁰, with prevalences of 16.3% and 17.1% in rural and urban regions of Canada, respectively¹⁰¹. Some common symptoms of depression include: absence of motivation; fatigue; irritability; feelings of hopelessness, sadness, and worthlessness; sleep and concentration difficulties; social withdrawal; and suicidal thoughts^{102,103}.

Depressive symptoms are often chronic, increasing the likelihood of long-term health problems such as cardiovascular and neurological illnesses. These illnesses are exacerbated by problems that often accompany depressive symptoms, such as poor health behaviours, sleep difficulties, and substance abuse, among others^{104,105}. Depressive symptoms may be a psychological reaction to cognitive problems¹⁰⁶ and could thus serve as an early sign of memory

decline and a prodrome of dementias. In contrast, some evidence suggests memory impairment is a risk factor for depressive symptoms^{10,107} (see Section 2.4.1). The nature of the relation between these two variables is difficult to tease apart because they frequently co-occur, leading to research on the bidirectionality of the association¹⁰⁸.

2.3.1. Measures of Depression

A clinical diagnosis of depression requires a comprehensive assessment by a medical doctor or mental health professional according to established clinical criteria¹⁰⁹. Fulfillment of these criteria is aided by clinical diagnostic guidelines (e.g., International Classification of Diseases [ICD]¹¹⁰ or Diagnostic and Statistical Manual of Mental Disorders [DSM-5]¹¹¹), self-reported history of clinical depression, and screening tools for depressive symptoms (e.g., CESD-10⁹⁸).

Screening tools ask respondents about the frequency of experiencing each of several depressive symptoms within a certain time period. The frequencies are typically displayed as Likert scales (e.g., none/some/all of the time) and are summed to obtain a total score. These screening tools are often the preferred mode of measuring ‘depression’ in research studies because of the practical challenges (time, cost, logistics) of sending every participant to a clinician for a formal diagnostic evaluation¹⁰⁹. In this thesis, depressive symptoms were measured with the CESD-10 (see Section 4.2.3 below).

2.3.2. Primary Factors Associated with Depressive Symptoms

Similar to memory, the literature has shown that age^{112,113}, sex^{113,114}, and chronic diseases^{15,115} are consistently associated with depressive symptoms. The prevalence of depressive symptoms varies across age groups. Structural and functional brain changes associated with aging, including the increased risk of brain atrophy, predispose older adults to developing depressive

symptoms¹¹⁶. Some older adults may also be more affected by depression because they hold negative stereotypes toward mental illness and are therefore less likely to seek psychological help^{112,113}. These individuals are also less likely to be diagnosed with depression and supported by appropriate mental healthcare services because depressive symptoms often mimic other illnesses of aging like dementia^{112,117,118}.

Females exhibit a higher prevalence of depressive symptoms than males^{113,114}. This may be due to disparities in how the brain processes stress and emotions in females versus males¹¹⁹. The hypothalamic-pituitary-adrenal (HPA) axis, which regulates stress, appears to be more reactive in females, leading them to ruminate more about unpleasant events, thereby increasing their risk of developing depressive symptoms^{120,121}. Sex differences in the genetic origins of depression have also been recognized, as certain depression-related genes (5-HTTLPR, val66met) increase the risk of depression only in females¹²⁰. Reporting biases may also account for some of the differences because females tend to be more willing than males to overtly report stressful life events and seek counselling to cope^{91,122,123}.

Depressive symptoms may be substantially higher in persons with chronic health conditions, particularly cardiac, cerebrovascular, and neurological diseases^{15,115}. This is largely due to the physiological and neurological changes that occur in the presence of these diseases. For instance, elevated blood sugar and structural brain changes predispose diabetic persons to developing depression^{122,124,125}. Shared risk factors (e.g., poor sleep, unhealthy lifestyle behaviours, and stress) that contribute to the development of depressive symptoms and chronic health conditions concomitantly may also be implicated in this association. Additionally, the burden of suffering from functional decline and chronic illnesses can negatively affect quality of life¹⁵ and lead to depressive symptoms.

2.4. Theoretical Frameworks Supporting Mediation Analysis

2.4.1. Cognitive Pathway to Depression

Several cognitive elements play a role in the onset and recurrence of depression³³. These elements are related to how one frames events, including one's attitudes, thoughts, conclusions, and interpretations of events. Impaired memory might lead people to excessively frame events negatively, which can evoke stress reactions that trigger or worsen depressive symptoms. Depressive symptoms may also develop as a result of a person's awareness of memory decline^{126,127}.

The vulnerability-stress theory proposes that cognitive impairment leads individuals to amplify the negative impact of life events, which exacerbates stress responses¹²⁸ and accelerates the incidence of depression and its severity^{129–131}. Pathophysiologically, stressful experiences are associated with cognitive reactivity processes in the brain that are critical for promoting the development of depression. Cognitively impaired individuals usually show poor cognitive responsiveness and reaction time, which may diminish their ability to manage stress and increase their vulnerability to developing depressive symptoms^{129,131,132}.

Memory problems can negatively affect performance in various areas of life, such as social interactions and routine daily activities. This performance loss often leads to increased stress and feelings of helplessness, which can produce or worsen depressive symptoms^{133–135}. Although the bidirectional relationship between memory and depression^{17–20} was mentioned in Section 2.1, and many researchers believe depressive symptoms are a prodromal feature of cognitive impairment^{21,23–25}, studies have shown that depression-free individuals who report memory difficulties at baseline are predisposed to developing depressive symptoms over time^{136,137}.

2.4.2. The Effect of Memory on Functional Social Support

Research has shown that good cognitive function is vital for building and maintaining sources of FSS^{57,138–140}. Persons with cognitive/memory impairment often withdraw from social interactions¹⁴¹ and reduce their sources of FSS¹²⁹. Some memory impaired individuals may experience altered perceptions of the amount of social support that is available to them, potentially leading to underestimations of true levels of FSS when completing study questionnaires⁵⁷. Individuals with better memory are more likely to build and maintain social networks to fulfil unmet needs and maintain FSS^{91,138,139,141}.

Cognitive impairment need not always lead to reduced FSS. The Theory of Selective Optimization with Compensation suggests that cognitive deterioration compels individuals to prioritize and optimize relationships that have the potential to provide the greatest FSS when needed, rather than seeking to maintain broader social connections¹⁴². Thus, persons with memory decline might retain higher proportions of close relatives in their social networks because these individuals will usually be more predisposed than non-relatives to provide long-term, tangible care, such as help with meal preparation or transport to medical appointments.

2.4.3. The Effect of Functional Social Support on Depressive Symptoms

Higher levels of FSS are generally protective against depressive symptoms^{26,44,83,143}. Empirically, FSS accounts for more variance in depressive symptomatology than structural measures of support (social isolation)^{144,145}. The self-esteem theory of social support may explain these findings. This theory suggests that perceived availability of FSS from others reduces negative self-perceptions. Individuals see themselves as ‘good’ or ‘worthy’ by virtue of the fact that others are willing to help them in times of need, especially with emotional and affectionate support, thereby contributing to the development of stronger self-esteem, which is protective against

depression¹⁴⁶. On the other hand, persons with low FSS may experience more dysfunctional and less fulfilling social relationships, which decreases their ability to resist negative self-perceptions (e.g., they blame themselves for poor interpersonal relationships) and increases the risk of depressive symptoms and depression^{145,147}. High stress is also a risk factor for depression. FSS alleviates stress by providing affectionate, emotional, and other forms of support. The availability of people in one's social network to provide this support and help with tasks can reduce stress and lower the number and severity of depressive symptoms. Since stress is linked to depressive symptoms, lower FSS may be associated with greater stress because fewer outlets exist for stress relief, which in turn also leads to higher levels of depressive symptoms^{148,149}.

2.5. The Effect of Memory on Depressive Symptoms Mediated by Functional Social Support

FSS may mediate the relationship between memory and depressive symptoms in middle-aged and older adults^{24,45,150,151}. As discussed above, persons experiencing memory difficulties could still possess high levels of FSS, in line with the Theory of Selective Optimization with Compensation. High FSS increases one's perceptions of goodness and self-worth, and lowers the impact of stress which is protective against depressive symptoms^{143,152}. On the other hand, some research has suggested memory concerns, low FSS, and depressive symptoms could co-exist as part of a prodrome of future neurocognitive disorder^{153–155}. What is unknown is whether and how much FSS might mediate the association between memory impairment and depressive symptoms, given different theoretical possibilities and the dearth of empirical research on the topic. Could the benefits of FSS mitigate the effect of memory impairment on depressive symptoms, or does social retrenchment on account of memory impairment lower FSS and negate these benefits? This thesis will empirically address the novel topic of whether FSS mediates the association between memory

and depressive symptoms. As will be seen in the literature review in Section 2.6 below, a thorough examination of published research did not uncover any previous work on this topic.

2.6. Cognitive Function, Functional Social Support, and Depressive Symptoms

Sections 2.6.1 and 2.6.2 below summarize the published literature on the associations between memory, global cognition, and FSS as exposures, and depressive symptoms as the outcome. Most of the articles included examined global cognition, rather than memory, and were included in the review because of the scarcity of relevant studies on memory. None of the articles specifically examined FSS as a mediator of the association between memory and depressive symptoms. Hence, the literature review included articles wherein FSS was treated as the exposure or a covariate.

The literature search used the PubMed and Scopus databases and covered the time period between the inception of each database and May 1, 2025. The search criteria were devised following consultation with a health sciences librarian. Covidence (Veritas Health Innovation, Melbourne, Australia) was used to manage the screening process. The search strategy is shown in Appendix A (Table A1 and Figure A1). The included articles had to explore associations between memory, cognition, or FSS as exposures, and depressive symptoms (or depression) as an outcome, to reflect how the variables are being employed in this thesis. Seventeen relevant articles were identified in the search, 15 of which were cross-sectional, one longitudinal, and the other reported both cross-appendal and longitudinal analyses. Appendix B contains a detailed table summarizing all 17 included articles.

2.6.1. Cross-sectional Studies

Out of the 16 articles reporting cross-sectional results, four articles employed secondary analyses of baseline data from large panel studies, namely the Korean Longitudinal Study on

Aging¹⁵⁶, Paris Elder Cancer Patient Study¹⁵⁷, Healthy Aging Longitudinal Study (HALST)¹¹⁴, and National Survey of Older Koreans¹³⁴. Four other studies utilized hospital-based participants^{113,158–160}, while the rest of the studies^{26,28,161–165} included participants who were community dwelling. The 16 articles included 16,401 individuals (sample sizes ranged from 304 to 6,100). Most studies were from Asia (11 studies); the remainder were from the United States (1 study), Canada (1 study), France (1 study), Tanzania (1 study), and Ethiopia (1 study). Nine of these studies^{26,28,113,134,158,162–165} assessed depressive symptoms using the Short-Form Geriatric Depression Scale⁹⁹, one study⁴⁴ used the Montgomery-Asberg Depression Rating Scale (MADRS)¹⁶⁶, and three studies^{114,156,161} used the CESD-10⁹⁸ to measure the severity of depressive symptoms. Three studies^{157,158,160} used the DSM-IV¹¹¹ criteria to classify patients as having major, minor, or no depression.

Twelve of the studies^{26,28,44,113,114,134,156,157,159,160,164,165} assessed global cognition using the Mini-mental State Examination (MMSE)¹⁶⁷, a standard screening tool for global cognitive impairment in clinical and community settings. Two studies^{158,161} used the Montréal Cognitive Assessment (MoCA)¹⁶⁸ or the Abbreviated Mental Test (AMT)¹⁶⁹, respectively. Two studies^{162,163} asked participants to self-report their history of memory decline.

FSS was measured using different approaches, with many articles^{26,114,157,158,160} forgoing validated instruments in favor of questions asking about the perceived adequacy of subtypes of functional social support (e.g., “In the last month, could you have used more emotional support for help with daily tasks than you received?”). Six studies employed validated tools that included the MOS-SSS⁴³, Social Support Interactive Scale¹⁷⁰, Oslo-3 Social Support Scale (OSS-3)¹⁷¹, ENRICH Social Support Instrument (ESSI)¹⁷², Social Support Index¹⁷³, and the Multidimensional Scale of Perceived Social Support¹⁷⁴.

Most of the included cross-sectional articles^{26,28,44,113,114,134,156,157,159,160,164,165} examined global cognition as the exposure variable and showed significant inverse associations with depressive symptoms, meaning better cognition was associated with fewer or less severe depressive symptoms. Similarly, the two studies^{162,163} that assessed memory decline through self-reports found positive associations with depressive symptoms. However, two articles^{158,161} reported no significant relation between cognitive decline and depressive symptoms.

FSS was included as an independent variable alongside cognition in regression models where depressive symptoms were the outcome^{26,28,44,113,114,134,156–164}. Most articles reported significant associations between lower scores on subtypes of FSS and more depressive symptoms^{26,44,114,134,159,161,164}. Among these subtypes, emotional support demonstrated the strongest inverse association with depressive symptoms¹⁶¹. None of the articles examined the association between memory or cognition as the exposure and FSS as the outcome. All the articles adjusted for age, sex, and education in their analyses.

2.6.2. Longitudinal Studies

Only two studies (both hospital-based) assessed the longitudinal association between memory, FSS, and depressive symptoms^{44,175}. Chau et al¹⁷⁵ examined FSS and memory as risk factors for depressive symptoms; Roh et al⁴⁴ assessed FSS as the main exposure and memory as a potential moderator of the relationship between FSS and depressive symptoms. Both studies analyzed two waves of data from small cities in Australia and South-Korea, respectively. Chau et al¹⁷⁵ used generalized estimating equations to examine variables from 147 participants at baseline and 81 participants at follow-up who had a mean age of 84.6 years, with average follow-up between 0.4 to 1.9 years. Meanwhile, Roh et al. used data from 1,088 adults aged between 60 and 90 years who were enrolled in a community-based mental health center registry at baseline, 502

of whom completed a one-year follow up evaluation⁴⁴. These articles assessed depressive symptoms using the GDS-15⁹⁹ and the Korean version of the MADRS¹⁶⁶. Both articles^{44,175} assessed global cognitive impairment using the MMSE¹⁶⁷. Chau et al¹⁷⁵ measured FSS using the Multidimensional Scale of Perceived Social Support (MSPSP)¹⁷⁴ and Roh et al.⁴⁴ utilized the ESSi¹⁷². Both articles^{44,175} found that greater FSS at baseline was associated with fewer depressive symptoms at follow up. Chau et al. did not find that cognition was statistically significantly associated with depressive symptoms¹⁷⁵; however, Roh et al. found evidence of effect modification by cognition in the FSS-depression association⁴⁴. Roh's study showed that FSS may not be as effective in reducing depression symptoms in older persons with deteriorating cognitive ability. Both studies employed age, sex, and education as control variables.

2.6.3. Conclusion

Overall, the literature review found associations between memory decline and depressive symptoms, and between low FSS and depressive symptoms. The differences in the strength and direction of the study-specific measures of association, and the width of the confidence intervals (Appendix B), depended on many factors that varied across the articles, including type of cognitive function (global cognition or memory), measures of global cognition/memory or FSS, sample size, sample characteristics, follow-up length, measures of depression/depressive symptoms, and different mixes of control variables in regression models. Examples of covariates included in some, but not all, articles included religion, living conditions, vascular disease, nutrition, polypharmacy, anxiety, body mass index, and sleep. Notably, the studies did not account for certain important factors that might be possible confounders, such as smoking status and use of alcohol.

Despite the possibility that FSS may mediate the association between memory and depressive symptoms, as described in Section 2.5, none of the included articles specifically investigated this issue.

3. THESIS RESEARCH AIMS

This thesis was undertaken to investigate the following three aims:

Aim 1. To explore the association between memory and depressive symptoms longitudinally, across three timepoints of data, using the Tracking Cohort of the Canadian Longitudinal Study on Aging (CLSA), controlling for relevant sociodemographic, health, and lifestyle covariates;

Aim 2. To investigate whether FSS mediates the association between memory and depressive symptoms; and

Aim 3. To examine moderated mediation by age group and sex, given the differential effects of these two variables on memory, depressive symptoms, and FSS.

3.1. Elaboration of Research Aims

Population: Persons aged 45 to 85 years at baseline;

Exposure: Combined immediate- and delayed-recall memory z-scores obtained from a modified version of the RAVLT⁵⁹;

Mediator: Continuous scores for overall FSS, measured by the MOS-SSS⁴³, with higher scores indicating greater FSS;

Outcome: Depressive symptoms measured using continuous scores obtained from the CESD-10⁹⁸;

Time: All variables were assessed using data from baseline (t_0), first wave of follow-up (three years post-baseline [t_1]), and second wave of follow-up (six years post-baseline [t_2]) from the CLSA;

Setting: Persons residing in the community in any Canadian province at baseline.

4. METHODS

4.1. Data Source

4.1.1. *The Canadian Longitudinal Study on Aging*

The CLSA is an ongoing, population-based, panel study that is gathering physical, biological, psychological, social, and environmental health data from middle-aged and older adults every 3 years over a planned minimum of 20 years¹⁷⁶. The main aims of the CLSA are to understand health determinants and leverage this knowledge to inform health policies and practices that promote successful aging.

Between 2011 and 2015, the CLSA enrolled 51,338 adults aged 45 to 85 years at baseline¹⁷⁷. The first follow-up was completed in 2018 and the second follow-up was completed in 2021¹⁷⁷. Participants were recruited into one of two separate cohorts, Tracking or Comprehensive, which are differentiated by sample frames and data collection methods. The Tracking Cohort, comprising 21,241 of the 51,338 baseline participants, includes individuals from all 10 provinces and uses computer-assisted telephone interview software to collect data. The Comprehensive Cohort, comprising 30,097 of the 51,338 baseline participants, includes persons living within 25 to 50 kilometers of 11 data collection sites spread over 7 provinces and obtains information through in-home and in-person interviews¹⁷⁷. A common set of questionnaire data are collected from all participants and Comprehensive Cohort participants undergo additional clinical and physical performance testing at their local data collection sites. Comprehensive participants are also asked to provide optional urine and blood samples during their data collection site visits¹⁷⁷.

Given the different sampling frames, the validity of merging data from both cohorts is questionable. An additional merging challenge arises when examining memory because the mode of administering cognitive tests (i.e., telephone versus in person) can affect participants'

performance and test scores on the RAVLT¹⁷⁸. Therefore, this thesis draws exclusively on the Tracking Cohort¹⁷⁹ to minimize challenges with cross-cohort data merging and take advantage of the larger geographical sample frame. Also, missing data arose for approximately 40% of Comprehensive Cohort participants who missed their second follow-up as a result of the closure of data collection sites during COVID-19.

4.1.2. Thesis Sampling Frame and Eligibility Criteria

CLSA participants were recruited into the Tracking Cohort from three sources: the registries of provincial healthcare systems (e.g., Ontario Hospital Insurance Plan rolls), a subset of individuals enrolled in Statistics Canada's Canadian Community Health Survey-Healthy Aging (CCHS-HA)¹⁸⁰, and through random digit dialing of landline telephones¹⁷⁷. Exclusion criteria from the CLSA were: inability to communicate in either English or French; signs of cognitive impairment during the recruitment interview; residing in a long-term care facility; full-time membership in the Canadian Armed Forces; and residence in any Canadian territory or on a First Nations settlement¹⁷⁷. Study participants were recruited into pre-established age and sex strata for each province. These strata were later supplemented with additional targeted sampling to increase the enrollment of participants from lower education backgrounds¹⁷⁷.

4.2. Measures: Exposure, Mediator, and Outcome

4.2.1. Memory

Participants' immediate (RAVLT I) and delayed (RAVLT II) recall memory were measured using a modified version of the RAVLT. The original RAVLT is a comprehensive test to assess working memory, short-term memory, and long-term memory¹⁸¹. The CLSA altered the RAVLT to suit the time constraints of the telephone interview by eliminating an interference list recall and

reducing the number of recall administrations from five to two. These revisions made the CLSA's modified RAVLT a measure of episodic memory only¹⁷⁹.

The modified RAVLT is administered in the CLSA as follows: for immediate recall, participants listen to a prerecorded list of 15 words during the telephone interview and are immediately asked to repeat as many of these words as they can within 90 seconds. After 5 minutes, the delayed recall test begins and participants are required to state as many of the same 15 words as they can within 60 seconds, without hearing the list again. One point is assigned for each correctly recalled word or variant word, with the latter being a word sounding similar to one of the original prerecorded words. The same variant word must be recalled at both timepoints to obtain points. Raw scores for each administration range from 0 to 15.

To convert raw scores into z-scores, participants were removed from the analytical sample if they completed the RAVLT in both English and French. The remaining participants were split into English and French subsamples and z-scores were calculated separately for each subsample. Within each language subsample, the sample mean ($\bar{x}$) and sample standard deviation (s) for the RAVLT I and II raw scores was computed using the cognitively healthy subgroup of participants. These summary statistics were then used to calculate z-scores using the formula, $z = \frac{x - \bar{x}}{s}$, where x is the sample raw score for any participant, $\bar{x}$ is the sample mean of the raw scores from the cognitively healthy subgroup, and s is the sample standard deviation of the raw scores from the cognitively healthy subgroup. The cognitively healthy subgroup excluding persons who self-reported a diagnosis of Alzheimer's disease and who reported medical conditions that could affect cognition (transient ischemic attack, stroke, memory problems, dementia or Alzheimer's disease, Parkinsonism or Parkinson's disease, multiple sclerosis, epilepsy, cancers of the nervous system,

and concussion injuries)¹⁸². The main exposure measure for this thesis took the form of a ‘memory score’ and was computed by adding together each participant’s RAVLT I and II z-scores.

4.2.2. Functional Social Support

FSS scores were calculated using the 19-item MOS-SSS⁴³ (see Appendix C). The scale has 18 questions asking about four FSS subtypes: affectionate [3 questions], tangible [4 questions], emotional/informational [8 questions], and positive social interactions [3 questions]. The 19th question in the MOS-SSS, "someone to do things with to help you get your mind off things", is used to calculate the overall FSS score, but it is not included in any of the subtype scores. The instrument uses a Likert scoring scale from 1 to 5, with response options ranging from “*none of the time*” (score of 1) to “*all of the time*” (score of 5). The CLSA aggregates all 19 responses into the overall FSS score using the RAND Health Care scoring formula¹⁸³. The overall score ranges from 0 to 100 and higher scores indicate more FSS. This overall score will be used in all regression models.

4.2.3. Depressive Symptoms

Depressive symptoms were measured using continuous scores obtained from the CESD-10⁹⁸. The CESD-10 measures the frequency of depressive symptoms in the previous week, with higher scores implying more severe levels of depressive symptoms. It includes three items on depressed mood symptoms, five items on somatic symptoms, and two on positive mood. Response options for each item range from “*rarely or none of the time*” (score of 0) to “*all of the time*” (score of 3), and the total score runs from 0 to 30. O’Connell et al. have shown measurement invariance of the CESD-10 across age, sex, education, ethnicity, language of administration, and cognition in the CLSA, which makes the CESD-10 an ideal tool for measuring depressive symptoms while limiting measurement bias¹⁸⁴ in this thesis.

4.3. Covariates

Based on the literature reviewed above^{20,113,114,134,157–160,175}, as well as research from other theses^{57,185,186}, the following variables obtained at baseline were included as potential confounding variables in the regression analyses: (1) sociodemographic: age group, sex, province, education, income, marital status; (2) health: number of chronic conditions, functional status; and (3) lifestyle: smoking and alcohol consumption. Appendix D contains a full description of these variables. Although some of these variables may have changed over time (income, marital status, functional status, chronic conditions, alcohol, and smoking), only the baseline values of these variables were included in the regression models. Using baseline covariates simplified the interpretability of the regression models by placing the focus on the changes in depressive symptoms being predicted solely by changes in memory and FSS. Some of the covariates – identified below – were dichotomized to minimize computational challenges and problems with using small counts in regression analyses.

4.3.1. *Sociodemographic*

The CLSA dataset categorized age group into four levels: 45-54 years, 55-64 years, 65-74 years, and 75 years or over. Sex was categorized as male or female. Education had four categories: less than high school, high school diploma, some post-secondary education, and post-secondary degree/diploma. Province of residence included the ten Canadian provinces. Income had five categories based on total annual household income: less than \$20,000, from \$20,000 to under \$50,000, from \$50,000 to under \$100,000, from \$100,000 to under \$150,000, and \$150,000 or more. Marital status was categorized into four levels: single, married/common law, widowed, divorced/separated. In this thesis, marital status was dichotomized as 'single' versus 'others'.

4.3.2. Health Status

Chronic conditions are evaluated in the CLSA using self-reports of whether a doctor had ever told participants they had cardiovascular problems, respiratory problems, osteoarthritis, neurological problems, cancer, gastrointestinal diseases, eye diseases, diabetes mellitus, hyperthyroidism, hypothyroidism, stroke, and osteoporosis. For the thesis, the count of self-reported chronic conditions was dichotomized into 'no chronic conditions' versus 'any chronic conditions'.

Functional status was evaluated with questions about activities of daily living (ADL) and instrumental activities of daily living (IADL), all obtained from the Older Americans Resources and Services (OARS) Multidimensional Assessment Questionnaire¹⁸⁷. ADLs refer to participants' capacity to complete seven basic daily activities, including grooming, dressing, eating, and walking. IADLs are the capacity to carry out seven high-level daily tasks such as money management, grocery shopping, taking medications, and meal preparation. Participants' ADL and IADL responses were transformed by CLSA into a five-level derived variable for functional status: (1) no functional impairment, (2) mild impairment, (3) moderate impairment, (4) severe impairment (5), and total functional impairment. Functional status was dichotomized in this thesis into 'no functional impairment' versus 'any level of functional impairment'.

4.3.3. Lifestyle Behaviours

The CLSA includes a derived variable for frequency of alcohol use in the previous year¹⁸⁸, based on a similar variable in Statistics Canada's CCHS-HA¹⁸⁹. Participants who did not drink in the past 12 months were classified as 'not at all'; participants who only drank occasionally throughout the year, but less than once a month, were classified as 'occasionally'; and those who drank at least once a month were classified as 'regularly'. Alcohol status was dichotomized as

‘user’ (i.e., occasional and regular users) versus ‘non-user’ (i.e., did not consume alcohol in the past year).

A self-report questionnaire based on the Canadian Health Measures Survey (CHMS)¹⁸⁹ and the Canadian Tobacco Use Monitoring Survey (CTUMS)¹⁹⁰ was used to assess smoking status. Participants were categorized based on smoking habits within the past month. Participants who had not smoked in the last 30 days were categorized as ‘non-user’; participants who took at least one cigarette in the last 30 days, but not daily, were categorized as ‘occasional user’; and participants who took at least one cigarette daily for the last 30 days were categorized as ‘daily user’. Smoking status was dichotomized as ‘user’ (occasional and daily smokers) versus ‘non-user’ (did not smoke in the last 30 days) in this thesis.

4.4. Derivation of the Analytical Sample

The analytical sample used for the primary analysis in this thesis was derived by removing participants who dropped out of the CLSA at the t_1 or t_2 ; who had missing information on the exposure, mediator, or outcome variable at t_0 , t_1 or t_2 ; or who had missing information on at least one baseline covariate. Overall, 17,065 of the 21,241 participants at t_0 (80.3%) provided information on all relevant variables at t_1 , while 14,848 of the 17,065 participants at t_1 (87%) provided information on all relevant variables at t_2 . After participants with missing information on memory, FSS, depressive symptoms, or any of the covariates were removed, 5,958 participants with complete data on all variables at all timepoints (40% of 14,848) remained in the analytical sample used for the primary analysis, which took the form of a complete case analysis. Figure 1 below illustrates the derivation of the analytical sample.

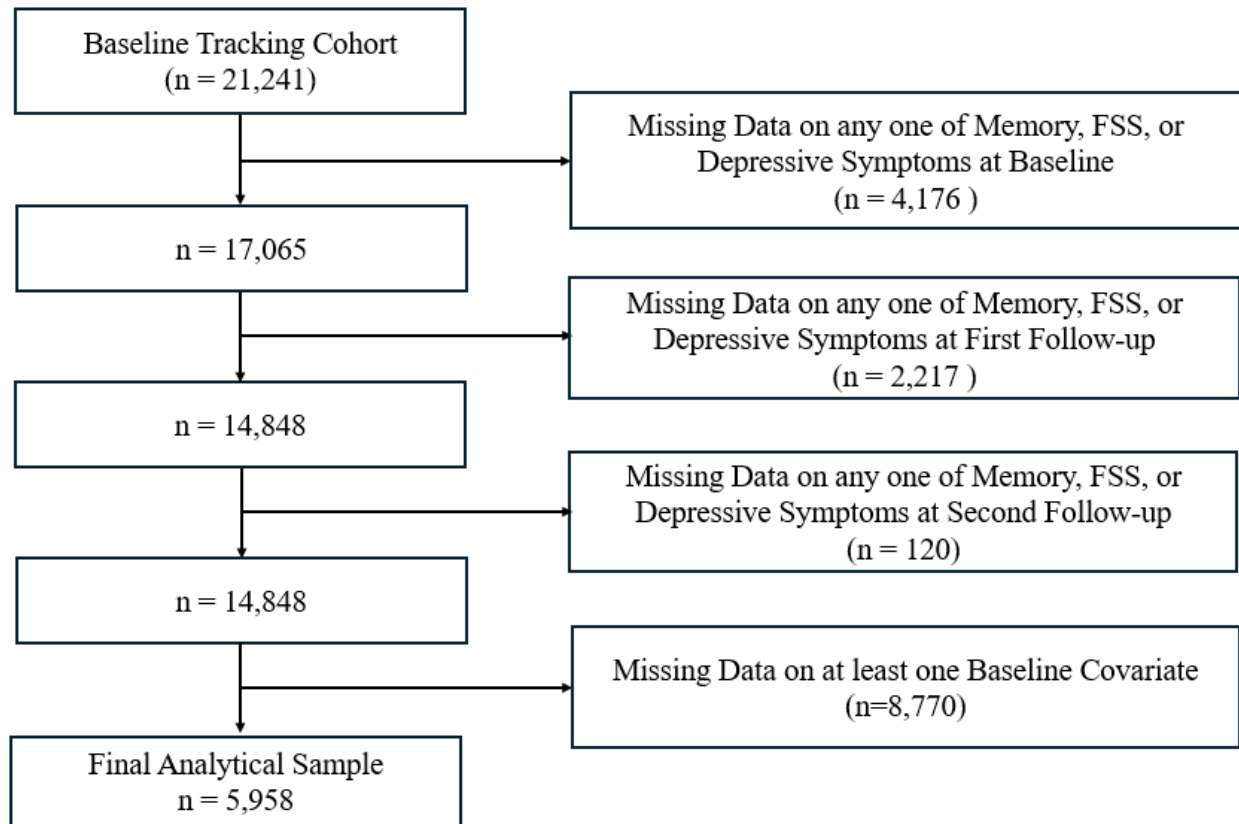


Figure 1. Derivation of Analytical Sample

4.5. Data Analyses

4.5.1. Descriptive Analyses

Baseline descriptive statistics were computed for all variables. Distributions for continuous variables were assessed using histograms and presented using means and standard deviations if normally distributed, or medians and interquartile ranges if non-normally distributed. Categorical variables were presented using frequencies and percentages. The Kruskal-Wallis test was used to check for statistically significant differences in the median scores for memory, FSS, and depressive symptoms across response categories for each covariate. The original format of the covariates (before dichotomization) was used in this assessment to ensure the descriptive analyses provides

information on the original form of the dataset. The average median scores for participants who were included in the complete case analysis and those who were excluded were computed and compared for memory, FSS, and depressive symptoms. The analyses conducted to address the three research aims from Section 3 are described below and summarized as a flow chart in Figure 2.

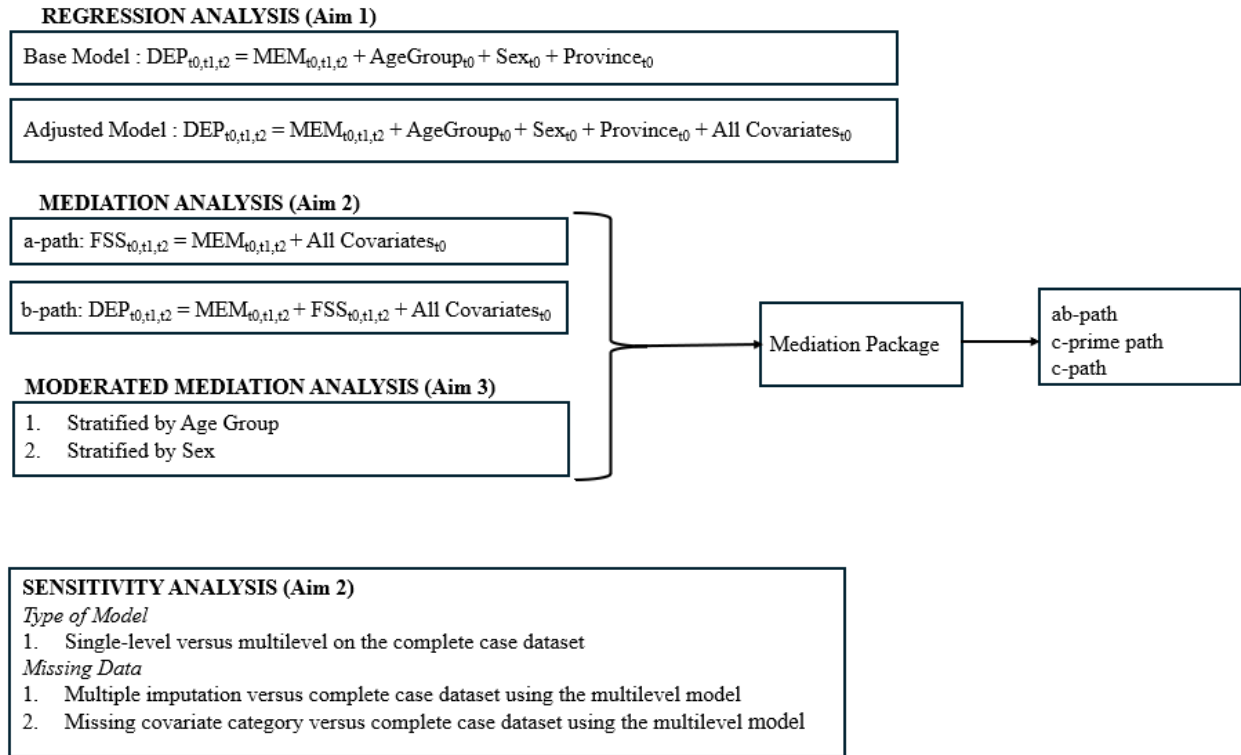


Figure 2. Graphical Depiction of Analytical Approach

4.5.2. Aim 1 - Association Between Memory and Depressive Symptoms Over Time

Multilevel modelling was employed to account for the longitudinal aspect of the study. This was implemented using a linear mixed effects model where the intercept and all independent variables were treated as fixed effects, and the time of follow-up was treated as a random effect. Participants' data were entered into a spreadsheet in 'long' format, with three rows of data per

participant. Each row represented one of the three timepoints: baseline values of the covariates were repeated across each row/timepoint in the spreadsheet, while the values for memory, FSS, and depressive symptoms varied by row/timepoint.

Two models were considered for Aim 1: (1) a base model and (2) an adjusted model containing all baseline covariates to account for possible confounding. In the base model, depressive symptoms scores were regressed on memory scores, controlling for age group, sex, and province of residence at baseline. The base model controlled for these latter three variables because the CLSA recommended adjusting for them to account for the complex survey design, as described in Section 4.1.2 above¹⁹¹. The adjusted model included the variables from the base model and all the covariates.

To decide whether to employ the base or adjusted model for Aims 2 and 3, the regression coefficient ($\hat{\beta}$) for memory was compared between these two models using the 10% rule²⁰⁰. If the $\hat{\beta}$ for memory in the adjusted model changed by at least $\pm 10\%$ compared to the $\hat{\beta}$ in the base model, then the covariates would be regarded as a confounding block of variables and the adjusted model would be used for Aims 2 and 3.

4.5.3. Aim 2 - Mediation Analysis

4.5.3.1. Methodological Background

Mediation analysis investigates the proportion of the relationship between an independent variable (X) and a dependent variable (Y) that is linked through an intermediary variable known as a mediator (M). Through a mediation analysis, the indirect effect, direct effect, and total effect can be obtained¹⁹². The indirect effect, or ‘mediation effect’ (“ab” path), is the effect of X on Y that passes through (‘is mediated by’) M. The “ab” path is the product of (1) $\hat{\beta}_X$ for the regression of M on X (“a” path) and (2) $\hat{\beta}_M$ for the regression of Y on M controlling for X (“b” path). The

direct effect of X on Y (or the “c-prime” path) is the relationship between X and Y, while adjusting for M. The total effect (“c” path) of X on Y is obtained by summing up the “ab” and “c-prime” paths. Mediation analysis can be performed with or without covariates, which would be included as additional independent variables in all the paths described above. A mediation analysis can be depicted by a ‘mediation triangle’, such as the one shown in Figure 3 below.

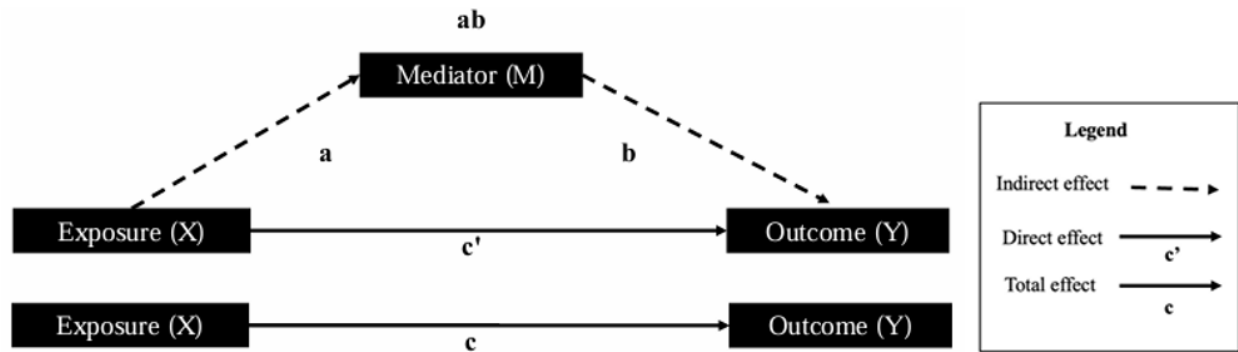


Figure 3. Mediation Model Conceptual Diagram

Notes: The outcome (Y) and the mediator (M) are both dependent variables. M is dependent upon the exposure (X) (“a” path), Y is dependent upon X and M (“b” and “c-prime” paths).

The “c-prime” path is equivalent to a standard regression model where Y is regressed on X and M is treated as a covariate, possibly along with other covariates. The “c” path captures the full effect of Y regressed on X when M is a mediator. The “c-prime” and “c” paths are equivalent when no mediation exists, and the same covariates are included in both models. When mediation does exist, looking only at “c-prime” will underestimate the total effect of X on Y because it omits the indirect effect of X on Y that occurs because of mediation by M.

Yzerbyt et al.’s joint significance test¹⁹³ was the method used to assess the presence of mediation in the thesis. According to this test, mediation is present if the relevant $\hat{\beta}$ s for the “a” and “b” paths ($\hat{\beta}_X$ and $\hat{\beta}_M$, respectively) are both statistically significant. Through simulation,

Yzerbyt et al. found that assessing the significance of the $\hat{\beta}$ for the “a” and “b” path individually, minimized Type I error compared to Hayes’ suggested approach of assessing the significance of the “ab” paths¹⁹⁴. Therefore, Hayes’ approach can falsely lead one to conclude that mediation exists when in fact it does not.

4.5.3.2. Analytical Approach

For Aim 2, the thesis candidate conducted mediation analysis in three steps:

- (1) Regressed FSS on memory to obtain the “a” path of the mediation triangle (effect of the exposure on the mediator, controlling for relevant covariates because the ‘10% rule’ in Aim 1 showed a greater than 10% change in $\hat{\beta}_{MEMORY}$);
- (2) Regressed depressive symptoms on FSS, controlling for memory and covariates to obtain the “b” path of the mediation triangle (effect of the mediator on the outcome, adjusting for the exposure and relevant covariates); and
- (3) Employed Yamamoto et al. and Imai et al.’s causal mediation approach^{204–207}, and the results from steps (1) and (2) above, to generate (i) the average direct effect of memory on depressive symptoms (“c-prime” path of the mediation triangle), (ii) the average indirect effect of memory on depressive symptoms that passes through (is mediated by) FSS (“ab” path of the mediation triangle), and (iii) the total effect of memory on depressive symptoms (“ab” + “c-prime” paths = “c” path of the mediation triangle). See Table 1 for a depiction of the components of the “a” and “b” paths and Figure 4 for an illustration of all mediation paths in the mediation triangle for this thesis. Equations for the “a” and “b” pathways are shown in Appendix E.

Table 1. Components of the "a" and "b" Paths

	"a" Path: regress M on X	"b" Path: regress Y on M, adjusted for X
Adjusted model	Exposure (X) Memory (t_0, t_1, t_2)	Exposure (M) Functional Social Support (t_0, t_1, t_2)
	Outcome(M) Functional Social Support (t_0, t_1, t_2)	Outcome (Y) Depressive Symptoms (t_0, t_1, t_2)
	Adjustment: Memory (t_0, t_1, t_2)	Adjustment: Memory (t_0, t_1, t_2)
	Variables included to account for the CLSA's complex survey design Age group (t_0) Sex (t_0) Province (t_0)	Variables included to account for the CLSA's complex survey design Age group (t_0) Sex (t_0) Province (t_0)
	The "a" and "b" path models were adjusted for the same set of baseline sociodemographic, health status, and lifestyle covariates	
	• Sociodemographic: Education (t_0), Marital Status(t_0), Total annual household income (t_0) • Health: Functional status (t_0), Chronic conditions (t_0) • Lifestyle: Smoking status (t_0), Alcohol consumption (t_0)	

Notes: t_0 =Baseline, t_1 =First Follow-up, t_2 =Second Follow-up

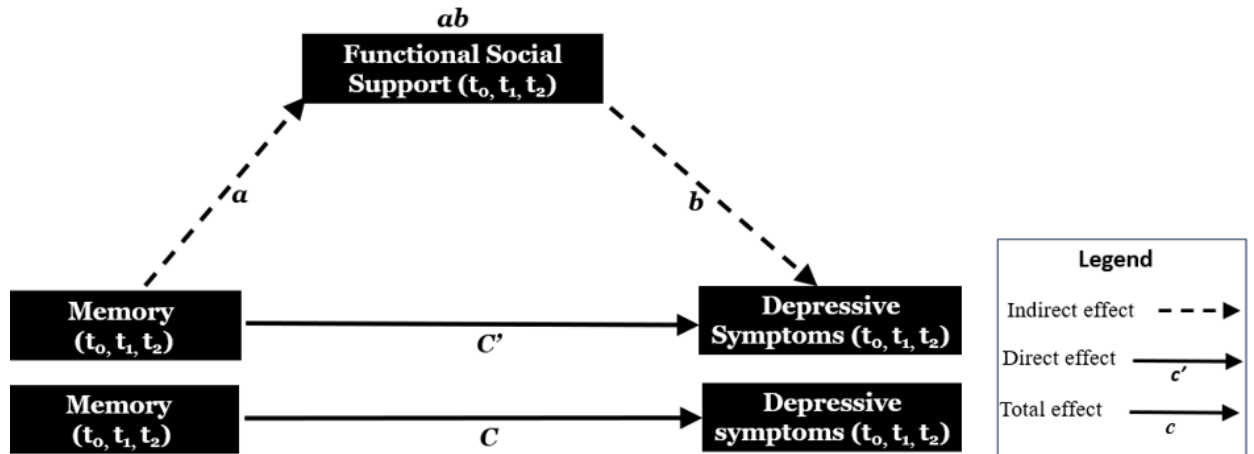


Figure 4. Conceptual Diagram for Mediation Analysis in the Thesis (the 'mediation triangle')

Notes: t_0 =Baseline, t_1 =First Follow-up, t_2 =Second Follow-up

The extent of any mediation (‘proportion mediated’) was estimated by calculating the proportion of the total effect of memory on depressive symptoms that is mediated by FSS: $PM = \frac{\beta_{ab}}{\beta_c}$; where β_{ab} = regression coefficient for the average indirect effect (“ab” path); β_c = regression coefficient for the average total effect; PM = proportion mediated by FSS.

The lme4²⁰⁸ and mediation²⁰⁹ packages in R version 4.4.0 (The R Foundation for Statistical Computing, Vienna, Austria) were used for the multilevel modelling and mediation analyses, respectively. The lme4 package permitted the thesis candidate to generate linear mixed effects models and the mediation package allowed the candidate to implement Yamamoto and Imai et al.’s^{201–203} algorithms for causal mediation analysis (and obtain the β_{ab} and β_c coefficients mentioned above). These algorithms employed the Monte Carlo sampling method, White’s heteroskedasticity-consistent estimator for the covariance matrix, and 10,000 simulations²⁰⁷ to generate the β s and 95% confidence intervals (CIs) for the “ab”, “c-prime”, and “c” paths. The algorithms also calculated and provided a 95% CI for the proportion mediated. Since the algorithms underlying the mediation package were not designed to handle sampling weights, the CLSA’s sampling weights and geographic strata variables were not used in the thesis. However, the inclusion of age group, sex, and province in all regression models followed CLSA guidance as a means of accounting for the study’s complex survey design¹⁹⁵.

To assess whether the study data fit the assumptions of the multilevel model, the patterns generated in Q-Q plots, autocorrelation function (ACF) plots, and residual versus fitted plots were assessed according to the recommendations of Kutner et al. and Montgomery et al.^{195,196}.

4.5.4. Aim 3 – Moderated Mediation Analysis

To examine moderated mediation by age group and sex, the analyses described in 4.5.3. Aim 2 - *Mediation Analysis* above were repeated individually for each of six strata based on sex (female and male) and age group (45-54, 55-64, 65-74, 75+ years). Cuzick's forest plot test¹⁹⁷ was used to check for moderated mediation separately for each of the “a”, “b”, “ab”, “c-prime”, and “c” paths. This was done by visually assessing whether the unstratified $\hat{\beta}$ for the path in question fell within the 95% CIs for all the stratified $\hat{\beta}$ s. Moderated mediation by sex would be present if the unstratified $\hat{\beta}$ did not fall within the bounds of the 95% CIs for the male and female strata. Moderated mediation by age group would be present if the unstratified $\hat{\beta}$ did not fall within the bounds of the 95% CIs for any of the age group strata.

4.5.5. Sensitivity Analyses for Aim 2

For the analyses described in Sections 4.5.2 to 4.5.4, this thesis utilized complete case analysis. Complete case analysis assumes the missing data for participants who were removed from the analytical sample (refer back to Figure 1) are missing completely at random (MCAR), which may not actually be the case. Therefore, two sensitivity analyses for missing data (multiple imputation [MI] and missing covariate category analyses) were conducted for Aim 2 above. The sensitivity analyses concerned Aim 2 because the mediation analysis was the primary focus of the thesis.

A single level regression analysis using the complete case analysis data was also conducted for Aim 2 as a means of assessing the robustness of the multilevel, mixed effects model. Each sensitivity analysis is described in Sections 4.5.5.1 to 4.5.5.3 below.

4.5.5.1. Missing Data - Multiple Imputation versus Complete Case Analysis: Multilevel Model

MI is a method for handling missingness in data on one or more variables¹⁹⁸. MI is performed in three stages: the first stage is the imputation phase, where variables with missing values are imputed under the assumption of missing at random (MAR) using a full conditional specification (FCS) algorithm. MAR suggests the likelihood of missing information is correlated with observed data, but not with unobserved data. Practically speaking, MAR means that missing data on one variable depend on the values of another variable (e.g., males are less likely to report their income, so missing data on income depends on sex). FCS involves specifying an imputation algorithm for each variable with missing data. These missing values are seen as being influenced by other variables in the dataset, which are identified at this stage. During the imputation process, missing data on each variable are imputed by iterative sampling based on the distribution of the values of the variables identified above.

In the first stage, the imputation is conducted multiple times via the FCS algorithm, with each imputation forming a separate imputed dataset (m). The imputed dataset contains original observed values with the missing cells replaced with imputed values obtained from the FCS algorithm. The second stage of MI involves analyzing each imputed dataset using a method such as multilevel modelling. The third and final stage of MI requires combining the analytical estimates obtained from each imputed dataset into a single set of summary estimates using Rubin's rules¹⁹⁹ where applicable.

In this thesis, MI was applied to all variables included in the adjusted model using the FCS algorithm, following the procedure outlined by Golberg¹⁹⁸, to generate an initial set of $m = 40$ imputed datasets. Each imputed dataset was independently analyzed to estimate the “a” and “b” paths of the mediation model. From these, a subset of $m = 30$ datasets, in which both “a” and “b”

path models successfully converged, was selected for further mediation analysis with the mediation package in R software. These 30 datasets were individually processed using the mediation package (as described in Section 4.5.3.2) to estimate the indirect, direct, and total effects of the mediation pathway. The mediation results from the 30 imputed data were then pooled using Rubin's rules to produce the final estimates reported in this thesis. We recommend this approach over the approach of combining individual a- and b-paths (from 30 imputed data) and then using mediation package because the mediate function in R will not be able to find a singular/common dataset for the combined "a" and "b" paths and will hence result in an error.

4.5.5.2. Missing Data - Missing Covariate Category versus Complete Case Analysis: Multilevel Model

To further assess the impact of missing data in this thesis, a 'missing data' category was created for each covariate to increase the sample size and allow participants with missing data on any covariate to be included in adjusted models for multilevel modelling and mediation analyses (Aim 2). For example, the chronic condition variable originally had two categories, 'no chronic conditions' versus 'any chronic conditions: an additional category ("missing") was created, and the variable was subsequently analyzed as a three-level variable. Missing data categories were not created for memory, FSS, or depressive symptoms: participants with missing data on these variables were excluded from this sensitivity analysis to avoid altering the existing state (missing or non-missing) of the three main variables. Once the missing covariate categories were created, the analyses for Aim 2 were repeated using the larger sample.

4.5.5.3. Single-level Model versus Multilevel Model: Complete Case Analysis

A single-level regression modeling approach based on complete case analysis was conducted for Aim 2 (mediation analysis). Single-level models may include constructs measured

at multiple timepoints, though each instance of a construct at a specific timepoint is entered in the model as a separate variable, e.g., $\hat{\beta}_{MEMORY_{t_0}}$ for memory at t_0 and $\hat{\beta}_{MEMORY_{t_1}}$ for memory at t_1 . This type of model assumes the standard errors of the β 's are independent from one another and does not explicitly model within-person correlation over time. Single-level regression models are appropriate for analyzing longitudinal data with few follow-ups. The single-level models employed in this thesis included all covariates at t_0 .

For Aim 2, a-path was modified such that FSS at t_1 was regressed on memory and FSS at t_0 ; and b-path was modified such that depressive symptoms score at t_2 was regressed on memory, FSS, depressive symptoms at t_0 in addition to FSS and depressive symptoms at t_1 . This modified model, similar to the multilevel model, controlled for the following baseline variables: education, income, marital status, functional status, chronic conditions, smoking status, and alcohol use. In a second set of single-level models, the “b” path was modified and adjusted for depressive symptoms at t_1 alone instead of both t_0 and t_1 (as was done in the first set of models) to assess whether ignoring the t_0 timepoint would affect the model results. Variables in single-level regression models covering multiple timepoints should be entered at each timepoint, though this could occasionally introduce multicollinearity when several timepoints of data exist. Since depressive symptoms was the only variable with more than two timepoints of data, separate single-level models for the “b” path were generated using t_1 and t_0 values. Mediation analysis was then conducted on the models to obtain the direct effects, indirect effects, total effects, and proportions mediated. The results from both sets of single-level models were compared to the multilevel analysis.

4.6. Ethics

Access to the CLSA data was approved under data access application # 23CA007. The University of Waterloo's Office of Research Ethics approved the project (file # 45307) and all CLSA participants provided informed consent prior to enrollment.

5. RESULTS

5.1. Descriptive Analysis

Table 2 shows the baseline sample characteristics of the 5,958 participants included in the primary complete case analysis. These are the individuals who had complete data on all the variables of interest in this thesis. Participants aged 75 years or over comprised the smallest proportion of the sample, whereas those aged 55 to 64 years constituted the largest proportion. There were slightly more female participants than males at baseline. The proportions of participants from most provinces were comparable at baseline, though Nova Scotia had the highest proportion and Prince Edward Island had the smallest proportion. Almost three-quarters of participants had a post-secondary degree or diploma. The majority of participants (59%) had annual household income levels between \$50,000 to < \$150,000, 14% had incomes above \$150,000, while less than 4% of participants had incomes below \$20,000. With regard to marital status, 77% of participants were either married or living with a partner. Almost all the participants (93%) had no impairment in functional status and just 0.1% (seven participants) had severe or total impairment. Similarly, only 10% of participants had at least one chronic condition. Most participants (88%) had not smoked in the past 30 and most reported being regular alcohol users (78%).

Table 2. Sample Characteristics at Baseline (n = 5,958)

Variable	Frequencies n (%)	Memory* Mean (SD)	Memory* Median (IQR)	Functional Social Support Median (IQR)	Depressive symptoms Median (IQR)
Sociodemographic					
<i>Age Group at Baseline</i>					
45-54 years	1,958 (33)	-1.0 (1.8)	-0.3 (2.2)	88.2 (23.7)	4 (6)
55-64 years	2,209 (37)	0.1 (1.9)	-0.1 (2.2)	88.2 (23.7)	4 (6)
65-74 years	1,216 (20)	0.2 (1.9)	-0.1 (2.3)	89.5 (23.7)	4 (5)

75+ years	575 (9.7)	-0.0 (1.8)	-0.3 (2.1)	88.2 (26.3)	4 (6)
<i>Sex</i>					
Male	2,911 (49)	0.1 (1.9)	-0.2 (2.2)	89.5 (25.0)	4 (5)
Female	3,047 (51)	-0.0 (1.8)	-0.2 (2.3)	88.2 (23.7)	4 (6)
<i>Province</i>					
Alberta	583 (9.8)	0.1 (1.8)	-0.2 (2.2)	86.8 (25)	4 (6)
Ontario	708 (12)	0.4 (1.9)	0.1 (2.4)	89.5 (23.7)	4 (6)
British Columbia	390 (6.5)	0.1 (1.9)	-0.2 (2.3)	87.5 (23.7)	4 (5)
Manitoba	368 (6.2)	0.0 (1.9)	-0.2 (2.3)	90.8 (23.7)	4 (6)
New Brunswick	329 (5.5)	-0.2 (1.9)	-0.5 (2.3)	89.5 (23.7)	4 (6)
Newfoundland and Labrador	471 (7.9)	-0.0 (1.9)	-0.2 (2.3)	89.5 (23.7)	4 (7)
Nova Scotia	1,311 (22)	-0.0 (1.8)	-0.2 (2.2)	89.5 (23.7)	4 (6)
Prince Edward Island	298 (5.0)	-0.1 (1.8)	-0.2 (2.1)	89.5 (23.7)	4 (5)
Québec	1,153 (19)	0.1 (1.9)	-0.2 (2.2)	88.2 (25)	4 (6)
Saskatchewan	347 (5.8)	-0.1 (1.8)	-0.3 (2.3)	86.8 (25)	4 (5)
<i>Education</i>					
Less than secondary (Ref)	359 (6.0)	0.3 (1.8)	-0.1 (2.2)	86.8 (26.3)	5 (7)
Completed secondary	797 (13)	0.1 (1.8)	-0.1 (2.2)	88.2 (25)	5 (6)
Some post-secondary	454 (7.6)	-0.1 (1.8)	-0.3 (2.3)	89.5 (25)	4 (5)
Post-secondary degree or diploma	4,348 (73)	0.0 (1.9)	-0.2 (2.3)	88.2 (22.4)	4 (5)
<i>Income</i>					
Below \$20,000	215 (3.6)	-0.4 (1.8)	-0.7 (2.3)	76.3 (35.5)	7 (9)
\$20,000 to <\$50,000	1,434 (24)	-0.0 (1.8)	-0.2 (2.2)	84.2 (26.3)	5 (6)
\$50,000 to <\$100,000	2,305 (39)	0.1 (1.8)	-0.1 (2.3)	89.5 (23.7)	4 (5)
\$100,000 to <\$150,000	1,180 (20)	0.1 (1.8)	-0.2 (2.2)	90.8 (22.4)	4 (5)
>\$150,000	824 (14)	0.2 (1.9)	-0.2 (2.3)	92.1 (19.7)	4 (4)
<i>Marital Status</i>					
Single/never married/never lived with a partner	371 (6.2)	-0.1 (1.8)	-0.3 (2.3)	77.6 (31.6)	5 (7)
Married/living with a partner	4,594 (77)	0.1 (1.8)	-0.2 (2.2)	90.8 (21.1)	4 (5)
Widowed	357 (6.0)	-0.0 (2.0)	-0.3 (2.4)	78.9 (29.0)	5 (6)
Divorced	499 (8.4)	-0.1 (1.9)	-0.1 (2.1)	77.6 (30.9)	5 (7)
Separated	137 (2.3)	-0.2 (1.8)	-0.3 (2.2)	77.6 (30.3)	4 (7)
Health Status					
<i>Functional Status</i>					
No impairment	5,542 (93)	0.1 (1.8)	-0.2 (2.3)	89.5 (22.4)	4 (5)
Mild impairment	377 (6.3)	-0.1 (1.9)	-0.4 (2.1)	84.2 (29.0)	6 (8)
Moderate impairment	32 (0.5)	-0.9 (1.5)	-0.8 (1.9)	83.6 (34.2)	10 (8.5)
Severe impairment	3 (0.1)	1.2 (1.8)	2.5 (3.0)	82.89 (22.0)	13 (8.5)

Total impairment	4 (0.1)	-0.6 (1.4)	-1.2 (2.6)	71.7 (23.7)	15 (11)
<i>Chronic conditions</i>					
No chronic conditions	5,338 (90)	0.0 (1.9)	-0.2 (2.3)	88.2 (23.4)	4 (6)
≥1 chronic condition(s)	620 (10)	0.2 (1.8)	-0.1 (2.3)	90.8 (22.4)	3 (4)
Lifestyle Behaviours					
<i>Smoking</i>					
Daily	553 (9.3)	-0.1 (1.9)	-0.4 (2.5)	84.2 (29)	4 (8)
Occasionally	153 (2.6)	0.2 (2.0)	-0.1 (2.5)	84.2 (25)	5 (6)
Not at all	5,252 (88)	0.2 (1.8)	-0.2 (2.2)	89.5 (23.7)	4 (5)
<i>Alcohol use</i>					
Regularly	4,643 (78)	0.1 (1.8)	-0.2 (2.3)	89.5 (22.4)	4 (5)
Occasionally	747 (13)	-0.1 (1.8)	-0.3 (2.2)	86.8 (25)	5 (7)
Not at all	568 (9.5)	-0.0 (1.9)	-0.3 (2.2)	84.2 (22.4)	4 (7)

Notes: $p < 0.05$ in bolded font (Kruskal-Wallis test); SD =standard deviation; IQR=interquartile range;

Ref=reference category; t_0 =baseline; *combined z-scores from RAVLT1 and RAVLT2

5.1.1. Memory

Memory scores at all three timepoints were roughly normally distributed with some right skewness (Figures 5a-c). Descriptive statistics for memory scores at t_0 , t_1 , and t_2 are reported in Table 3.

Table 3. Continuous Memory Scores at Baseline and Follow-up (n=5,958)

Memory scores*	Mean (SD)	Median(IQR)	Minimum	Maximum
Baseline	0.05 (1.85)	-0.17 (10.54)	-5.12	9.34
First Follow-up	0.31 (1.82)	0.15 (2.37)	-4.93	10.00
Second Follow-up	0.05 (1.90)	-0.03 (2.5)	-4.55	7.25

Notes: p values across all timepoints < 0.5 (Wilcoxon signed rank test); SD = Standard deviation; IQR =Interquartile range; *combined z-scores from RAVLT1 and RAVLT2

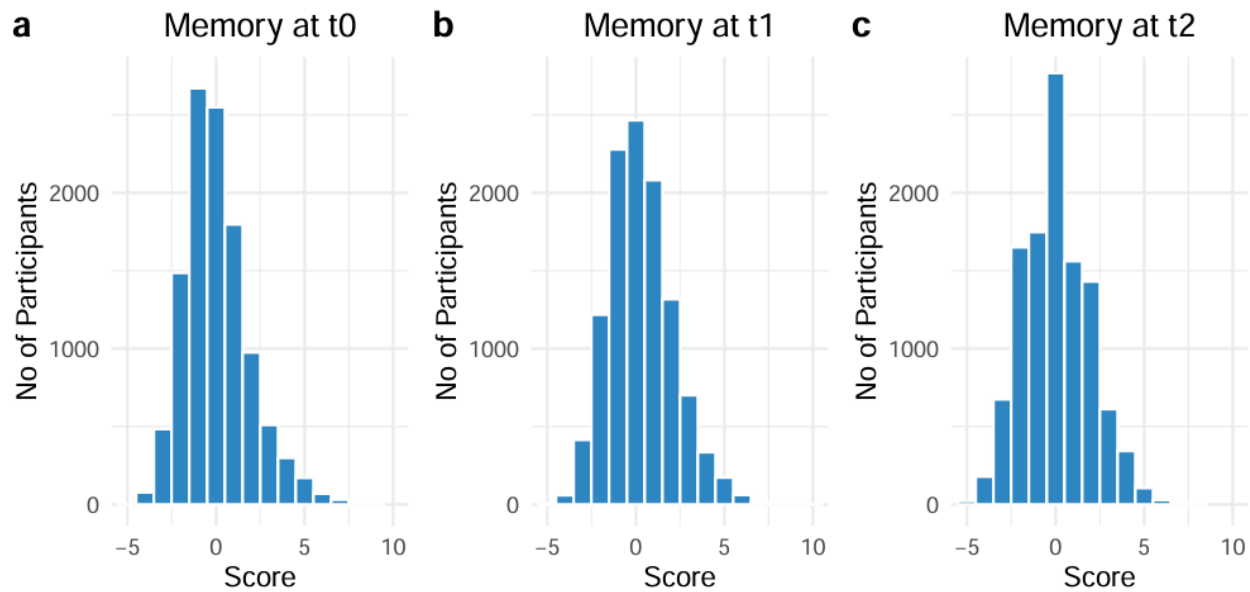


Figure 5 (a-c). Distribution of Memory Scores at Three Timepoints

Note: t_0 = baseline; t_1 = first follow-up; t_2 = second follow-up

Table 2 above shows baseline memory, FSS, and depressive symptom scores stratified by the covariates. Median memory scores were fairly stable across the age groups. Across males and females, memory scores had the same median values. Median memory scores across provinces were also comparable; participants residing in Ontario had the highest median memory score and those in New Brunswick the lowest. Participants in the lowest income category (earning below \$20,000) had the lowest median memory scores. Excluding seven participants with severe or total impairment, participants with no impairment in functional status had the highest median memory scores, while those with moderate impairment had the lowest median memory scores. Individuals with more than one chronic condition had slightly higher median memory scores compared to those without chronic conditions. Participants who consumed alcohol regularly had slightly higher memory scores compared to those who occasionally consumed or did not consume alcohol.

5.1.2. Functional Social Support

The distribution of FSS scores at t_0 , t_1 , and t_2 were left skewed (Figure 6a-c). FSS scores ranged from 0 to 100 with most participants (at least 80%) scoring above 70 at all time points. The median scores for overall FSS at t_0 , t_1 , and t_2 were 88.16 (IQR: 22.67), 89.47 (IQR: 23.68), and 90.79 (IQR: 23.68), respectively.

Individuals aged between 65 and 74 years had the highest median FSS scores among the age group categories (Table 2). Males had higher median FSS scores compared to females. Across provinces, median FSS scores ranged from 86.8 to 90.8 out of 100. FSS scores were observed to increase with income, as participants earning below \$20,000 had the lowest median score, while those earning above \$150,000 had the highest score. Participants who were married or living with a partner had the highest median FSS scores compared to other categories. In terms of health status, those without functional impairment had the highest median FSS scores; FSS scores decreased as levels of impairment increased. Individuals with more than one chronic condition had slightly higher median FSS scores compared to those with no chronic conditions. Among lifestyle behaviours, non-smokers had the highest median FSS scores compared to daily and occasional smokers; regular alcohol consumers reported the highest median scores compared to non- or occasional drinkers. Overall, FSS was generally higher among individuals with higher socioeconomic status, better health, and more stable marital relationships. FSS did not differ across education levels.

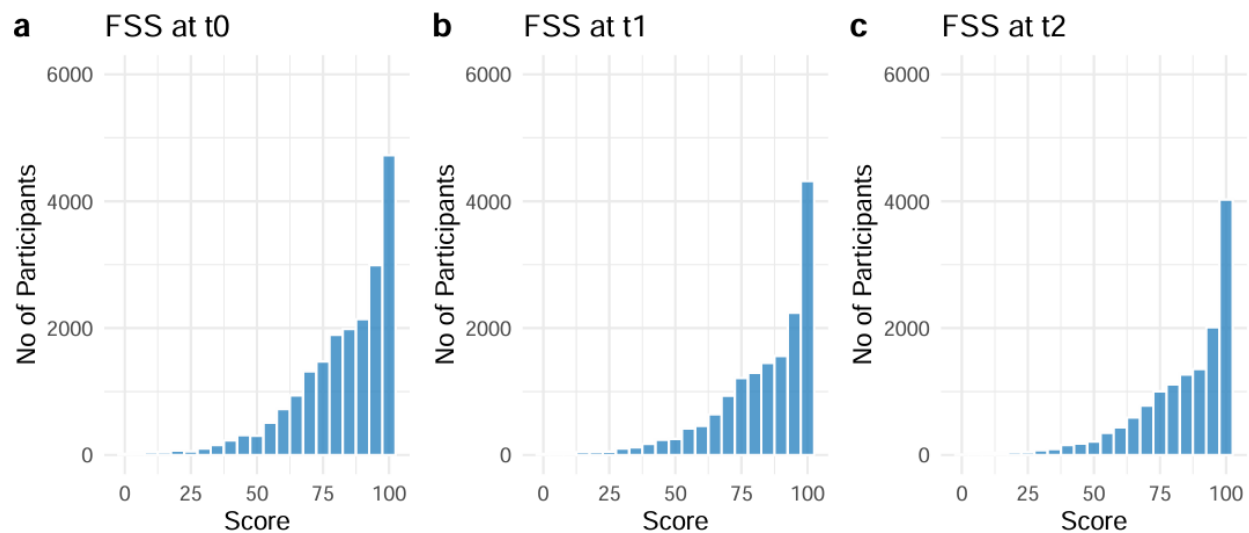


Figure 6 (a-c). Distribution of Functional Social Support Scores at Three Timepoint

Note: FSS = Functional social support; t_0 = baseline; t_1 = first follow-up; t_2 = second follow-up

5.1.3. Depressive Symptoms

The distribution of depressive symptom scores was right skewed and spanned the full CESD-10 score range of 0 to 30 at each time point (Figure 7a-c). More than half of the participants scored below 10 at each time point. The median scores for depressive symptoms were similar across the three time points and were 4 (IQR: 5), 4(IQR: 5), and 3 (IQR: 5) respectively.

The median baseline depressive symptom scores shown in Table 2 differed by 1-5 points across categories for the following variables (education, income, marital status, functional status, chronic conditions, smoking, and alcohol use). However, median depressive symptom scores were highest for the lowest and second lowest income categories and the same for the other three categories. Depressive symptom scores increased with functional impairment. Those with no impairment had a median score of 4, while participants with severe or total impairment had markedly higher median scores (13 and 15, respectively). Baseline median depressive symptom scores were not significant across age group, sex, and province.

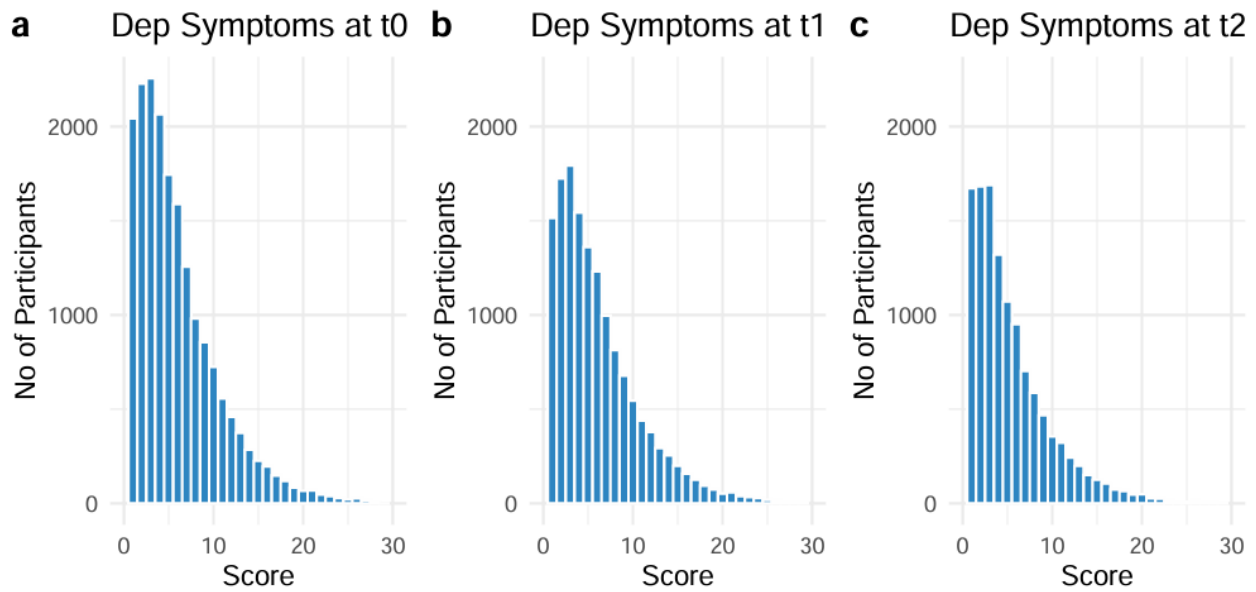


Figure 7 (a-c). Distribution of Depressive Symptoms Scores at Three Timepoints

Note: Dep = Depressive symptoms; t_0 = baseline; t_1 = first follow-up; t_2 = second follow-up

5.2. Comparison of Excluded versus Included Participants Over Follow-up

On average, participants who were excluded from the complete case analysis, compared to those who were included, had lower median scores on memory, but similar median scores on the “a” path and “b” path outcome variables (FSS and depressive symptoms, respectively) (Table 4). Although the differences in median FSS and depressive symptoms between excluded and included participants were statistically significant ($p < 0.001$; Mann-Whitney U test), the small p-values likely occurred due to the large sample size rather than clinically important differences.

Table 4. Median Baseline Scores: Persons Excluded Versus Included in the Complete Case Analysis

Variable	Excluded Median (IQR) (n = 15,283)	Included Median (IQR) (n = 5,958)
Memory*	-0.11 (2.09)	-0.03 (2.4)
Functional Social Support	86.8 (23.7)	85.5 (27)
Depressive Symptoms	4 (5)	5 (7)

*Note: $p < 0.001$ in bolded font (Mann-Whitney U test); *combined z-scores from RAVLT1 and RAVLT2*

5.3. Aim 1: Association Between Memory and Depressive Symptoms Over Time

The associations described in the next three sections (Sections 5.3, 5.4, and 5.5) are based on the complete case analysis. In the base model for Aim 1 (which involved regressing depressive symptoms scores onto memory scores while adjusting for age group, sex, and province) found an inverse association between depressive symptoms and memory but it was not statistically significant ($\hat{\beta} = -0.10$; 95% CI: -0.14, 0.07). After adjusting for all the baseline sociodemographic, health, and lifestyle covariates, the direction of the $\hat{\beta}$ for the effect of memory on depressive symptoms was maintained but the size changed marginally ($\hat{\beta} = -0.08$; 95% CI: -0.11, -0.04) and became statistically significant. The degree of change between the $\hat{\beta}$ for memory in the base model when compared to the adjusted model differed by more than $\pm 10\%$ ($\frac{(-0.08 - (-0.10))}{-0.10} = -0.2$ or -20%), thereby indicating possible confounding²¹¹. Therefore, the adjusted model was used to conduct the mediation and moderated mediation analyses (Aims 2 and 3). The full regression outputs for the base and adjusted models are shown in Appendix F– Table F-1.

5.4. Aim 2: Mediation Analysis

The mediation results for all five pathways were statistically significant (Figure 8). On the “a” path, memory was positively associated with FSS after adjusting for all baseline covariates. On the “b” path, FSS was inversely associated with depressive symptoms after adjusting for all baseline covariates. Since the $\hat{\beta}$ estimates from the “a” and “b” paths were both statistically significant, Yzerbyt et al.’s joint significance test provides evidence that FSS mediates the effect of memory on depressive symptoms¹⁹³. The indirect effect of memory on depressive symptoms – mediated by FSS – was smaller (“ab” path: $\hat{\beta} = -0.02$; 95% CI: -0.02, -0.01) than the direct effect

of memory on depressive symptoms (“c-prime” path: $\hat{\beta} = -0.07$; 95% CI: -0.10, -0.04). The total effect of memory on depressive symptoms was inverse (“c” path: $\hat{\beta} = -0.08$; 95% CI: -0.12, -0.05). Since mediation by FSS accounts for a small proportion of the overall association between memory and depressive symptoms (proportion mediated = 0.25; 95% CI: 0.10, 0.31), these results reflect partial mediation. Full regression output and mediation results from the Mediation Package in “R” can be found in Appendix F (Table F-2 and Table F-3).

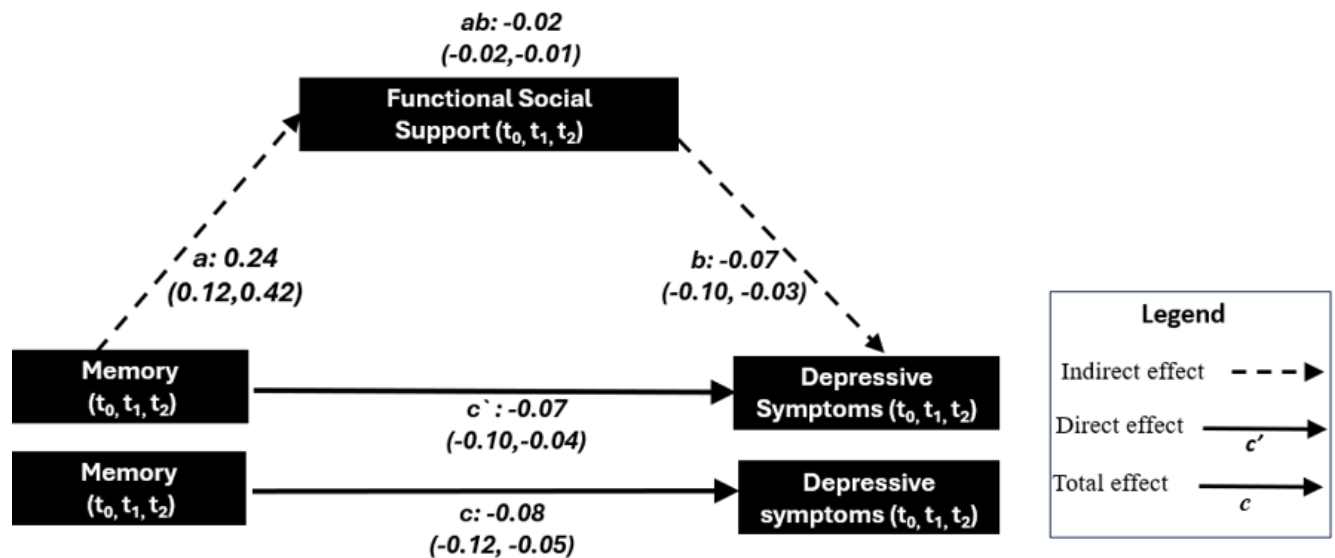


Figure 8. Mediation Model: Memory, Functional Social Support, and Depressive Symptoms

Notes; Adjusted for functional social support, memory, baseline sociodemographic factors, health status, and lifestyle behaviours. t_0 = Baseline; t_1 = First follow-up; t_2 = Second follow-up.

5.5. Aim 3: Moderated Mediation Analysis

Graphical illustrations of moderated mediation are shown in Figures 9 (a-e) and Figures 10 (a-e). There was no evidence of moderated mediation by age group and sex on any of the paths as per Cuzick’s test, since the 95% CI estimates in Figures 9 and 10 included the unstratified $\hat{\beta}$ s from Figure 8.

Appendix G presents tabular versions of the data shown in Figures 9 (a-e) and 10 (a-e). Tables G-1 and G-2 show the “a” and “b” path models stratified by sex and age group, respectively; Tables G-3 and G-4 depict the “ab”, “c-prime”, and “c” paths stratified by sex and age group, respectively.

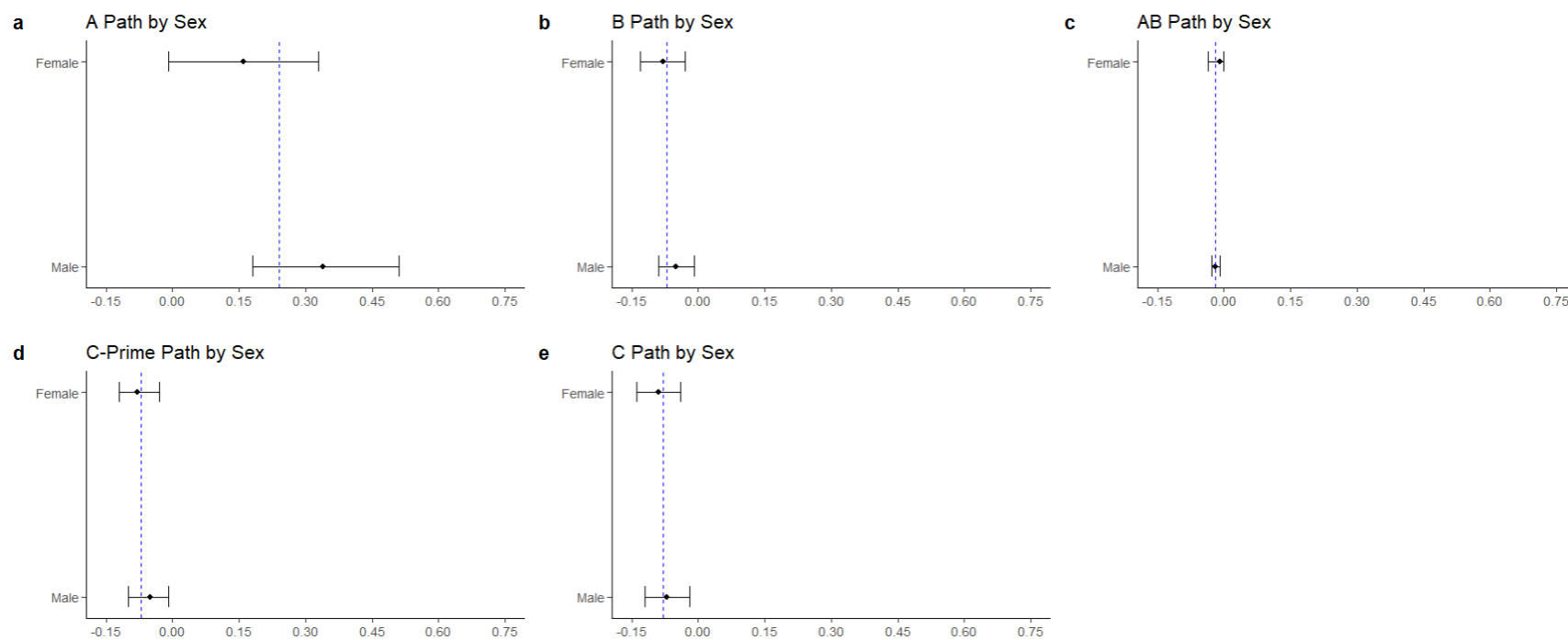


Figure 9 (a-e). Forest Plots: Moderated Mediation Analysis by Sex

Notes: Adjusted for functional social support, memory, baseline sociodemographic factors, health status, and lifestyle behaviours; vertical line represents the unstratified regression coefficient.

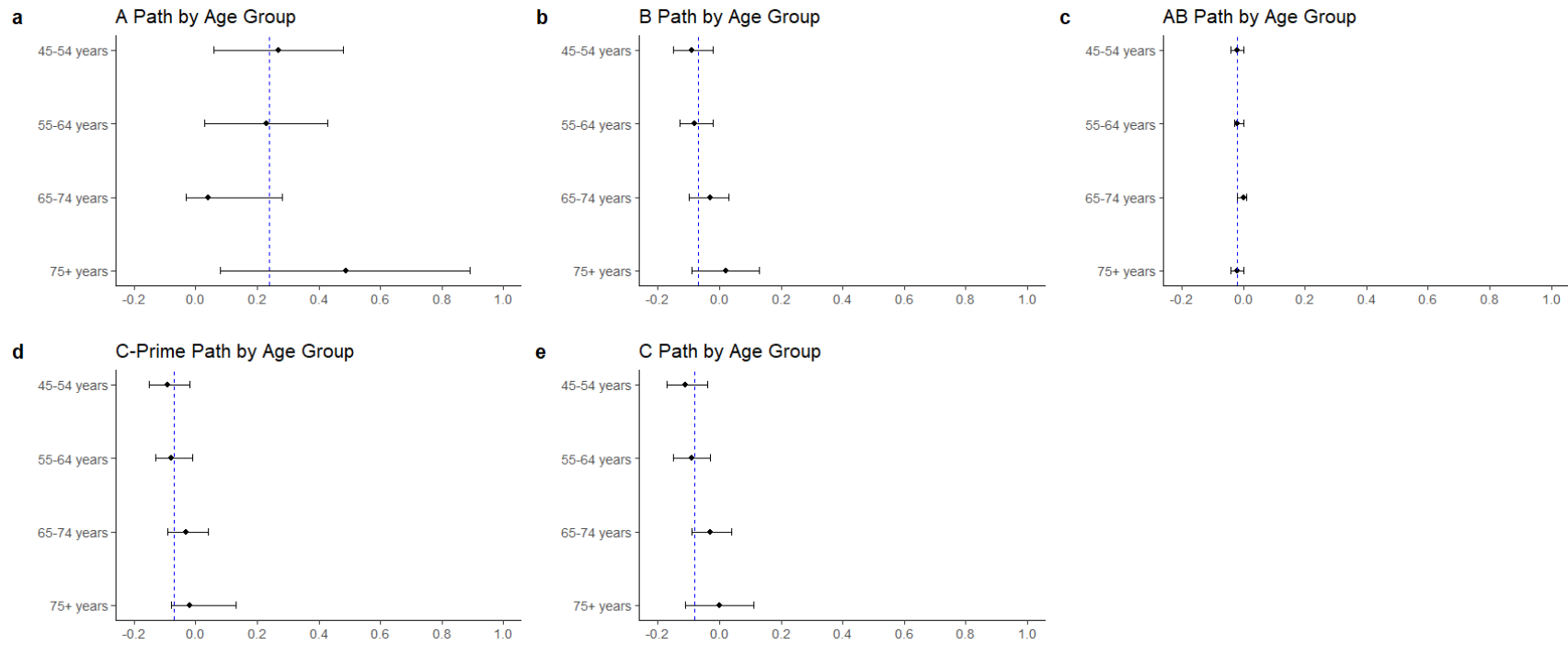


Figure 10 (a-e). Forest Plots: Moderated Mediation Analysis by Age Group

Notes: Adjusted for functional social support, memory, baseline sociodemographic factors, health status, and lifestyle behaviours; vertical line represents the unstratified regression coefficient

5.6. Sensitivity Analyses

As described in 4.5.5, above, the sensitivity analyses conducted for this thesis involved: (1) Multiple imputation analysis to assess the robustness of the results obtained using complete case analysis data; (2) missing category analysis to also assess the robustness of the results obtained using complete case analysis data; and (3) single level analysis using the complete case analysis sample to compare against the multilevel analysis. Table 5 shows the mediation paths that were obtained in each sensitivity analysis. The results of these analyses are discussed in Sections 5.6.1 to 5.6.3 below.

Table 5. Sensitivity Analyses Models

Analysis Approach	a-path	b-path	Indirect effect	Direct effect	Total effect	Comment
Multiple imputation	×	×	✓	✓	✓	Compared to the multilevel complete case analysis
Missing covariate category	✓	✓	✓	✓	✓	Compared to the multilevel complete case analysis
Single-level model	✓	✓	✓	✓	✓	Compared to the multilevel complete case analysis

Note: × = not computed, ✓ = computed

5.6.1. Missing Data - Multiple Imputation versus Complete Case Analysis: Multilevel Model

Following multiple imputation, the sample size of the imputed data increased from 5,958 (of complete case analysis) to 10,441 (75% increase). Compared to the multilevel analysis using complete cases only, the multiple imputation results were similar in magnitude and direction of effect for the "ab", "c-prime", and "c" paths. As can be expected when sample sizes increase, the 95% confidence intervals were narrower for all pathways on the adjusted imputed models, relative to the adjusted models obtained from the complete case analysis sample. Figure 11 is a graphical comparison of the indirect, direct, and total effects of complete case analysis and multiple

imputation. Appendix H – Table H-1 shows the mediation results obtained through multiple imputation.

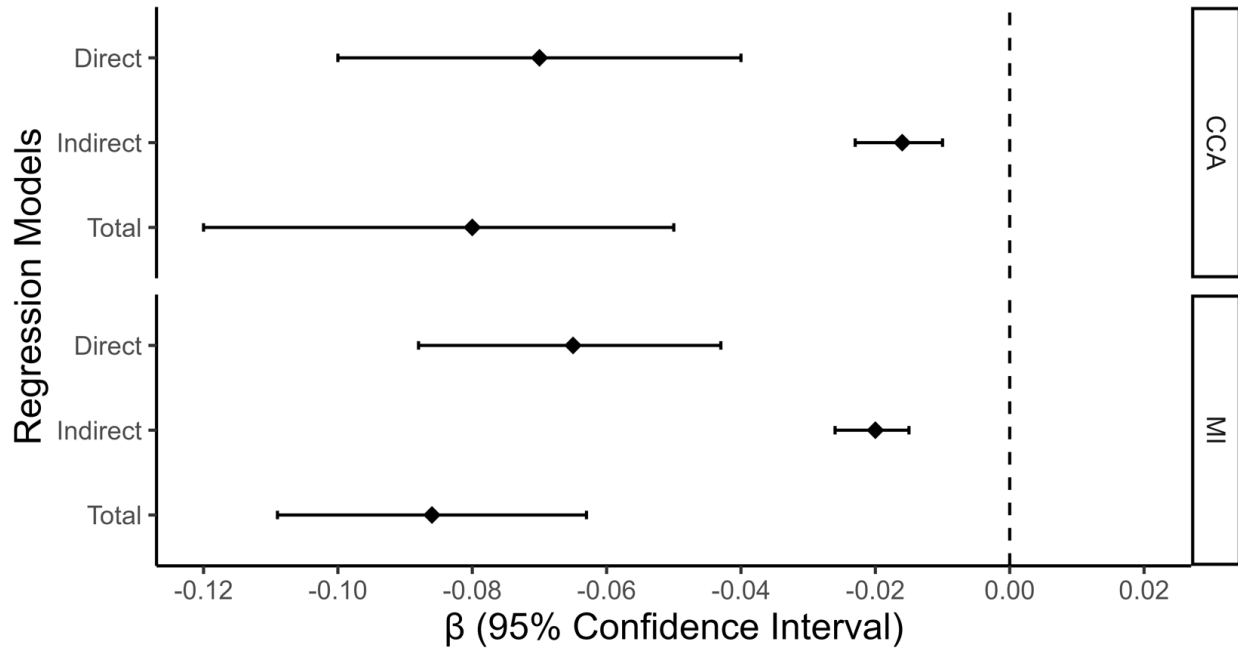


Figure 11. Forest Plot Comparison of Complete Case Analysis (CCA) and Multiple Imputation (MI) Results

5.6.2. Missing Data - Missing Covariate Category versus Complete Case Analysis: Multilevel Model

For this analysis, a ‘missing data’ category was created for each covariate to allow participants with missing data on any covariate to be included in the multilevel modelling and mediation analysis. This was done for the adjusted model and resulted in a sample size increase from 5,958 for complete case analysis to 9,274 (56% increase). The results obtained from this analysis were similar in direction and magnitude to the complete case analysis; however, some of the regression coefficients had slightly narrower CIs. All five paths of the mediation analysis were also statistically significant, like what was found in the complete case analysis. Figure 12 compares

the results of complete case analysis with the missing covariate category analysis. The full regression output for the “a” and “b” paths and the mediation results for the missing covariate category analysis can be found in Appendix I (Table I-1 and Table I-2, respectively).

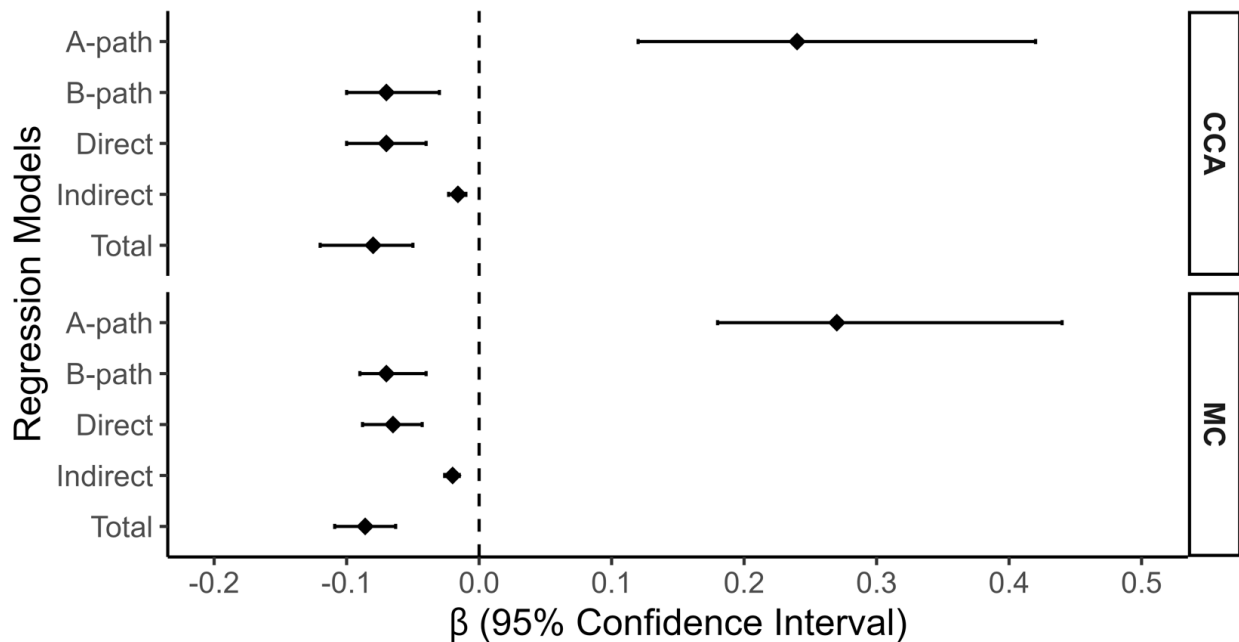


Figure 12. Forest Plot Comparison of Complete Case Analysis (CCA) and Missing Covariate Analysis (MC) Results

5.6.3. Single-level Models versus Multilevel Model: Complete Case Analysis

This sensitivity analysis used the complete case analysis sample of 5,958 participants. The full regression outputs for the “a” and “b” paths, and mediation analysis for these adjusted models are shown in Appendix J (Tables J-1 and J-2, respectively). The base models were adjusted for age, sex, and province, while the adjusted model controlled for all covariates.

Findings for the “a” path did not show any significant associations between FSS and memory, in contrast with the multilevel model which showed significant positive associations between memory and FSS; however, the directions of association were consistent with the results

of the multilevel model. On the “b” path, similar to the multilevel model, the models showed inverse associations between memory and depressive symptoms, though the β s were smaller than the multilevel model and statistically significant only in the model that adjusted for depressive symptoms at first follow-up.

Regarding the mediation analysis, there was no evidence of any statistically significant indirect effect of FSS in the association between memory and depressive symptoms, unlike what was found in the multilevel model, even though the direction of effect remained the same as the multilevel model. The direct effects showed inverse associations between memory and depressive symptoms, like the multilevel model; however, only the model adjusting for depressive symptoms at t_1 was statistically significant. The regression coefficients were also smaller than those of the multilevel model. The total effects observed similarly showed inverse associations between memory and depressive symptoms, like the multilevel model, but only the model that adjusted for depressive symptoms at t_1 was significant. There was no proportion mediated identified in the single level models because there was no mediation effect of FSS on the association between memory and depressive symptoms. The proportion mediated in the multilevel model was 25%. Overall, the results of these additional analyses were similar to the multilevel model in direction, although they had varying magnitude which is to be expected because of the different sample sizes used for the complete case compared to the multiple imputation and missing covariate category analyses. Also, some of the variables in the single-level models were not statistically significant when compared to the multilevel model. This is expected because the random effects in a multilevel model will change the standard errors of the $\hat{\beta}$'s for the fixed effects. Also, the single-level models adjusted for depressive symptoms at earlier timepoints, whereas the multilevel model only included depressive symptoms as an outcome.

5.6.4. Model Diagnostics

Model diagnostics were checked for the adjusted, complete case analysis, multilevel models on the “a” and “b” paths of the mediation triangle. The assumptions of linear regression were not violated in these models. Q-Q plots in Appendix K (Figures K1 and K2) show points following the diagonal line closely, supporting the normality of residuals. Residuals were evenly distributed across time points, and the autocorrelation function (ACF) plots in Appendix K (Figures K3 and K4) suggest no significant autocorrelation in the examined models. Further, outliers were not problematic. The residuals versus fitted plots in Appendix K (Figures K5 and K6) appear randomly spread across fitted values. This suggests the absence of heteroscedasticity and verifies the assumption of constant variance.

6. Discussion

6.1. Summary of Study Findings

This thesis examined the mediating role of FSS in the association between memory and depressive symptoms. The thesis candidate could not find any other study that examined this specific mediation pathway.

Aim1: Is memory associated with depression symptoms across three timepoints of the Tracking Cohort of the Canadian Longitudinal Study on Aging while adjusting for relevant covariates, i.e., sociodemographic factors, health status, and lifestyle behaviors?

In the regression analysis, we found evidence that memory function was significantly and inversely associated with depressive symptoms. On average, CESD-10 scores were lower in persons with higher memory scores compared to persons with lower memory scores. This finding aligns with previous literature^{129–131}.

Aim 2: Does FSS mediate the association between memory and depressive symptoms?

The results showed evidence that FSS had an indirect (mediating) effect in the relationship between memory and depressive symptoms. However, the direct and total effects were quite similar, indicating that the mediation effect was small.

Aim3: Is there moderated mediation by sex or age group

The findings showed no evidence of moderated mediation by either sex or age group on any of the paths of the mediation model.

6.2. Sample Characteristics

The associations that were observed between the covariates and the three main variables (memory, FSS, depressive symptoms) in the analytical sample mostly showed expected results.

For example, participants with greater annual household income levels reported on average, better memory scores, higher FSS, and fewer depressive symptoms than those with lower income levels, in a dose-response fashion. Additionally, as expected, the oldest age group (75 years or over) had the lowest memory scores and persons who were married or living with a partner reported considerably higher FSS, as well as fewer depressive symptoms, compared to other marital status groups. Participants with functional impairments at baseline also reported on average, more depressive symptoms, lower FSS, and lower memory scores. These results are consistent with previous literature^{81,200}. One exception was education which was not significantly associated with memory. This may have occurred because the analytical sample was overwhelmingly composed of persons with a post-secondary degree (73%) who were cognitively healthy at baseline and less likely to drop out of the study compared to persons with lower cognitive scores.

6.3. The Indirect Effect

The statistically significant, though small, indirect effect of FSS reflects a psychosocial pathway underlying the association between cognitive function and depressive symptoms. Memory deficits can negatively impact people's ability or willingness to interact socially and sustain satisfying interpersonal relationships, weakening these relationships and reducing their perceived FSS. This, in turn, can lead to higher levels of depressive symptoms over time because the stress release effects of FSS diminish^{201,202}. However, the opposite is also true. Better memory is associated with higher FSS, as seen by the positive association on the “a” path in Figure 8. Similarly, higher FSS is protective against depressive symptoms, as evidenced by the negative association on the “b” path in Figure 8. The total effect is slightly larger (more inverse) than the direct effect in Figure 8 because the increases in FSS that happen when memory scores increase, combined with the protective effect of FSS on depression symptoms, add to the inverse association

observed in the direct effect of memory on depression symptoms. When the mediation effect of FSS is taken into account, higher memory scores become more protective against depression symptoms.

These findings add to existing literature on the role of psychosocial factors in influencing mental health trajectories in middle-aged and older adults. Although previous studies have established a robust relationship between memory and depressive symptoms^{21,23–25}, the mediating role of FSS in this relationship has been understudied until now. This study has therefore laid a foundation for further studies to understand this nuanced relationship even better. The findings are consistent with previous works suggesting that the perception of having available supportive social relationships may lessen the impact of life stressors, such as cognitive impairment, on emotional well-being^{145,146,150}. In line with the Theory of Selective Optimization and Compensation, high levels of FSS lead to improved perceptions of self-worth by allowing individuals to selectively focus on meaningful social relationships and optimize emotional support, even if they experience cognitive challenges. These social relationships affirm people's values and reinforce a sense of purpose, which minimizes the susceptibility to depressive symptoms¹⁴².

The findings on the “a” path showed a positive association between memory and FSS, which is consistent with existing literature^{138,139,141}. Better memory enables people to create and sustain social networks that address their unfulfilled social support needs. The finding of this thesis on the “b” path, which examined the FSS-depression pathway, also aligned with published research that treated FSS as an independent variable^{23,26}. Notably, studies from the literature review found FSS to be protective against depressive symptoms^{26,28,44,155,162}. For example, Song et al.'s study¹⁶¹ of 154 community-dwelling adults, aged 60 years or over, with mild cognitive impairment noted that positive social interaction was strongly associated with fewer depressive symptoms. This

finding, in conjunction with the thesis results, suggests that FSS may be an important component of the complex links between memory and depressive symptoms.

Interventions to strengthen FSS, especially programs and initiatives that promote community-based and locally tailored social support, may be especially beneficial in managing the sequelae of memory dysfunction in aging adults. Examples of such programs include the “Friendship Circle” in Montréal²⁰³, which has programs designed to bring care partners and persons living with cognitive impairments together informally to enjoy activities (such as art, music, yoga, and dance) within the community; Memory Cafés in Nova Scotia²⁰⁴, where inclusive spaces (virtual and in-person) are made available for individuals experiencing memory decline and their care partners to socialize and connect with other persons in the community; Ontario’s Aging with Confidence and Seniors Active Living Centres²⁰⁵, plus the New Horizons for Seniors Program²⁰⁶, are government initiatives that fund programs such as community hubs, book clubs, and multicultural social groups that engage seniors in the community and support their social participation and inclusion. Programs such as these may form the targets of social prescribing, where health professionals connect clients to social activities, groups, and resources in an effort to improve health and well-being^{207–209}.

6.4. The Direct Effect

The literature contains generally consistent findings about the association between memory and depressive symptoms. Most papers in the literature review^{26,28,44,113,156,158,159} identified significant inverse associations between memory and depressive symptoms, which aligns with the results of this thesis. Four studies^{44,157,160,164} did not identify any statistically significant relations, but these studies measured overall cognitive function rather than memory specifically.

Some pathophysiological mechanisms explain the association between memory and depressive symptoms. In memory impaired-individuals, stressful experiences often fail to trigger protective reactions in the brain, which are required to successfully cushion the effects of these experiences and protect against stress-induced depressive symptoms^{129,131}. Further, the vulnerability-stress theory suggests that cognitive impairment, particularly in memory, can lead individuals to exaggerate the unfavorable consequences of stressful experiences over the life course, thereby aggravating stress responses and increasing susceptibility to depression in midlife and older adulthood¹²⁷. Finally, memory decline can directly hinder an individual's self-sufficiency and daily functioning, which may trigger negative feelings such as worthlessness and induce or exacerbate depressive symptoms²⁰¹.

6.5. The Total Effect

The total effect observed in this thesis was statistically significant. If the regression model is properly specified (i.e., the model is valid) and other challenges such as selection or information bias are kept to a minimum, ignoring mediators when mediation is present will improperly estimate the "true" (total) effect and researchers will only be aware of the direct effect, which excludes the additional contribution of mediation by FSS. Mediation by FSS in this thesis has shown that the protective effect of memory on depressive symptoms likely exceeds what has been estimated in existing literature.

The total effect in this thesis reinforces the importance of targeted FSS interventions to minimize depressive symptoms. Since the total effect was observed over six years in a community-dwelling and cognitively healthy sample of middle-aged and older adults, future research in other settings (e.g., clinical samples of older adults) and over longer follow-up periods is needed to assess the robustness of the findings.

6.6. Moderated Mediation

Although age^{66,85} and sex^{82,86} have been found to affect all three main variables in the thesis, their roles as effect modifiers in the mediation analysis remain unclear from previous research^{57,210,211}. Some studies reported effect modification by age group, sex, or both^{66,67} in associations between memory and depressive symptoms. However, these results do not extend to mediation by FSS.

Outside of the mediation analysis, the direct (“c-prime”) model in Aim 2 is equivalent to the adjusted model in Aim 1: depressive symptoms score is the outcome in these models, and memory, FSS, and the covariates are independent variables. Unlike this thesis, the studies reporting effect modification excluded individuals between 45 and 50 years^{66,67}, were conducted outside Canada^{66,67}, were cross-sectional⁶⁷, and involved geographically restricted sample frames⁶⁶. These differences in study-level factors may account for the divergent findings about effect modification. Another issue is the small regression coefficients in the thesis. Given these small effect sizes, the thesis may have been underpowered to identify stratum-specific differences in subgroup analyses. Overall, no evidence existed to support effect modification by age group or sex, though these results are not definitive.

6.7. Strengths

The use of CLSA data provided an opportunity for a robust investigation of Aims 1 to 3. First, having access to three timepoints of data that spanned across six years allowed for a robust investigation of the research questions and for the making of temporality inferences. The literature suggests that three timepoints of data between the study timepoints is optimal for mediation analysis because it allows a reasonable time to lapse between each exposure and effect²¹². Second, the availability of many relevant covariates helped address residual confounding compared to

previous studies^{113,158–160}. Third, earlier research predominantly focused on older adults, limiting the generalizability of findings across the adult life course. In contrast, this study incorporated middle-aged and older adults in the analysis, thereby allowing for a more complete picture of the relation between memory and depressive symptoms in aging adults.

Fourth, the study utilized the CLSA's Tracking Cohort, which included community-dwelling adults from all 10 provinces, such that the results of this thesis are applicable to a wider population of middle-aged and older adults with a healthy aging trajectory, unlike previous studies that featured limited sample frames such as hospitals, single cities or single counties^{113,158–160}.

Fifth, the results of the associations between the covariates and memory, and the covariates and depressive symptoms, yielded results that were in line with expectations from the underlying theoretical framework, thereby supporting the validity of the analytical approach and results. Also, various types of sensitivity analysis (multiple imputation and missing covariate category) were conducted to examine the validity of results and assess different means of handling missing data. The results of these sensitivity analyses were similar in magnitude and direction compared to the primary complete case analysis, which further validated our analytical approach and results.

Finally, and most notably, while some studies examined the effects of memory or FSS on depressive symptoms, none to the knowledge of the thesis candidate examined the mediation effects of FSS on the association between memory and depressive symptoms. As such, this thesis adds novel information to the literature.

6.8. Limitations

Given the CLSA's restriction to cognitively healthy individuals and the results of recent theses in the research group^{81,186}, selection bias is known to exist in the CLSA. This may have led to the underestimation of the inverse association between memory and depressive symptoms.

Participants with high FSS and low CSED-10 scores were also more likely to participate in the CLSA, which may have further contributed to underestimates of associations. Males who constitute a reasonable proportion of our analytical sample have also been identified to generally underreport depressive symptoms¹²³. This may also have affected CLSA and contributed to underestimate of associations. Therefore, the results of the thesis apply to groups of people who resemble the analytical sample – i.e., persons who have a “healthy” aging trajectory – rather than to the entire CLSA sample or to the whole target population of middle-aged and older adults in Canada.

An important limitation of this thesis relates to the scale of measurement for the primary variables. Memory scores were standardized as z-scores, while FSS and depressive symptoms scores were raw scores that ranged from 0 to 100 and from 0 to 30, respectively. Because standardized scores reflect differences in standard deviation units, they are not directly comparable to raw scores. As a result, associations involving memory may appear smaller in magnitude when modeled alongside variables with larger raw ranges, such as FSS and depression symptoms scores. This difference in scaling may have contributed to the near-zero effect sizes observed in the study and could complicate the interpretation of the absolute magnitude of the effects, even though the direction and statistical significance of the reported associations are valid.

To address computational constraints and facilitate model convergence, some categorical covariates with multiple response options (functional status, marital status, alcohol use, and smoking status) were collapsed into binary responses. For these collapsed variables, the thesis could not account for differences across multiple response categories (e.g., gradients of severity), which could lead to residual confounding or differential misclassification.

6.9. Implications and Future Directions

The findings of this thesis have important public health implications, particularly in view of shifting global demographics toward aging populations. This research extends knowledge of the complex relationship between memory and depressive symptoms in middle-aged and older adults by identifying FSS as a partial mediator of this association. In populations with poorer health status or in studies with longer follow-ups, the mediation effect of FSS may be more pronounced.

The identification of FSS as an important mediator has practical implications for intervention strategies. This finding underscores the importance of considering social factors in the care of aging individuals. Public health initiatives could benefit from integrating strategies that assess and address FSS during routine care, particularly among individuals exhibiting signs of cognitive decline. Ensuring older adults have adequate access to various types of social support may help mitigate the consequences of declining memory on depressive symptoms.

Interventions may include community-based engagement initiatives, caregiver support training, or technological innovations to sustain interaction among those experiencing cognitive problems. An effective strategy will emphasize connecting patients to community-based resources that promote both mental and physical health, such as the examples mentioned earlier in Section 6.3. As FSS may also reflect unmet psychosocial or physical needs, identifying older adults with memory impairments who also report low levels of FSS could help target individuals most at risk for developing depressive symptoms. Rather than relying solely on medical interventions, healthcare systems might benefit from social prescribing and strengthening community-based outreach programs that identify older adults at risk of both cognitive decline and declining functional social support. For example, embedding social support assessments within routine primary care or geriatric screening could help flag individuals who may benefit from referrals to

local senior centers, peer support groups, or caregiver services. Individuals experiencing both memory difficulties and emerging depressive symptoms may benefit substantially from psychosocial interventions such as supportive counseling, group therapy, and social skills training^{213,214}. Additionally, including caregivers and family members in treatment planning can improve patients' access to functional support resources^{213,214}.

Future research should aim to build on the thesis by using additional follow-up waves from the CLSA. As the cohort ages, a larger proportion of participants will likely experience memory decline and increase in depressive symptom severity. This will boost the heterogeneity of the sample and lead to greater differentiation between healthy and unhealthy participants, possibly leading to larger effect sizes. Moreover, further exploration of specific subtypes of FSS – such as emotional support, informational support, or tangible assistance – in the CLSA could identify whether some subtypes have stronger mediation effects than other subtypes. Different FSS subtypes may have distinct relationships with memory and depression, and policies or interventions specifically tailored to these subtypes may prove more effective than generalized approaches.

7. CONCLUSION

The mediating pathways linking memory and depressive symptoms in middle-aged and older adults have been underexplored in the literature. This thesis is the first empirical investigation of the mediating role of FSS in this relation. The findings showed a statistically significant, though modest mediation effect for FSS and a statistically significant direct relation between memory and depressive symptoms. The total protective effect of memory on depressive symptoms was slightly larger when accounting for mediation by FSS, compared to the direct relation alone. Although selection biases might have underestimated effect sizes, this thesis contributed important and novel insights into the complex interplay among memory, FSS, and depressive symptoms in aging populations. The findings provide a foundation for future research, particularly with extended longitudinal data from the CLSA and FSS subtypes, to support cognitive and mental well-being in aging populations.

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APPENDICES

Appendix A. Literature Review

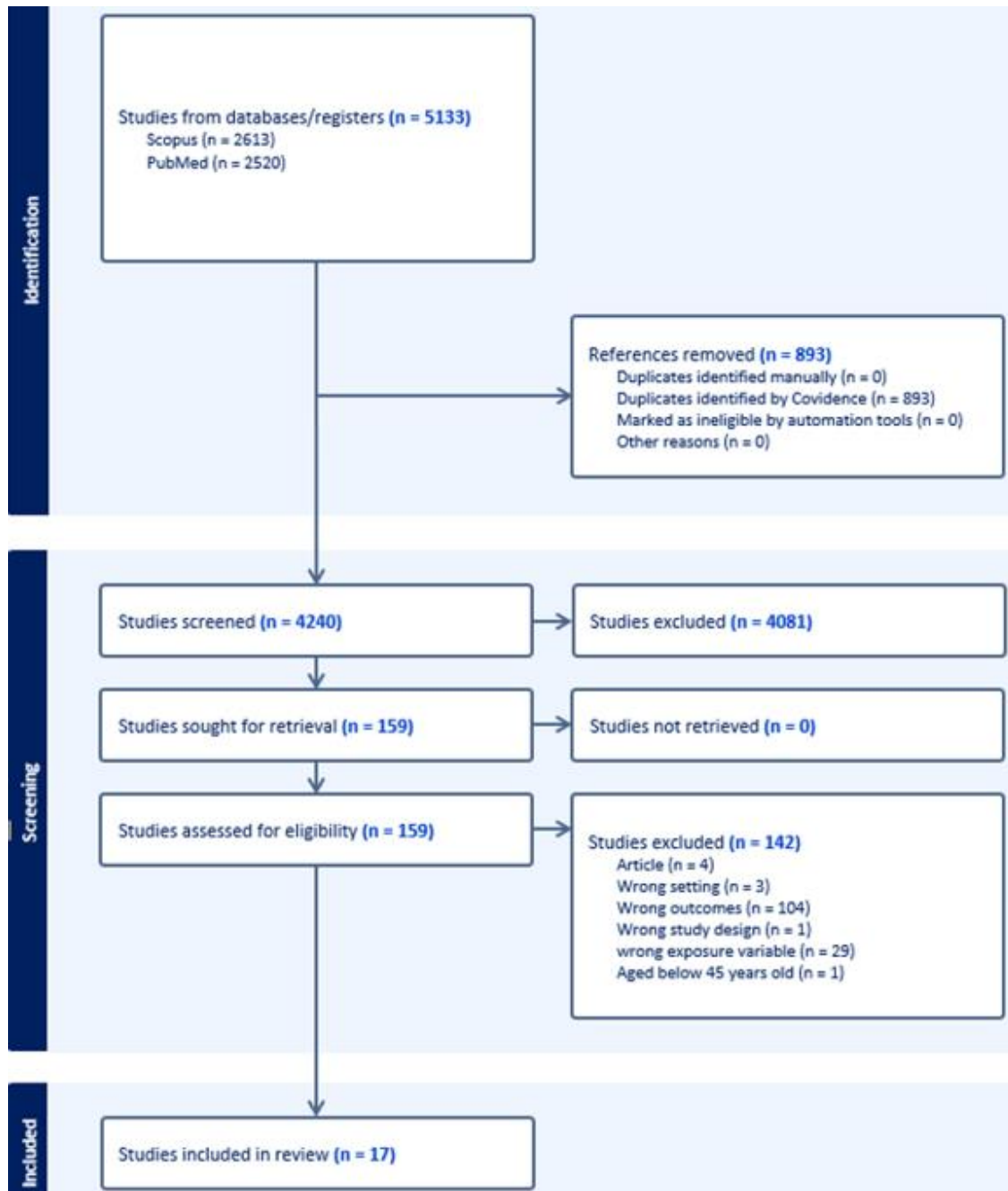


Figure A-1. Literature Search Strategy

Table A-1. Search Terms for the Literature Search

Scopus	PubMed
((Memory[tiab] OR Memory[MeSH] OR cognition*[tiab] OR cognitive function*[tiab] OR Cognitive Impairment*[tiab] OR Executive function[tiab] OR Cognitive Decline[tiab] OR Cognitive Dysfunction[tiab] OR Dementia[MeSH] OR Cognitive Dysfunction[MeSH]) AND (Depressive Symptom*[tiab] OR Depression[tiab] OR Depression[MeSH] OR Depressive disorder[MeSH]) AND (Functional Social Support[tiab] OR Social Support*[tiab] OR Social Relations*[tiab] OR Social Engagement*[tiab] OR Social Participation[tiab] OR Social Capital[tiab] OR Social Resources[tiab] OR Social Relationship*[tiab] OR Community Network*[tiab] OR Social Support[MeSH] OR Interpersonal Relations[MeSH:noexp] OR Interpersonal Relation*[tiab] OR Social Interaction[MeSH] OR Social Isolation[MeSH] OR Social Isolation[tiab] OR Social Environment[tiab] OR Social Integration[tiab]))	TITLE-ABS-KEY (memory OR cognition OR “cognitive function” OR “Executive function” OR “Cognitive decline*” OR “Cognitive impairment*” OR dementia) AND TITLE-ABS-KEY (“Depressive symptom*” OR Depression OR “Depressive disorder”) AND TITLE-ABS-KEY (“Functional Social Support” OR “Social Support” OR “Social Relation*” OR “Social Engagement” OR “Social Participation” OR “Social Capital” OR “Social Resource*” OR “Social Relationship” OR “Social Network” OR “Community Network” OR “Family Relationship” OR “Family Support” OR “Interpersonal Relation*” OR “Social Interaction” OR “Social Isolation” OR “Social Environment” OR “Social Integration” AND TITLE-ABS-KEY (aging OR ageing OR elderly OR older OR Seniors
Retrieved 2,613 as of 1 st May 2025	Retrieved 2,520 as of 1 st May 2025

Appendix B. Summary of Literature on the Association Between Memory, Functional Social Support, and Depressive Symptoms

Author	Title	Study design	Study population	Exposure variables	Outcome variables	Covariates	Conclusion and findings
Adams et al., (2021)	Depression and Associated factors among geriatric population in Moshi District Council, Northern Tanzania	Cross-sectional	304 adults aged ≥ 60	Cognitive function: self-report of history of cognitive impairment. Social support: Oslo-3 Social Support Scale (OSS-3)	Geriatric depression scale (GDS)	Age, sex, education, Marital status, Occupation, Education level, marital status, living alone, alcohol consumption, tobacco consumption, chronic illness,	Self-reported history of cognitive impairment was associated with higher prevalence of depressive symptoms (OR= 1.66, 95% CI: 1.16, 2.38) Strong social support (OR= 0.27, 95% CI: 0.17, 0.44) was protective against depressive symptoms.
Alhalaseh et al., (2022)	Loneliness and Depression among Community Older Adults during the COVID-19 Pandemic: A cross-sectional study.	Cross-sectional	456 adults aged ≥ 60 years	Cognitive function: History of memory decline Social support: UCLA Loneliness Scale	Geriatric depression scale (GDS)	Age, education, baseline function, multimorbidity, concern about contracting COVID	History of memory decline ($r= 0.69$, $p= 0.03$) and loneliness ($r= 0.55$, $p= <0.05$) were predictors of depression

Anbesaw et al., (2022)	Depression and associated factors among older adults in Bahir Dar city administration, Northwest Ethiopia, 2020: Cross-sectional study.	Cross-sectional	423 adults aged $\geq$ 60 years	Cognition: Mini-Mental State Examination (MMSE) Social support: WHOQOL-BREF.	Geriatric Depression Scale (GDS)	Marital status, educational status, occupational status, monthly income, current living conditions, chronic medical illness	Cognitive impairment was a significant predictor of depression (OR= 3.54, 95% CI: 2.16, 5.81) Poor quality of support was also significantly associated with depressive symptoms. (OR= 2.78, 95% CI: 1.74, 4.46)
Canoui-Poitaine et al., (2016)	Geriatric assessment findings independently associated with clinical depression in 1092 older patients with cancer: the ELCAPA Cohort Study.	Cross-sectional	1092 adults aged $\geq$ 70 years	Cognitive status: Mini-Mental State Examination (MMSE) Social support: questions on primary caregiver, support at home, or circle of family and friends	semi-structured interview by senior geriatricians specialized in geriatric oncology	Functional status, gender, mobility, nutrition, comorbidities, polypharmacy	Clinical depression was independently associated with cognitive impairment ($r= 1.76$, $p= <0.05$) and inadequate social support ($r=1.66$, $p= <0.05$)
Chau et al., (2021)	Risk Factors for Depression in Long-term Care: A	Longitudinal	228 adults aged $\geq$	Cognition: Mini-Mental State	Geriatric Depression Scale short form	Age, gender, Education, Marital status, pain, sleep	Cognitive impairment was not a statistically significant predictor of depression over

	Prospective Observational Cohort Study.		65 years	Examination(M MSE) Social support: Multidimensional scale of perceived social support (MSPSP)		disturbance , Barthel index of activities living (BIADL), aged care fit	time ($r = -0.00$, $p = 0.98$) social support was a statistically significant predictor of depression score over time ($r = -0.02$, $p < 0.05$)
Eisses et al., (2004)	Risk indicators of depression in residential homes	Cross-sectional	479 adults aged ≥ 65 years	Cognitive function: Mini Mental Status Examination (MMSE) Social support: shortened Social Support Interactive Scale	Geriatric depression scale (GDS)	Age, sex, socioeconomic status, physical health, life events, social support, personality, familial vulnerability, chronic illness.	Cognitive function and social support were negatively correlated with depression ($r = -0.06$ and $r = -0.101$ respectively, $p < 0.05$)
Kim et al., (2017)	The Impacts of Social Support and Cognitive Function on Depression among Community-Dwelling Older Japanese Americans	Cross-sectional	207 elders aged ≥ 75 years	Cognition: Mini-Mental Status Examination (MMSE) Social support: Measurement of Social Support in the Elderly (MOSS-E) scale	Geriatric Depression Scale	Gender, marital status, age, education, monthly income	Participants with lower cognitive function were more likely to be depressed, and cognitive function was found to be a significant predictor of depression. ($r = -0.48$, $p < 0.05$)

							Participants with lower social support were more likely to be depressed and social support is a significant risk factor for depression. ($r = -0.36$, $p < 0.05$)
Lee et.al (2005)	Correlates of cognitive impairment and depressive symptoms among older adults in Korea and Japan.	Cross-sectional	1298 adults aged ≥ 65	Cognitive function: Mini Mental State Examination (MMSE) Social support: Social Support Index (receiving and giving social support)	Geriatric Depression Scale	Age, gender, and education, physical function, chronic conditions, social support, and health behaviours	Cognitive impairment was a predictor of depressive symptoms. (OR= 2.32, 95% CI: 1.56, 3.43) Social support was independently associated with depressive symptoms. (OR= 0.90, 95%CI: 0.86, 0.94)
Lee et al., (2011)	Gender Differences in Predictors of Mental Health among older adults in South Korea	Cross-sectional	4155 adults aged ≥ 65 years	Cognitive function: Mini-Mental State Examination (MMSE) Social support: questions on engagement in social activities	Center for Epidemiologic Studies Short Depression Scale (CESD-10)	Age, marital status, gender, education, chronic illness	Reporting lower cognitive functions was indicative of depressive symptoms ($r = -3.02$, $p < 0.05$) “Engagement in a variety of social leisure activities, mutual aid groups and religious involvement did not

							seem to prevent depression [pg. 213-219]”.
McCusker et al., (2005)	The prevalence and correlates of major and minor depression in older medical inpatients.	Cross-sectional	380 adults aged ≥ 65 years.	Cognitive function: the Mini-Mental State Examination Social support (functional): questions that covered perceived adequacy of emotional and tangible support	Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) criteria	Premorbid disability, comorbidity, vascular disease	“Cognitive impairment and perceived adequacy of support were associated with depression [pg. 1346-1347]”. Cognitive impairment ($r = 1.82$, $p = 0.10$) Social support (tangible $r = 0.76$, $p = 0.10$; emotional $r = 0.45$, $p < 0.05$)
Roh et al., (2022)	The moderating effect of cognitive function on the association between social support and depressive symptoms among community-dwelling older	Cross-sectional and Longitudinal	1088 adults between 60 and 90 years,	Cognitive function: Mini-Mental State Examination (MMSE) Social support (functional): ENRICH Social Support Instrument	Montgomery-Asberg Depression Rating Scale (MADRS)	Age, Gender, education, Hypertension, Diabetes, BMI, Sleep, Anxiety	<i>Cross-sectional analysis</i> Cognitive function ($r = -0.480$, $p < 0.05$) Social support: ($r = -0.248$, $p < 0.05$) <i>Longitudinal analysis</i> Cognitive function: ($r = -0.25$, $p = 0.10$) Social support: ($r = -0.11$, $p < 0.05$)

	adults: Cross-sectional and longitudinal analyses.						“Social support and cognitive impairment were associated with late-life depressive symptoms in both analyses [pg 187-188]”
Song et al., (2019)	Identifying the factors related to depressive symptoms amongst community dwelling older adults with mild cognitive impairment	Cross-sectional	154 older adults aged $\geq$ 60 years	Cognitive function: Montreal Cognitive Assessment [Objective cognitive function, subjective memory complaint] Social support: Medical Outcomes Study Social Support Survey (MOS-SSS)	Geriatric Depression Scale (GDS)	Gender, marital status, living condition	Subjective memory complaint ($r= 0.20$, $p = <0.05$) were correlated with depressive symptoms Poor perceived positive social interaction ($r= -0.28$, $p= <0.05$)
Tiong et al., (2013)	Prevalence and risk factors of depression in the elderly nursing home	Cross-sectional	375 adults aged $\geq$ 55 years	Cognitive function: Abbreviated Mental Test (AMT)	Diagnostic and Statistical Manual of Mental Disorders	Age, gender, race, religion, education level, marital status, physical	Cognitive dysfunction was not a significant predictor of depression in the elderly.

	residents in Singapore			Social support: questions asked on social contact	(DSM-IV) criteria	comorbidities, length of stay, stroke, difficulty in communication with staff, Activities of daily living score	(OR =1.06, 95%: 0.64, 1.75) No or lack of social contact was identified as a significant risk factor for depression in the elderly. (OR= 2.02, 95%: 1.12, 3.65)
Tsai et al (2005)	Comparison of the prevalence and risk factors for depressive symptoms among elderly nursing home residents in Taiwan and Hong Kong	Cross-sectional	364 adults aged $\geq$ 65 years.	Cognitive deficit: Mini-Mental State Examination (MMSE) Social support: Social support Scale.	Geriatric Depression Scale(GDS)Short Form	Age, Gender, perceived health condition, perceived income adequacy, satisfaction with living situation, functional status	Cognitive status was associated with depression ($r= 0.92$, $p = < 0.05$) Social support was significantly ($p \leq 0.01$) and negatively related to depressive symptoms.
Tsai et al (2005)	Prevalence and risk factors for depressive symptoms among community-dwelling elders in Taiwan	Cross-sectional	1200 adults aged $\geq$ 65 years	Cognitive status: Mini-Mental State Examination (MMSE) Social support: Social Support Scale	Geriatric Depression Scale-Short Form (GDS-S)	Respiratory disease, satisfaction with living situation, perceived health status, perceived	“Poor cognitive function and poor social support were significant predictors of depressive symptoms [pg. 1097-1102]” Cognitive status

						income adequacy	OR= 0.95, 95% CI: 0.90, 1.00) Social support (OR=0.88, 95% CI: 0.82, 0.94)
Wu et al., (2017)	Prevalence of and risk factors for minor and major depression among community-dwelling older adults in Taiwan.	Cross sectional	5,664, adults aged $\geq$ 55 years	Cognition: Mini Mental State Examination (MMSE) Social support: self-report on the number of interpersonal contacts over the past year	Center for Epidemiological Studies Depression Scale (CESD-10)	Sex, education, Physical function, marital status, employment, medical conditions, lifestyle behaviours, social support network, and life events.	“Depression was associated with poor social support and cognitive impairment [pg 1116-1117]” Cognitive impairment: (OR= 2.26, 95% CI: 1.24, 4.12) Social support: (OR: 2.36, 95% CI: 1.35, 4.13)
Yun et al., (2020)	Influence of Health Status, Cognitive Function, and Social Capital on Depressive Symptoms in Korean Older Adults.	Cross-sectional	6100 adults aged $\geq$ 65 years	Cognitive function: Mini Mental State Examination (MMSE) Social support (structural and cognitive): questions corresponding to leisure	Short-Form Geriatric depression scale (GDS)	Gender, age, education, income level, economic activity status, religion type of household, self-rated health	Cognitive function ($r = -0.25$, $p < 0.05$) was negatively correlated with depressive symptoms. structural social capital ($r = -0.22$, $p < 0.05$) and cognitive social capital ($r = -0.45$, $p < 0.05$) were

				activities, social activities, and quality of life			correlated negatively with depression.
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Appendix C. Medical Outcomes Study – Social Support Survey (MOS–SSS)

Item	Questions	Type of Functional Social Support
3	Someone you can count on to listen to you when you need to talk	Emotional/ Informational
4	Someone to give you advice about a crisis	
8	Someone to give you information in order to help you understand a situation	
9	Someone to confide in or talk to about yourself or your problems	
13	Someone whose advice you really want	
16	Someone to share your most private worries and fears with	
17	Someone to turn to for suggestions about how to deal with a personal problem	
19	Someone who understands your problems	Instrumental
2	Someone to help you if you were confined to bed	
5	Someone to take you to the doctor if you needed it	
12	Someone to prepare your meals if you were unable to	
15	Someone to help you with daily chores if you were sick	
6	Someone who shows you love and affection	Affectionate
10	Someone who hugs you	
20	Someone to love you and make you feel wanted	
11	Someone to get together with for relaxation	Positive social interaction
18	Someone to do something enjoyable with	
7	Someone to have a good time with	
14	Someone to do things with to help you get your mind off	Additional item

Appendix D. Control Variables

	Control variable	Measurement	Variable Name
Sociodemographic	Sex	Male Female	SEX_ASK_TRM
	Age	45-54 years (reference) 55-64 years 65-74 years 75 years or over	AGE_GRP_TRM
	Education	Less than high school (reference) High school diploma Some post-secondary education Post-secondary degree/diploma	ED_UDR04_TRM ED_OTED_TRF1 ED_OTED_TRF2
	Province of residence	One of the ten provinces	WGHTS_PROV_TRM WGHTS_PROV_TFF1 WGHTS_PROV_TFF2
	Total annual household income	Less than \$20,000 (reference) From \$20,000 to under \$50,000 From \$50,000 to under \$100,000 From \$100,000 to under \$150,000 \$150,000 or more	INC_TOT_TRM INC_TOT_TRF1 INC_TOT_TRF2
	Marital status	1 = single (reference) 2 = married/common-law 3 = widowed 4 = divorced/separated	SDC_MRTL_TRM SDC_MRTL_TRF1 SDC_MRTL_TRF2
Health status	Functional status	1 = no assistance required for any activity (reference) 2 = assistance required for at least one activity	ADL_DCLS_TRM ADL_DCLS_TRF1 ADL_DCLS_TRF2
	Chronic conditions	1 = no chronic condition (reference) 2 = one or more chronic conditions	CCT_F2_TRM CCT_F2_TRF1 CCT_F2_TRF2
Lifestyle Behaviours	Smoking status	1 = Non-user (reference) 2 = Occasional user 3 = Daily user	SMK_CURRCG_TRM SMK_CURRCG_TRF1 SMK_CURRCG_TRF2
	Alcohol consumption	1 = Non-user (reference) 2 = Occasional drinker 3 = Regular drinker	ALC_TTM_TRM ALC_TTM_TRF1 ALC_TTM_TRF2

Note: Variable names are original CLSA variables. The suffix “TRM” indicates a variable at baseline, “TRF1” indicates variable at follow-up 1, and “TRF2” indicates a variable at follow-up 2.

https://www.clsa-elcv.ca/wp-content/uploads/2023/06/clsa_tra_mainwave_60min_v4.0_2018_jun08.pdf

https://www.clsa-elcv.ca/wp-content/uploads/2023/06/clsa_telephone_fup1_cv2.2_2019may22.pdf

https://www.clsa-elcv.ca/wp-content/uploads/2023/06/clsa_telephone_fup2_v1.1_2019oct22.pdf

Appendix E. Equations for the “a” and “b” Pathways

$$\mathbf{x}_i = \alpha_0 + \alpha_1 \mathbf{t}_i + \alpha_2 \mathbf{w}_i + \boldsymbol{\eta} \mathbf{H}_i + \boldsymbol{\xi} \mathbf{Z}_i + \mathbf{v}_i \quad (1)$$

$$\mathbf{y}_i = \beta_0 + \beta_1 \mathbf{t}_i + \beta_2 \mathbf{x}_i + \beta_3 \mathbf{w}_i + \boldsymbol{\gamma} \mathbf{H}_i + \boldsymbol{\zeta} \mathbf{Z}_i + \boldsymbol{\varepsilon}_i \quad (2)$$

where ;

$\mathbf{y}_i = (y_{0i}, y_{1i}, y_{2i})'$ represents the observed and random longitudinal continuous depression score for times $j = 0$ (baseline), 1 (follow-up 1), 2 (follow-up 2) for subject i ;

$\mathbf{t}_i = (0, 1, 2)'$ represents the fixed and observed time variable for all subjects;

$\mathbf{x}_i = (x_{0i}, x_{1i}, x_{2i})'$ represents the fixed and observed longitudinal continuous memory score for times $j = 0$ (baseline), 1 (follow-up 1), 2 (follow-up 2) for subject i ;

$\mathbf{w}_i = (w_{0i}, w_{1i}, w_{2i})'$ represents the fixed and observed longitudinal continuous functional social support score for times $j = 0$ (baseline), 1 (follow-up 1), 2 (follow-up 2) for subject i ;

$\mathbf{H}_i$ represents a matrix corresponding to control variables listed in

Appendix **D. Control Variables** which have values fixed from baseline for subject i ;

$\mathbf{Z}_i$ represents a 3×2 matrix corresponding to the random intercept and random slope for $\mathbf{t}_i$ for subject i ;

$\boldsymbol{\varepsilon}_i$ represents trivariate independent normal errors with zero mean and constant variance σ_{ε}^2 for all subjects;

$\mathbf{v}_i$ represents trivariate independent normal errors with zero mean and constant variance σ_v^2 for all subjects with $\boldsymbol{\varepsilon}_i \perp \mathbf{v}_i \perp (\mathbf{H}_i, \mathbf{x}_i, \mathbf{w}_i)$;

$\beta_0, \beta_1, \beta_2, \beta_3, \boldsymbol{\gamma}, \boldsymbol{\zeta}, \alpha_0, \alpha_1, \alpha_2, \boldsymbol{\eta}, \boldsymbol{\xi}$ are the fixed and unknown regression coefficients for corresponding variables in equations 1 and 2.

Appendix F. Full Regression Output for Multilevel Analysis

Table F-1. Base and Adjusted Models for Aim 1 (n=5,958)

Variable	Base Model $\hat{\beta}$ (95% CI)	Adjusted Model $\hat{\beta}$ (95% CI)
Memory at t_0	-0.10 (-0.14, 0.07)	-0.08 (-0.11, -0.04)
Age (Ref: 45-54 years)		
55-64 years	-0.43 (-0.65, -0.21)	-0.75 (-0.96, -0.54)
65-74 years	-0.43 (-0.69, -0.17)	-1.08 (-1.34, -0.81)
75 years or over	-0.09 (-0.42, 0.25)	-1.07 (-1.41, -0.73)
Sex (Ref: male)		
Female	0.94 (0.75, 1.12)	0.44 (0.25, 0.62)
Province (Ref: Alberta)		
British Columbia	0.03 (-0.37, 0.42)	-0.09 (-0.46, 0.29)
Manitoba	-0.13 (-0.59, 0.33)	-0.34 (-0.78, 0.10)
News Brunswick	-0.06 (-0.53, 0.41)	-0.40 (-0.85, 0.05)
Newfoundland and Labrador	-0.15 (-0.64, 0.33)	-0.43 (-0.90, 0.04)
Nova Scotia	0.21 (-0.23, 0.65)	-0.10 (-0.52, 0.33)
Ontario	-0.10 (-0.45, 0.25)	-0.11 (-0.44, 0.23)
Prince Edward Island	-0.50 (-1.00, 0.00)	-0.71 (-1.19, -0.22)
Quebec	-0.28 (-0.64, 0.08)	-0.60 (-0.95, -0.25)
Saskatchewan	0.14 (-0.34, 0.62)	-0.05 (-0.51, 0.41)
Education (Ref: Less than high school)		
High school diploma		-0.34 (-0.78, 0.11)
Some post-secondary education		-0.48 (-0.96, -0.01)
Post-secondary degree / diploma		-0.30 (-0.68, 0.08)
Income (Ref: less than \$20,000)		
\$20,000 to under \$50,000		-1.37 (-1.89, -0.86)
\$50,000 to under \$100,000		-2.24 (-2.76, -1.72)
\$100,000 to under \$150,000		-2.47 (-3.02, -1.91)
\$150,000 or more		-2.97 (-3.55, -2.40)
Marital Status (Ref: Single)		
Others		-0.37 (-0.60, -0.14)
Functional Status (Ref: No)		
Yes		2.12 (1.77, 2.46)
Chronic conditions (Ref: No)		
Yes		-1.17 (-1.46, -0.87)
Smoking Status (Ref: Daily smoker)		
Others		-0.74 (-1.02, -0.46)

<i>Alcohol Use</i> (Ref: Regular user)		
Others		0.69 (0.39, 0.99)

Notes: $p < 0.05$ in bolded font; Adjusted for baseline sociodemographic factors, health status, and lifestyle behaviors;
 $\hat{\beta}$ = regression coefficient; CI = confidence interval; Ref= reference category

Table F-2. “a” and “b” Paths – Adjusted Model Regression Output for Aim 2 (n=5,958)

Variable	a-Path $\hat{\beta}$ (95% CI)	b-Path $\hat{\beta}$ (95% CI)
Memory	0.24 (0.12, 0.36)	-0.07 (-0.1, -0.03)
Functional social support		-0.07 (-0.07, -0.06)
Age (Ref: 45-54 years)		
55-64 years	1.45 (0.62, 2.28)	-0.65 (-0.85, -0.45)
65-74 years	2.9 (1.88, 3.92)	-0.88 (-1.13, -0.63)
75 years or over	2.46 (1.15, 3.78)	-0.9 (-1.21, -0.58)
Sex (Ref: male))		
Female	1.4 (0.7, 2.1)	0.53 (0.36, 0.7)
Province (Ref: Alberta)		
British Columbia	1.64 (0.17, 3.1)	0.03 (-0.32, 0.38)
Manitoba	2.62 (0.91, 4.33)	-0.15 (-0.56, 0.26)
News Brunswick	3.61 (1.87, 5.36)	-0.16 (-0.57, 0.26)
Newfoundland and Labrador	1.86 (0.06, 3.67)	-0.31 (-0.74, 0.13)
Nova Scotia	2.47 (0.84, 4.1)	0.07 (-0.32, 0.46)
Ontario	1.75 (0.45, 3.05)	0.01 (-0.3, 0.32)
Prince Edward Island	2.32 (0.46, 4.19)	-0.55 (-1.0, -0.11)
Quebec	2.65 (1.31, 3.99)	-0.41 (-0.74, -0.09)
Saskatchewan	1.22 (-0.55, 2.99)	0.05 (-0.38, 0.47)
Education (Ref: Less than high school)		
High school diploma	-0.7 (-2.39, 0.98)	-0.39 (-0.8, 0.01)
Some post-secondary education	0.1 (-1.78, 1.97)	-0.47 (-0.92, -0.02)
Post-secondary degree / diploma	-0.93 (-2.42, 0.56)	-0.36 (-0.72, -0.01)
Income (Ref: less than \$20,000)		
\$20,000 to under \$50,000	5.3 (3.32, 7.28)	-1.01 (-1.49, -0.54)
\$50,000 to under \$100,000	8.12 (6.11, 10.12)	-1.68 (-2.17, -1.2)
\$100,000 to under \$150,000	9.1 (6.96, 11.25)	-1.84 (-2.35, -1.32)
\$150,000 or more	10.63 (8.4, 12.87)	-2.24 (-2.78, -1.7)
Marital Status (Ref: Single)		
Others	9.73 (8.84, 10.63)	0.28 (0.06, 0.5)
Functional Status (Ref: No)		
Yes	-3.09 (-4.45, -1.73)	1.9 (1.58, 2.23)
Chronic conditions (Ref: No)		
Yes	1.73 (0.61, 2.86)	-1.05 (-1.32, -0.78)
Smoking Status (Ref: Daily smoker)		

Others	1.9 (0.83, 2.97)	-0.61 (-0.86, -0.35)
Alcohol Use (Ref: Regular user)		
Others	-2.52 (-3.69, -1.34)	0.52 (0.24, 0.81)

Notes: $p < 0.05$ in *bolded font*; Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors; $\hat{\beta}$ = regression coefficient; CI = confidence interval; Ref= reference category

Table F-3. Mediation Results for Aim 2 (n =5,958)

	Adjusted Model $\hat{\beta}$ (95%CI)
a-path	0.24 (0.12, 0.36)
b-path	-0.07 (-0.1, -0.03)
Indirect Effect (ab)	-0.02 (-0.02, -0.01)
Direct Effect (c- prime)	-0.07 (-0.10, -0.04)
Total Effect (c)	-0.08 (-0.12, -0.05)
Proportion Mediated	0.25 (0.10, 0.31)

Notes: $p < 0.05$ in *bolded font*; Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors; $\hat{\beta}$ = regression coefficient; CI = confidence interval.

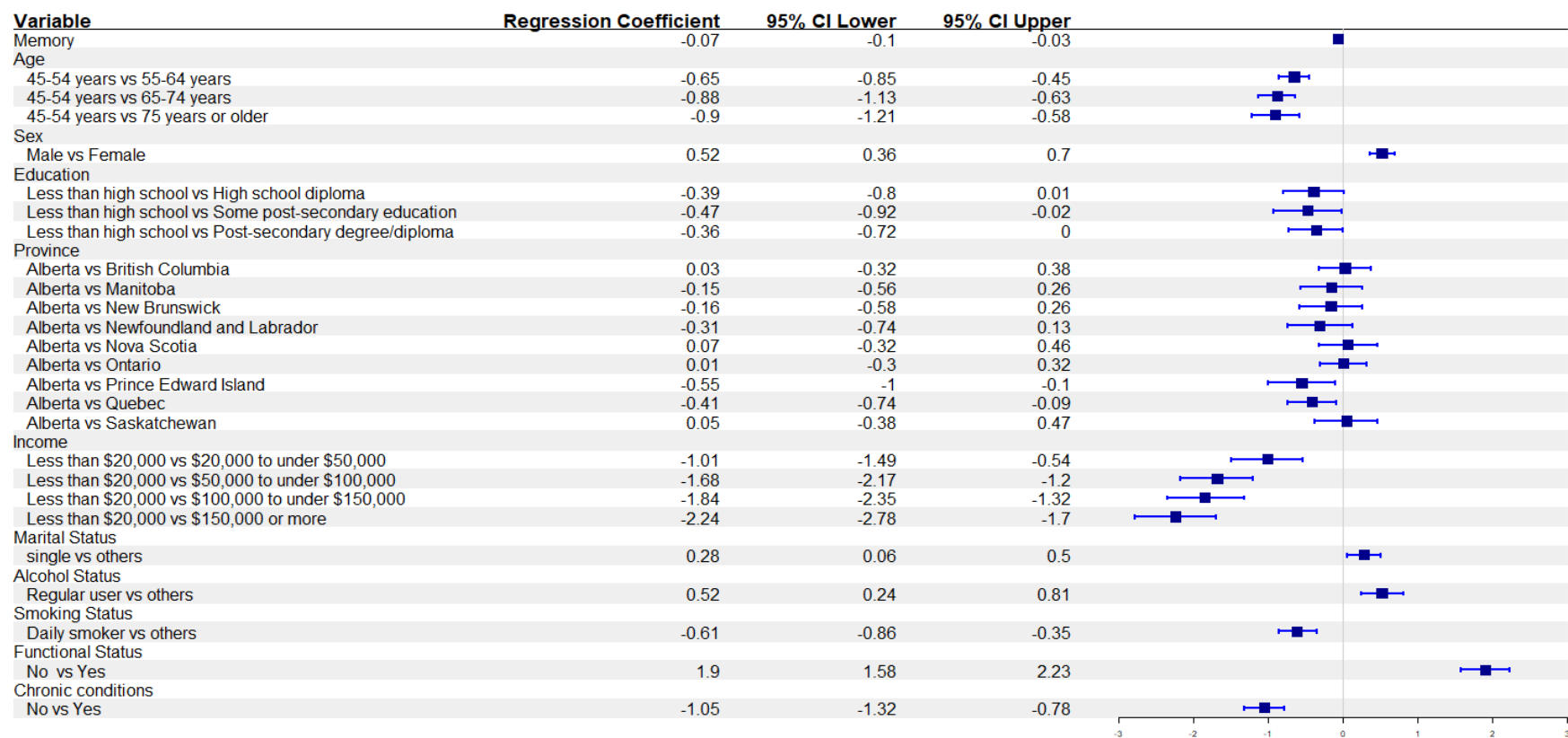


Figure F-1. Regression results for Covariates for Adjusted Multilevel Model

Appendix G. Full Regression Output For Moderated Mediation

Table G-1. “a” and “b” Path Adjusted Models Stratified by Sex (n=5,958)

	FEMALES		MALES	
	a-Path $\hat{\beta}$ (95% CI)	b-Path $\hat{\beta}$ (95% CI)	a-Path $\hat{\beta}$ (95% CI)	b-Path $\hat{\beta}$ (95% CI)
Memory	0.16 (-0.01, 0.33)	-0.08(-0.13,-0.03)	0.34 (0.18, 0.51)	-0.05 (-0.09, -0.01)
Functional social support		0.08 (-0.09, -0.07)		-0.06 (-0.06, -0.05)
Age (Ref: 45-54 years)				
55-64 years	0.54 (-0.64, 1.71)	-0.76 (-1.06,-0.47)	2.10 (0.93, 3.26)	-0.53 (-0.80, -0.26)
65-74 years	1.64 (0.13, 3.15)	-1.11 (-1.48, -0.73)	3.58 (2.20, 4.96)	-0.68 (-1.00, -0.36)
75 years or over	2.30 (0.31, 4.30)	-1.18 (-1.67, -0.68)	1.85 (0.09, 3.60)	-0.61 (-1.02, -0.21)
Province (Ref: Alberta)				
British Columbia	1.91 (-0.19, 4.01)	0.11 (-0.41, 0.64)	1.45 (-0.57, 3.47)	-0.06 (-0.53, 0.41)
Manitoba	2.76 (0.32, 5.20)	-0.26 (-0.87, 0.34)	2.35 (-0.03, 4.72)	-0.01 (-0.57, 0.54)
News Brunswick	3.31 (0.78, 5.85)	0.23 (-0.40, 0.86)	3.90 (1.51, 6.29)	-0.53 (-1.08, 0.03)
Newfoundland and Labrador	1.42 (-1.18, 4.03)	-0.10 (-0.75, 0.55)	2.33 (-0.15, 4.81)	-0.47 (-1.05, 0.11)
Nova Scotia	1.44 (-0.87, 3.74)	-0.00 (-0.58, 0.57)	3.50 (1.22, 5.77)	0.14 (-0.39, 0.67)
Ontario	2.70 (0.86, 4.54)	-0.09 (-0.55, 0.37)	0.87 (-0.95, 2.68)	0.15 (-0.27, 0.58)
Prince Edward Island	2.38 (-0.31, 5.07)	-0.59 (-1.26, 0.08)	2.27 (-0.29, 4.83)	-0.49 (-1.09, 0.11)
Quebec	2.26 (0.37, 4.15)	-0.32 (-0.79, 0.15)	3.05 (1.17, 4.94)	-0.54 (-0.98, -0.10)
Saskatchewan	2.26 (-0.22, 4.73)	-0.04 (-0.65, 0.58)	0.05 (-2.45, 2.55)	0.19 (-0.40, 0.77)
Education (Ref: Less than high school)				
High school diploma	-0.99 (-3.37, 1.39)	-0.29 (-0.88, 0.30)	-0.35 (-2.72, 2.02)	-0.53 (-1.09, 0.02)
Some post-secondary education	1.01 (-1.65, 3.67)	-0.40 (-1.06, 0.26)	-0.85 (-3.48, 1.77)	-0.55 (-1.16, 0.06)
Post-secondary degree / diploma	-1.44 (-3.57, 0.69)	-0.52 (-1.05, 0.01)	-0.58 (-2.66, 1.49)	-0.22 (-0.71, 0.26)
Income (Ref: less than \$20,000)				
\$20,000 to under \$50,000	5.38 (3.01, 7.74)	-0.82 (-1.41, -0.23)	6.28 (2.64, 9.92)	-1.19 (-2.04, -0.35)
\$50,000 to under \$100,000	8.18 (5.74, 10.62)	-1.49 (-2.11, -0.88)	9.24 (5.61, 12.87)	-1.84 (-2.69, -1.00)

\$100,000 to under \$150,000	8.55 (5.86, 11.24)	-1.72 (-2.39, -1.05)	10.63 (6.87,14.39)	-1.96 (-2.84, -1.09)
\$150,000 or more	10.90 (8.00, 13.79)	-2.19 (-2.92, -1.47)	11.38 (7.55, 15.21)	-2.32 (-3.21, -1.43)
Marital Status (Ref: Single)				
Others	7.25 (6.06, 8.43)	0.48 (0.19, 0.78)	13.52 (12.14,14.91)	-0.12 (-0.45, 0.21)
Functional Status (Ref: No)				
Yes	-2.96 (-4.59, -1.34)	1.97 (1.57, 2.38)	-3.66 (-6.15, -1.17)	1.67 (1.09, 2.25)
Chronic conditions (Ref: No)				
Yes	0.79 (-0.97, 2.55)	-0.98 (-1.41, -0.54)	2.36 (0.90, 3.81)	-1.13 (-1.47, -0.80)
Smoking Status (Ref: Daily smoker)				
Others	2.02 (0.58, 3.45)	-1.00 (-1.36, -0.64)	1.82 (0.23, 3.42)	-0.08 (-0.45, 0.29)
Alcohol Use (Ref: Regular user)				
Others	-1.44 (-3.11, 0.24)	0.50 (0.09, 0.92)	-3.47 (-5.11, -1.83)	0.53 (0.15, 0.91)

Notes: Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors;

$\hat{\beta}$ = regression coefficient; CI = confidence interval; Ref= reference category

Table G-2. “a” and “b” Path Adjusted Models Stratified by Age Group (n = 5,958)

	45-54 YEARS		55-64 YEARS		65-74 YEARS		≥75YEARS	
	a-Path $\hat{\beta}$ (95% CI)	b-Path $\hat{\beta}$ (95% CI)	a-Path $\hat{\beta}$ (95% CI)	b-Path $\hat{\beta}$ (95% CI)	a-Path $\hat{\beta}$ (95% CI)	b-Path $\hat{\beta}$ (95% CI)	a-Path $\hat{\beta}$ (95% CI)	b-Path $\hat{\beta}$ (95% CI)
Memory	0.27 (0.06,0.48)	-0.09 (-0.15,0.02)	0.23 (0.03,0.43)	-0.08 (-0.13,0.02)	0.04 (-0.03,0.28)	-0.03 (-0.10, 0.03)	0.49 (0.08, 0.89)	0.02 (-0.09, 0.13)
Functional social support		-0.08 (-0.08, -0.07)		-0.07 (-0.07, -0.06)		-0.06 (-0.07, -0.05)	-0.05 (-0.06, - 0.03)	0.05 (-0.06, -0.03)
Sex (Ref: male))								
Female	2.04 (0.85, 3.22)	0.72 (0.43, 1.02)	0.48 (-0.67, 1.64)	0.56 (0.29, 0.83)	0.48 (-1.05, 2.00)	0.27 (-0.10, 0.64)	3.70 (0.89, 6.50)	0.33 (-0.30, 0.97)
Province (Ref: Alberta)								
British Columbia	1.53 (-0.98, 4.04)	-0.25 (-0.87, 0.37)	0.55 (-1.84, 2.94)	0.18 (-0.38, 0.73)	5.24 (2.04, 8.43)	-0.33 (-1.11, 0.44)	0.56 (-4.88, 6.00)	0.71 (-0.51, 1.94)
Manitoba	1.53 (-1.45, 4.51)	-0.60 (-1.34, 0.14)	2.13 (-0.67, 4.92)	0.26 (-0.39, 0.91)	5.65 (2.00, 9.30)	-0.30 (-1.18, 0.58)	1.86 (-4.34, 8.06)	0.06 (-1.33, 1.46)
News Brunswick	1.17 (-1.84, 4.19)	-0.01 (-0.76, 0.74)	3.78 (0.87, 6.68)	-0.53 (-1.20, 0.15)	6.91 (3.35, 10.47)	-0.30 (-1.16, 0.56)	5.15 (-1.53, 11.83)	0.64 (-0.87, 2.15)
Newfoundland and Labrador	1.25 (-1.83, 4.32)	-0.45 (-1.21, 0.31)	1.11 (-1.85, 4.07)	0.00 (-0.69, 0.69)	3.82 (-0.19, 7.82)	-0.40 (-1.37, 0.56)	3.01 (-3.50, 9.53)	-0.55 (-2.02, 0.91)
Nova Scotia	3.45 (0.70, 6.20)	-0.46 (-1.14, 0.22)	2.18 (-0.56, 4.93)	0.43 (-0.21, 1.07)	1.71 (-1.68, 5.10)	0.18 (-0.64, 1.00)	3.46 (-2.68, 9.60)	-0.01 (-1.40, 1.37)
Ontario	2.01 (-0.23, 4.24)	-0.51 (-1.06, 0.05)	0.34 (-1.80, 2.47)	0.31 (-0.19, 0.81)	4.54 (1.80, 7.28)	-0.09 (-0.75, 0.58)	1.96 (-3.05, 6.98)	0.57 (-0.56, 1.70)
Prince	1.37	-0.77	2.16	-0.11	3.64	-1.09	3.27	-0.10

Edward Island	(-1.91, 4.65)	(-1.59, 0.04)	(-1.03, 5.36)	(-0.86, 0.63)	(-0.15, 7.43)	(-2.00, -0.17)	(-2.99, 9.53)	(-1.51, 1.31)
Quebec	3.26 (0.95, 5.57)	-0.93 (-1.50, -0.36)	2.23 (0.06, 4.40)	-0.13 (-0.64, 0.37)	3.07 (0.18, 5.97)	-0.28 (-0.98, 0.42)	0.83 (-4.38, 6.05)	0.12 (-1.05, 1.30)
Saskatchewan	-0.22 (-3.23, 2.78)	-0.52 (-1.26, 0.22)	1.61 (-1.36, 4.57)	0.32 (-0.37, 1.01)	3.45 (-0.22, 7.12)	-0.39 (-1.28, 0.49)	0.81 (-5.99, 7.62)	1.88 (0.34, 3.41)
Education (Ref: Less than high school)								
High school diploma	-0.81 (-4.28, 2.67)	-1.02 (-1.88, -0.16)	-0.74 (-3.68, 2.19)	-0.00 (-0.69, 0.68)	-1.58 (-4.93, 1.76)	-0.29 (-1.10, 0.52)	-1.46 (-6.02, 3.11)	-0.34 (-1.36, 0.69)
Some post-secondary education	0.05 (-3.71, 3.81)	-0.92 (-1.85, 0.02)	-0.03 (-3.25, 3.18)	0.05 (-0.70, 0.79)	-1.37 (-5.13, 2.40)	-0.68 (-1.59, 0.23)	1.09 (-4.49, 6.68)	-0.93 (-2.19, 0.33)
Post-secondary degree/ diploma	-1.91 (-5.10, 1.27)	-0.54 (-1.33, 0.25)	-1.23 (-3.87, 1.42)	-0.17 (-0.79, 0.45)	-0.60 (-3.49, 2.29)	-0.46 (-1.16, 0.24)	-0.54 (-4.15, 3.07)	-0.54 (-1.36, 0.27)
Income (Ref: less than \$20,000)								
\$20,000 to under \$50,000	7.29 (3.17, 11.41)	-1.70 (-2.73, -0.68)	7.09 (3.47, 10.7)	-0.18 (-1.02, 0.67)	2.18 (-1.38, 5.75)	-0.32 (-1.18, 0.54)	2.86 (-2.37, 8.09)	-2.56 (-3.74, -1.38)
\$50,000 to under \$100,000	11.13 (7.10, 15.17)	-2.25 (-3.25, -1.25)	9.61 (6.00, 13.23)	-1.02 (-1.86, -0.17)	4.84 (1.13, 8.55)	-1.09 (-1.98, -0.19)	5.34 (-0.31, 10.98)	-2.73 (-4.00, -1.45)
\$100,000 to under \$150,000	12.19 (8.02, 16.37)	-2.62 (-3.66, -1.58)	10.86 (7.04, 14.68)	-1.02 (-1.91, -0.12)	4.14 (-0.13, 8.42)	-1.13 (-2.16, -0.10)	7.50 (0.89, 14.11)	-2.86 (-4.35, -1.36)
\$150,000 or more	14.01 (9.75, 18.26)	-2.89 (-3.95, -1.83)	12.23 (8.26, 16.21)	-1.54 (-2.47, -0.61)	5.36 (0.61, 10.11)	-1.67 (-2.82, -0.53)	5.42 (-2.88, 13.73)	-2.46 (-4.33, -0.58)
Marital Status (Ref: Single)								

Others	10.27 (8.63, 11.91)	0.16 (-0.25, 0.58)	8.78 (7.28, 10.28)	0.46 (0.11, 0.82)	11.15 (9.32, 12.99)	-0.07 (-0.52, 0.38)	9.33 (6.39, 12.27)	0.18 (-0.49, 0.85)
Functional Status (Ref: No)								
Yes	-5.34 (-8.11, -2.56)	2.78 (2.10, 3.47)	-2.28 (-4.62, 0.05)	2.03 (1.48, 2.57)	-1.39 (-4.13, 1.34)	1.28 (0.62, 1.94)	-3.14 (-6.68, 0.40)	1.23 (0.43, 2.03)
Chronic conditions (Ref: No)								
Yes	1.14 (-0.45, 2.73)	-0.78 (-1.17, -0.39)	2.52 (0.61, 4.43)	-1.27 (-1.71, -0.83)	0.05 (-3.09, 3.18)	-1.24 (-2.00, -0.48)	6.55 (-1.01, 14.11)	-1.02 (-2.73, 0.68)
Smoking Status (Ref: Daily smoker)								
Others	1.48 (-0.17, 3.14)	-1.06 (-1.47, -0.65)	2.10 (0.45, 3.75)	-0.22 (-0.61, 0.16)	0.49 (-2.54, 3.53)	-0.30 (-1.04, 0.43)	5.82 (-0.24, 11.88)	0.29 (-1.07, 1.66)
Alcohol Use (Ref: Regular user)								
Others	-2.40 (-4.63, -0.16)	0.71 (0.16, 1.27)	-4.90 (-6.84, -2.96)	0.65 (0.20, 1.10)	1.19 (-1.23, 3.61)	0.38 (-0.21, 0.96)	-2.08 (-5.62, 1.47)	0.13 (-0.67, 0.92)

Notes: $p < 0.05$ in bolded font; Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors;
 $\hat{\beta}$ = regression coefficient; CI = confidence interval; Ref= reference category

Table G-3. Mediation Analysis Stratified by Sex (n =5,958)

	FEMALES $\hat{\beta}$ (95% CI)	MALES $\hat{\beta}$ (95% CI)
Indirect Effect (ab)	-0.01 (-0.03, 0.00)	-0.02 (-0.03, -0.01)
Direct Effect (c-prime)	-0.08 (-0.12, -0.03)	-0.05 (-0.1, -0.01)
Total Effect (c)	-0.09 (-0.14, -0.04)	-0.07 (-0.12, -0.02)
Proportion Mediated	0.13 (-0.05, 0.30)	0.27 (0.14, 0.77)

Notes: Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors;

$\hat{\beta}$ = regression coefficient; CI = confidence interval

Table G-4. Mediation Analysis Stratified by Age Group (n = 5,958)

	45-54 YEARS $\hat{\beta}$ (95% CI)	55-64 YEARS $\hat{\beta}$ (95% CI)	65-74 YEARS $\hat{\beta}$ (95% CI)	≥75YEARS $\hat{\beta}$ (95% CI)
Indirect Effect (ab)	-0.02 (-0.04, 0.00)	-0.02 (-0.03, 0.00)	-0.00 (-0.02, 0.01)	-0.02 (-0.04, 0.00)
Direct Effect (c-prime)	-0.09 (-0.15, -0.02)	-0.08 (-0.13, -0.01)	-0.03 (-0.09, 0.04)	0.02 (-0.08, 0.13)
Total Effect (c)	-0.11 (-0.17, -0.04)	-0.09 (-0.15, -0.03)	-0.03 (-0.09, 0.04)	-0.00 (-0.11, 0.11)
Proportion Mediated	0.18 (0.03, 0.56)	0.17 (0.01, 0.69)	0.06 (-1.86, 1.18)	0.11 (-11.95, 3.94)

Notes Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors;

$\hat{\beta}$ = regression coefficient; CI = confidence interval

Appendix H. Mediation Output for Multiple Imputation Analysis

Table H-1. Mediation Results for Multiple Imputation Analysis (n =10,441)

	$\hat{\beta}$ (95%CI)
Indirect Effect (ab)	-0.02 (-0.03, -0.02)
Direct Effect (c-prime)	-0.07 (-0.09, -0.04)
Total Effect (c)	-0.09 (-0.11, -0.06)

Notes: $p < 0.05$ in bolded font; Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors; $\hat{\beta}$ = regression coefficient; CI = confidence interval.

Appendix I. Full Regression Output for Missing Covariate Category Sensitivity Analysis

Table I-1. “a” and “b” paths for Missing Covariate Category Analysis (n = 9,274)

Variable	a-Path $\hat{\beta}$ (95% CI)	b-Path $\hat{\beta}$ (95% CI)
Memory	0.27 (0.18, 0.36)	-0.07 (-0.09, -0.04)
Functional social support		-0.07 (-0.07, -0.06)
Age (Ref: 45-54 years)		
55-64 years	1.46 (0.79, 2.13)	-0.66 (-0.82, -0.5)
65-74 years	2.7 (1.89, 3.52)	-0.81 (-1.01, -0.62)
75 years or over	3.17 (2.14, 4.21)	-0.99 (-1.24, -0.75)
Sex (Ref: male))		
Female	1.73 (1.16, 2.29)	0.54 (0.41, 0.68)
Province (Ref: Alberta)		
British Columbia	1.0 (-0.18, 2.17)	-0.22 (-0.5, 0.06)
Manitoba	1.49 (0.11, 2.87)	-0.29 (-0.62, 0.04)
News Brunswick	3.62 (2.21, 5.02)	-0.47 (-0.8, -0.13)
Newfoundland and Labrador	2.23 (0.76, 3.7)	-0.38 (-0.73, -0.03)
Nova Scotia	2.53 (1.22, 3.84)	-0.27 (-0.58, 0.04)
Ontario	2.01 (0.98, 3.04)	-0.17 (-0.41, 0.08)
Prince Edward Island	2.41 (0.94, 3.89)	-0.6 (-0.95, -0.25)
Quebec	2.86 (1.77, 3.94)	-0.54 (-0.8, -0.28)
Saskatchewan	1.47 (0.04, 2.89)	-0.21 (-0.55, 0.12)
Education (Ref: Less than high school)		
High school diploma	-0.19 (-1.59, 1.21)	-0.53 (-0.87, -0.2)
Some post-secondary education	0.56 (-1.01, 2.13)	-0.73 (-1.1, -0.36)
Post-secondary degree / diploma	-0.41 (-1.64, 0.83)	-0.64 (-0.93, -0.35)
Missing	-0.19 (-0.41, 0.56)	-0.64 (-0.73, 0.53)
Income (Ref: less than \$20,000)		
\$20,000 to under \$50,000	5.21 (3.58, 6.84)	-1.01 (-1.4, -0.62)
\$50,000 to under \$100,000	7.65 (6.0, 9.3)	-1.63 (-2.02, -1.23)
\$100,000 to under \$150,000	8.91 (7.16, 10.66)	-1.81 (-2.23, -1.39)
\$150,000 or more	10.27 (8.45, 12.08)	-2.22 (-2.65, -1.79)
Missing	6.01 (4.02, 7.99)	-1.23 (-1.71, -0.76)
Marital Status (Ref: Single)		
Others	9.99 (9.29, 10.7)	0.32 (0.15, 0.49)
Missing	9.56 (-3.53, 22.65)	2.57 (-0.54, 5.68)
Functional Status (Ref: No)		
Yes	-3.23 (-4.32, -2.14)	1.99 (1.73, 2.25)
Missing Functional Status	-0.97 (-5.22, 3.29)	-0.11 (-1.12, 0.91)
Chronic conditions (Ref: No)		
Yes	1.62 (0.73, 2.51)	-1.03 (-1.24, -0.82)

Missing	-0.12 (-5.84, 5.6)	-1.75 (-3.11, -0.39)
Smoking Status (Ref: Daily smoker)		
Others	1.85 (0.82, 2.88)	-0.61 (-0.86, -0.37)
Missing	2.02 (0.93, 3.12)	-0.89 (-1.15, -0.63)
Alcohol Use (Ref: Regular user)		
Others	1.85 (0.82, 2.88)	0.38 (0.16, 0.6)
Missing	2.02 (0.93, 3.12)	-0.54 (-0.95, -0.14)

Notes: $p < 0.05$ in bolded font; Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors; $\hat{\beta}$ = regression coefficient; CI = confidence interval; Ref= reference category

Table I-2. Mediation Results for Missing Category Analysis (n = 9,274)

	Adjusted Model $\hat{\beta}$ (95%CI)
a-path	0.27 (0.18, 0.44)
b-path	-0.07 (-0.09, -0.04)
Indirect Effect (ab)	-0.02 (-0.02, -0.01)
Direct Effect (c-prime)	-0.07 (-0.09, -0.04)
Total Effect (c)	-0.08 (-0.11, -0.06)
Proportion mediated	0.21 (0.14, 0.31)

Notes: $p < 0.05$ in bolded font; Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors; $\hat{\beta}$ = regression coefficient; CI = confidence interval.

Appendix J. Full Regression Output for Single Level Analysis

Table J-1. “a” and “b” Path for the Adjusted Model (n = 5,958)

Variable	a-Path $\hat{\beta}$ (95% CI) adjusted for dep at t_1	a-Path $\hat{\beta}$ (95% CI) adjusted for dep at t_0 and t_1	b-Path $\hat{\beta}$ (95% CI) adjusted for dep at t_1	b-Path $\hat{\beta}$ (95% CI) adjusted for dep at t_0 and t_1
Memory at t_0	0.04 (-0.15, 0.23)	0.04 (-0.15, 0.23)	-0.06 (-0.11, -0.01)	-0.04 (-0.09, 0.01)
Functional Social Support at t_0	0.6 (0.57, 0.62)	0.6 (0.57, 0.62)	-0.02(-0.03,-0.02)	-0.01 (-0.02, -0.00)
Functional Social Support at t_1			-0.02 (-0.03, -0.02)	-0.02 (-0.03, -0.02)
Depressive Symptoms at t_0				0.22 (0.20, 0.25)
Depressive Symptoms at t_1			0.43 (0.41, 0.45)	0.34 (0.32, 0.37)
Age (Ref: 45-54 years)				
55-64 years	0.54 (-0.29, 1.37)	0.54 (-0.29, 1.37)	-0.37(-0.60,-0.14)	-0.33 (-0.55, -0.11)
65-74 years	0.47 (-0.56, 1.49)	0.47 (-0.56, 1.49)	-0.14 (-0.43, 0.14)	-0.04 (-0.32, 0.23)
75 years or over	0.6 (-0.71, 1.92)	0.6 (-0.71, 1.92)	-0.15 (-0.51, 0.21)	0.04 (-0.31, 0.40)
Sex (Ref: male)				
Female	0.16 (-0.54, 0.86)	0.16 (-0.54, 0.86)	0.30 (0.11, 0.49)	0.22 (0.03, 0.40)
Province (Ref: Alberta)				
British Columbia	1.13 (-0.33, 2.59)	1.13 (-0.33, 2.59)	0.06 (-0.34, 0.46)	0.08 (-0.31, 0.47)
Manitoba	1.8 (0.1, 3.51)	1.8 (0.1, 3.51)	0.11 (-0.36, 0.58)	0.16 (-0.29, 0.62)
News Brunswick	1.4 (-0.34, 3.15)	1.4 (-0.34, 3.15)	0.32 (-0.15, 0.80)	0.32 (-0.15, 0.78)

Newfoundland and Labrador	0.9 (-0.91, 2.7)	0.9 (-0.91, 2.7)	-0.22 (-0.71, 0.28)	-0.23 (-0.71, 0.25)
Nova Scotia	0.01 (-1.62, 1.63)	0.01 (-1.62, 1.63)	0.20 (-0.24, 0.64)	0.18 (-0.26, 0.61)
Ontario	0.78 (-0.52, 2.07)	0.78 (-0.52, 2.07)	-0.06 (-0.42, 0.30)	-0.09 (-0.44, 0.26)
Prince Edward Island	0.29 (-1.57, 2.15)	0.29 (-1.57, 2.15)	-0.11 (-0.62, 0.40)	-0.08 (-0.58, 0.42)
Quebec	1.16 (-0.18, 2.5)	1.16 (-0.18, 2.5)	-0.04 (-0.40, 0.33)	-0.05 (-0.40, 0.31)
Saskatchewan	2.08 (0.31, 3.84)	2.08 (0.31, 3.84)	0.46 (-0.03, 0.94)	0.45 (-0.02, 0.92)
Education (Ref: Less than high school)				
High school diploma	-1.12 (-2.8, 0.57)	-1.12 (-2.8, 0.57)	-0.41 (-0.87, 0.05)	-0.43 (-0.88, 0.02)
Some post-secondary education	-1.86 (-3.74, 0.01)	-1.86 (-3.74, 0.01)	-0.68 (-1.20, -0.17)	-0.62 (-1.12, -0.12)
Post-secondary degree / diploma	-2.05(-3.54,-0.56)	-2.05(-3.54,-0.56)	-0.35 (-0.76, 0.06)	-0.35 (-0.74, 0.05)
Income (Ref: less than \$20,000)				
\$20,000 to under \$50,000	4.15 (2.17, 6.13)	4.15 (2.17, 6.13)	-0.80 (-1.34, -0.26)	-0.62 (-1.14, -0.09)
\$50,000 to under \$100,000	5.83 (3.81, 7.84)	5.83 (3.81, 7.84)	-0.90 (-1.46, -0.35)	-0.67 (-1.21, -0.13)
\$100,000 to under \$150,000	6.72 (4.57, 8.87)	6.72 (4.57, 8.87)	-0.84 (-1.43, -0.25)	-0.56 (-1.13, 0.02)
\$150,000 or more	7.76 (5.52, 10.01)	7.76 (5.52, 10.01)	-1.14 (-1.76, -0.52)	-0.89 (-1.49, -0.29)
Marital Status (Ref: Single)				
Others	3.09 (2.17, 4.01)	3.09 (2.17, 4.01)	0.09 (-0.16, 0.35)	0.05 (-0.19, 0.30)
Functional Status (Ref: No)				
Yes	-1.15 (-2.51, 0.21)	-1.15 (-2.51, 0.21)	0.78 (0.41, 1.16)	0.50 (0.14, 0.87)
Chronic conditions (Ref: No)				

Yes	1.52 (0.4, 2.65)	1.52 (0.4, 2.65)	-0.32 (-0.63, -0.01)	-0.20 (-0.50, 0.10)
<i>Smoking Status</i> (Ref: Daily smoker)				
Others	1.09 (0.02, 2.16)	1.09 (0.02, 2.16)	-0.34 (-0.63, -0.05)	-0.25 (-0.54, 0.03)
<i>Alcohol Use</i> (Ref: Regular user)				
Others	-0.09 (-1.27, 1.10)	-0.09 (-1.27, 1.10)	0.36 (0.04, 0.68)	0.35 (0.03, 0.66)

Notes: $p < 0.05$ in bolded font; Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviors.
 $\hat{\beta}$ = regression coefficient; CI = confidence interval; dep=depressive symptoms score; t_0 =baseline, t_1 = first follow-up; Ref = Reference category

Table J-2: Mediation results for Single Level Analysis (n = 5,958)

	$\hat{\beta}$ (95%CI) (adjusted for dep at t ₀ & t ₁)	$\hat{\beta}$ (95%CI) (adjusted for dep at t ₁ only)
Indirect effect (ab)	-0.00 (-0.01 , 0.00)	-0.00 (-0.01, 0.00)
Direct effect (c-prime)	-0.04 (-0.09 , 0.02)	-0.06 (-0.11, -0.01)
Total effect (c)	-0.04 (-0.09 , 0.02)	-0.06 (-0.12, -0.02)
Proportion Mediated	0.00 (-0.30, 0.26)	0.00 (-0.07, 0.13)

Notes: $p < 0.05$ in bolded font; Adjusted for functional social support, baseline sociodemographic factors, health status, and lifestyle behaviours. $\hat{\beta}$ = regression coefficient; CI = confidence interval; dep=depressive symptoms score; t₀=baseline, t₁= first follow-up.

Appendix K. Model Diagnostics

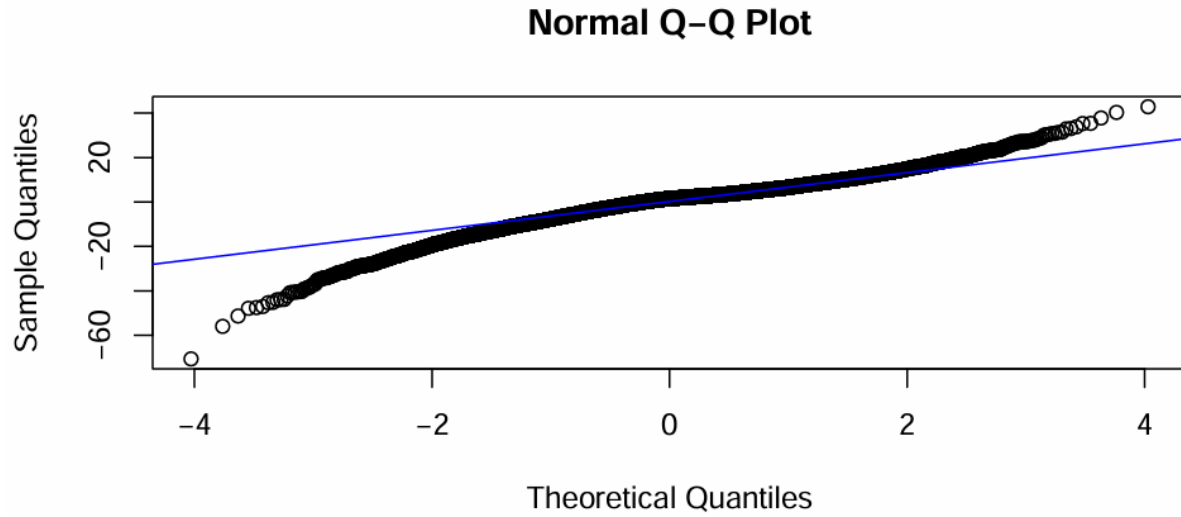


Figure K-1. Model Diagnostics for Linear Regression of the “a” Path - Q-Q Residuals

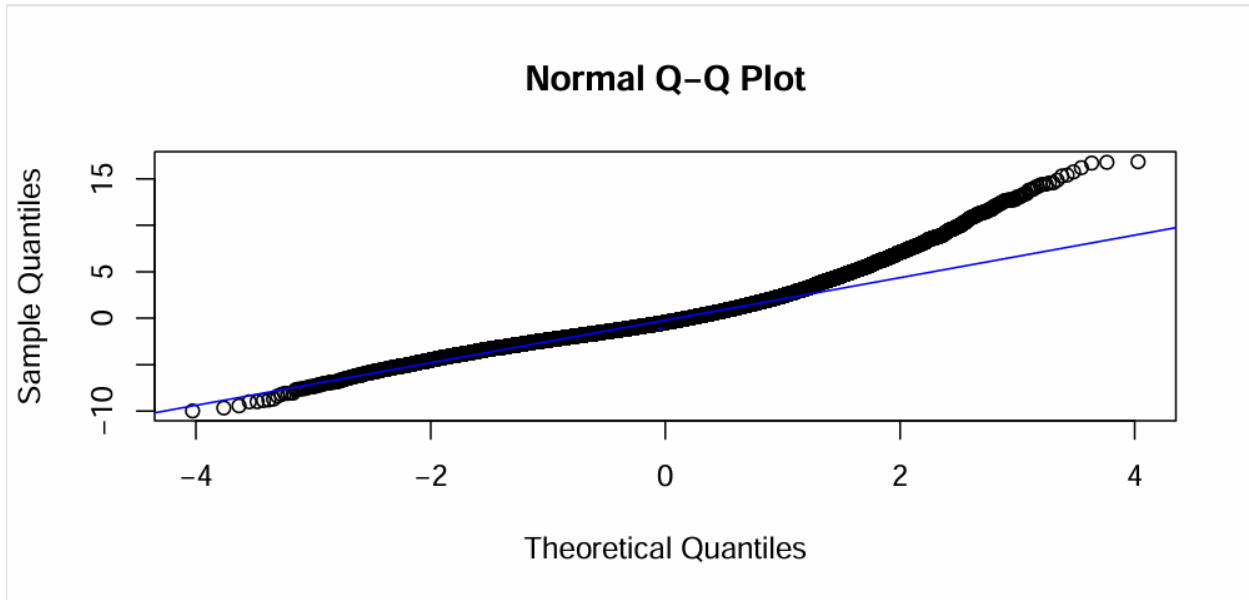


Figure K-2. Model Diagnostics for Linear Regression of the “b” Path - Q-Q Residuals

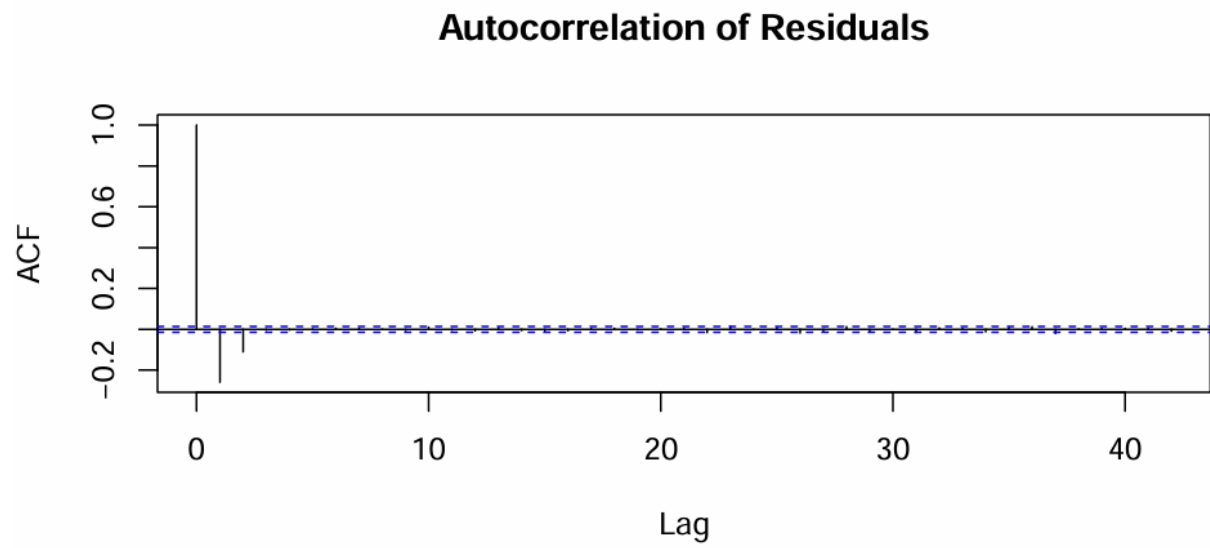


Figure K-3. Model Diagnostics for Linear Regression of the “a” Path– Autocorrelation of Residuals

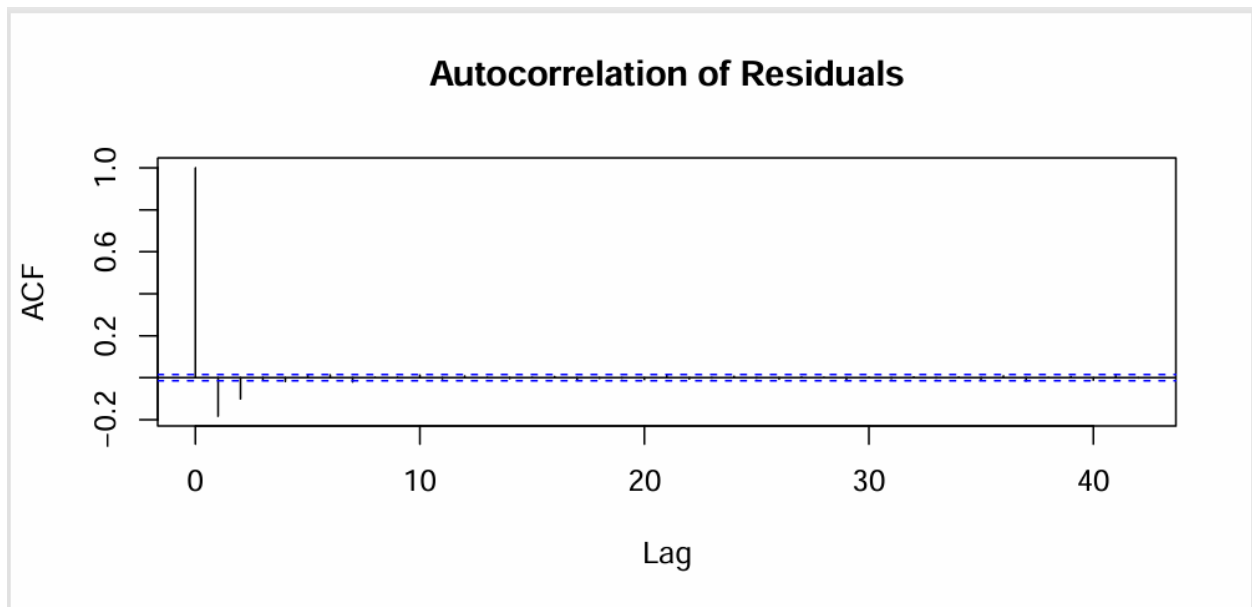


Figure K-4. Model Diagnostics for Linear Regression of the “b” Path– Autocorrelation of Residuals

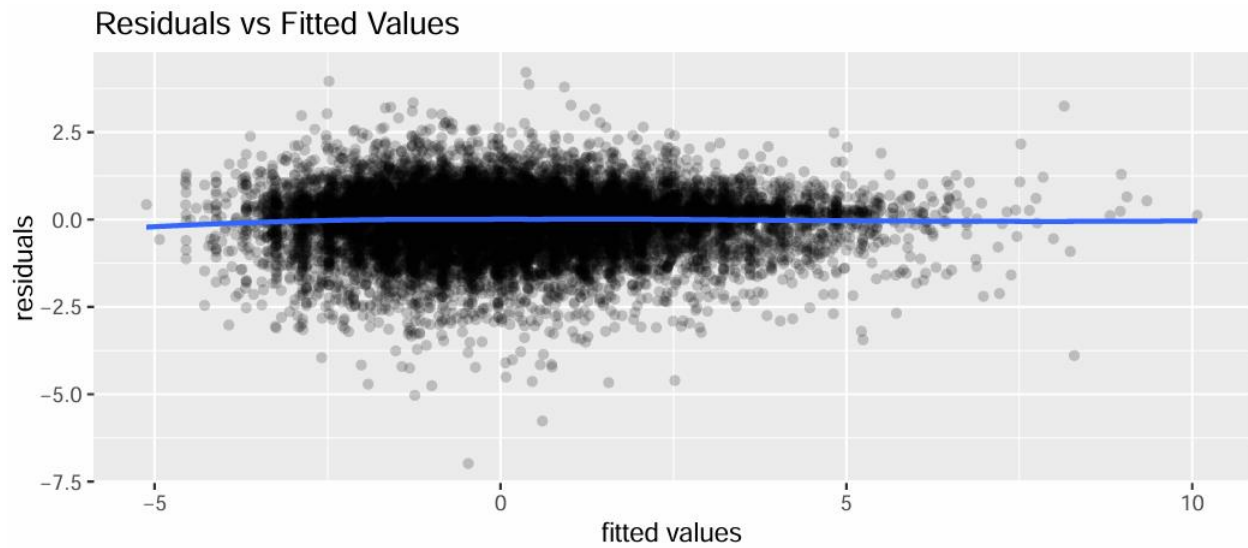


Figure K-5. Model Diagnostics for Linear Regression of the “a” Path – Residuals versus Fitted

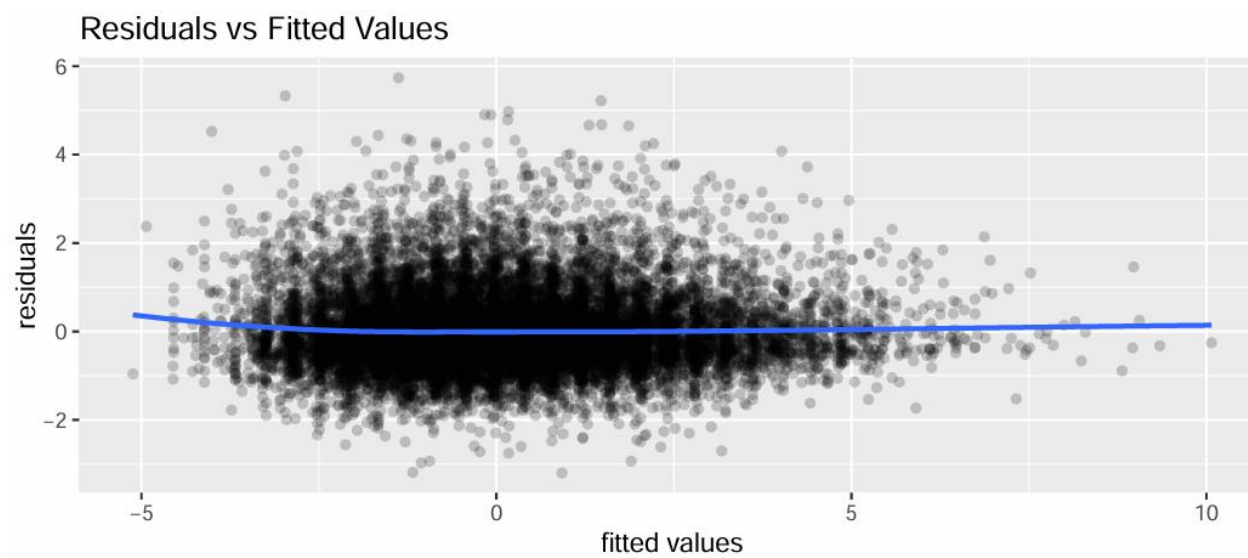


Figure K-6. Model Diagnostics for Linear Regression of the “b” Path –Residuals versus Fitted