The Association Between Physical Activity and Sleep Quality on Risk of Anxiety and Depression across Cognitive Statuses in Older Adults

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.

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Abstract

Introduction: Anxiety and depression are prevalent neuropsychiatric issues among older adults with cognitive impairment. They are associated with accelerated cognitive decline, increased caregiver burden, and reduced quality of life. Given the noticeable side effects of pharmacological treatments, there is growing interest in non-pharmacological approaches to tackle anxiety and depression. Physical activity and sleep quality have shown promise in reducing anxiety and depression in the general population, but their potential benefits remain largely underexplored in older adults with cognitive impairment. The objectives of this thesis were to: 1) examine the associations between physical activity and sleep quality with odds of having anxiety and depression among older adults with different cognitive statuses; 2) investigate whether physical activity moderates the association between sleep quality with anxiety and depression; and 3) explore whether the associations between sleep, physical activity, and anxiety and depression vary by dementia subtype.

Methods: This was a secondary analysis of data from the Comprehensive Assessment of Neurodegeneration and Dementia study. Physical activity was assessed using the Physical Activity Scale for the Elderly (PASE) and sleep quality with the Pittsburgh Sleep Quality Index (PSQI). Anxiety and depression symptoms were assessed using the Generalized Anxiety Disorder 7–item (GAD-7) and the Geriatric Depression Scale (GDS). Cutoff scores of GAD-7 ≥ 5 and GDS ≥ 10 were used to identify participants who are likely to have at least mild anxiety or depression. Logistic regression models with a backward selection of covariates were used to evaluate associations.

Results: The study sample included 956 older adults: 150 with no cognitive impairment, 116 with subjective cognitive impairment, 460 with mild cognitive impairment, and 230 with dementia. Poor sleep quality was strongly associated with increased odds of both anxiety (OR = 1.138, CI = 1.09–1.19, $p < 0.001$) and depression (OR = 1.355, CI = 1.137–1.646, $p = 0.001$). Increased physical activity was associated with lower odds of depression (OR = 0.996, CI = 0.994–0.999, $p = 0.038$), but higher odds of anxiety (OR = 1.003, CI = 1.000–1.006, $p = 0.007$). The relationship between physical activity and outcomes was consistent across cognitive groups, whereas the association between sleep quality and depression was weaker among people with dementia. Moreover, no significant interaction between sleep quality and physical activity was found, suggesting that there is no moderating effect in their relationship with anxiety and depression. Additionally, none of the associations varied by dementia type, indicating consistent relationships across different types of dementia.

Conclusion: The consistent association between poor sleep quality and higher odds of anxiety and depression emphasizes the need to prioritize sleep interventions among older adults with various cognitive statuses. Physical activity may be beneficial in reducing depressive symptoms, but its unexpected positive association with anxiety highlights the need for further investigation.

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Table of Contents

Author's Declaration ii
Abstract iii
Acknowledgements v
List of Tables viii
List of Abbreviations ix
1.0 Review of Literature 1
1.1 Cognitive Impairment Spectrum and Its Impact 1
1.2 Impact of Anxiety and Depression 3
1.3 Treatments for Anxiety and Depression 7
1.3.1 Pharmacological Treatments 8
1.3.2 Non-pharmacological Approaches 8
1.3.2.1 Physical Activity and Exercise 10
1.3.2.2 Sleep Quality 12
1.4 Mechanisms Linking Physical Activity to Reduced Anxiety and Depression 14
1.5 Mechanisms Linking Sleep Quality to Reduced Anxiety and Depression 16
1.6 Effects of Physical Activity on Sleep Quality 16
2.0 Current Study 18
2.1 Rationale 18
2.2 Objectives and Hypothesis 18
3.0 Methods 20
3.1 Study Design 20
3.2 Participants 20
3.3 Assessments 21
3.4 Data Analysis 22

3.4.1 Logistic Regression Model Framework 23
3.4.2 Selection of Covariates 23
3.4.3 Logistic Regression Assumption Checks 25
4.0 Results 27
4.1 Descriptive Statistics 27
4.2 The Association Between Physical Activity and Sleep Quality with Anxiety (Objective 1) 29
4.3 The Association Between Physical Activity and Sleep Quality with Depression (Objective 2) 30
4.4 Moderation Effect of Physical Activity (Objective 3) 31
4.5 Differential Association of Physical Activity and Sleep Quality with Anxiety and Depression Across Dementia Subtypes (Objectives 4 & 5) 33
5.0 Discussion 38
5.1 Strengths and Limitations 41
5.2 Conclusion and Future Directions 42
References 44
Appendices 64
Appendix A: Box-Tidwell Test Results 64
Appendix B: Questionnaires 65

List of Tables

Table 1. Summary of Logistic Regression Models by Study Objective 24
Table 2. Participants' Characteristics by Cognitive Status 28
Table 3. Regression Results for the Odds of Anxiety (GAD ≥ 5) 30
Table 4. Regression Results for the Odds of Depression (GDS ≥ 10) 31
Table 5. Regression Results for the Moderation Effect of Physical Activity 32
Table 6. Regression Results for the Association Between Physical Activity and Odds of Anxiety (GAD-7 ≥ 5) Across Dementia Subtypes 34
Table 7. Regression Results for the Association Between Sleep Quality and Odds of Anxiety (GAD-7 ≥ 5) Across Dementia Subtypes 35
Table 8. Regression Results for the Association Between Physical Activity and Odds of Depression (GDS ≥ 10) Across Dementia Subtypes 36
Table 9. Regression Results for the Association Between Sleep Quality and Odds of Depression (GDS ≥ 10) Across Dementia Subtypes 37

List of Abbreviations

AD ……..Alzheimer's Disease

CU ……..Cognitively Unimpaired

FTD ……... Frontotemporal Dementia

GAD-7 ……Generalized Anxiety Disorder-7 item

GDS ……Geriatric Depression Scale

LBD ……Lewy Body Dementia

MCI ……... Mild Cognitive Impairment

PASE……...Physical Activity Scale for Elderly

PSQI……Pittsburgh Sleep Quality Index

SCI ……..Subjective Cognitive Impairment

VaD……..Vascular Dementia

1.0 Review of Literature

1.1 Cognitive Impairment Spectrum and Its Impact

Cognitive impairment refers to a decline in one or more cognitive domains, such as memory, language, attention, and executive function (Harvey, 2019). It can result from different etiologies, including neurodegenerative disorders, psychiatric conditions, or medical comorbidities (Dhakal & Bobrin, 2025). Even mild stages of cognitive impairment can lead to challenges in performing daily activities, increased dependence on others, and reduced quality of life (Aretouli & Brandt, 2010). In the context of aging and neurodegeneration, cognitive impairment is largely viewed as a spectrum consisting of three primary categories: subjective cognitive impairment (SCI), mild cognitive impairment (MCI), and dementia (Jongsiriyanyong & Limpawattana, 2018). Each stage is characterized by specific criteria and varying impacts on cognitive function, daily activities, and emotional well-being, with the degree of impairment and care needs increasing across the spectrum (Facal et al., 2018).

Subjective cognitive impairment (SCI), also known as subjective cognitive decline, is characterized by self-reported cognitive difficulties without objectively measurable deficits. The term was conceived in 2014 to describe a condition when individuals have a self-perceived memory decline, but performance on cognitive tests remains in a normal range for their age (Jessen et al., 2020).

SCI prevalence is reported to range between 15-54% in population-based studies and academic memory clinics (Pippenger, 2023). Studies revealed that the prevalence of SCI can be influenced by factors such as gender, education, ethnicity, and income level (Röhr et al., 2020). Importantly, longitudinal evidence suggests that SCI can modestly increase the risk of progression to MCI or dementia over several years (Jessen et al., 2010). Research shows that people with SCI often report difficulties in performing complex instrumental activities of daily living, such as managing finances or medication (Rotenberg et al., 2020). Emerging evidence also suggests the presence of early functional limitations in this population, despite the absence of measurable cognitive deficits on standardized tests (Rotenberg & Dawson, 2022). Moreover, SCI is also associated with higher anxiety and depressive symptoms, which can further reduce well-being, social engagement, and quality of life (Sabatini et al., 2022; Lee & Ho Chung, 2022).

Mild cognitive impairment (MCI) is a condition characterized by cognitive changes that are noticeable but do not yet substantially interfere with daily functioning, allowing individuals to maintain relative independence in everyday activities (Knopman & Petersen, 2014). MCI affects over 15% of adults aged 55 and older worldwide, making it an important public health concern due to its potential progression to dementia (Bai et al., 2022). People with MCI may experience impaired memory and executive function, with lesser severity than people with dementia (described below) (Bayles et al., 1987; Petersen et al., 2014). Increased rates of anxiety and depression are also frequently reported in people with MCI and may exacerbate cognitive and functional challenges (Ma, 2020).

MCI is considered a transitional and dynamic stage between normal cognitive aging and dementia. While some individuals remain stable or even revert to normal cognition, people with MCI are at increased risk of progressing to dementia (Lovell, 2010). This transitional nature underscores the importance of MCI as a critical stage for early identification, intervention, and monitoring (Roberts & Knopman, 2013).

Dementia is an umbrella term for a progressive decline in cognitive abilities. It is currently the seventh leading cause of death and a major contributor to disability and dependency among older adults worldwide (WHO, 2023). According to the World Health Organization (WHO) statistics, more than 55 million people had dementia in 2023. This figure is anticipated to almost double every two decades, with projections estimating that by 2050, 139 million individuals will be living with dementia on a global scale (WHO, 2021). In Canada, the situation mirrors the global trend, with over 650,000 people currently living with dementia, and the numbers are rapidly increasing (Alzheimer Society of Canada, 2024). Each day, more than 350 Canadians are diagnosed with dementia (Alzheimer Society of Canada, 2024).

Dementia is associated with a broad range of cognitive, functional, and behavioral symptoms, including memory impairment, disorientation, communication difficulties, and reduced ability to perform daily activities, all of which increase care needs as the disease progresses (Jutkowitz et al., 2017; Rabins et al., 1982). Dementia encompasses various types, such as Alzheimer's disease (AD), vascular dementia (VaD), frontotemporal dementia (FTD), and dementia with Lewy bodies (LBD), each with distinct symptoms and potential causes (Duong et al., 2017)

In addition to cognitive and functional impairments, people with dementia often experience significant emotional distress, including anxiety, depression, and frustration (Cerejeira et al., 2012). Individuals may exhibit behaviors such as agitation or withdrawal, reflecting their struggle to adapt to the changes in their cognitive abilities and the associated loss of independence (Müller-Spahn, 2003). Thus, a comprehensive understanding of these mental and emotional impacts of dementia is essential for developing holistic care approaches that enhance the quality of life for people with dementia and their caregivers.

1.2 Impact of Anxiety and Depression

Anxiety and depression are among the most prevalent psychiatric disorders in older adults, and they frequently present together (Dong et al., 2020). The co-occurrence of anxiety and depression is associated with a greater impact on cognitive function and quality of life than either occurring alone (Zu et al., 2025). Therefore, understanding the combined and individual impacts of anxiety and depression is essential to improve care in people with cognitive impairment.

While the terms anxiety and depression are often used to describe both clinical conditions and general emotional symptoms, it is important to distinguish the two in research contexts. A clinical diagnosis of anxiety and depression requires comprehensive psychiatric evaluations by a physician based on established diagnostic criteria. In this study, anxiety and depression symptoms were assessed using self-reported questionnaires that are designed to capture the presence and severity of symptoms rather than a formal diagnosis. However, the cut-off scores used were validated against clinical diagnoses and thus provide an estimate of whether an individual may be experiencing clinically significant anxiety or depression. Therefore, throughout this thesis, we refer to anxiety and depression symptoms when discussing continuous scale scores and (odds of) having anxiety or depression when referring to the dichotomous outcome that was validated against clinical examinations.

Anxiety and depression are particularly common in people across the cognitive impairment spectrum, including those with SCI, MCI, and dementia (Hill et al., 2016; Ma, 2020; Cerejeira et al., 2012). Prevalence rates vary widely based on the diagnostic criteria and assessment tools, but both anxiety and depression are consistently reported to be higher in people with cognitive impairment compared to people without cognitive impairment. For example, studies have shown anxiety affects approximately 14 -31% of people with MCI and up to 72% of those with dementia (Badrakalimuthu & Tarbuck, 2012; Chen et al., 2018). Similarly, the overall prevalence of depression has been

reported to be 32% in people with MCI and up to 69% in people with dementia (Collins et al., 2023; Ismail et al., 2017). These rates vary widely across different types of dementia. Most studies report higher prevalence rates in FTD and VaD compared to those with AD (Collins et al., 2023; Porter et al., 2003). While earlier studies may suggest that moderate stages have higher rates of neuropsychiatric symptoms like anxiety (Sadak et al., 2014), a recent meta-analysis revealed that anxiety and depression symptoms are consistently high among all the stages, with no significant trend (Leung et al., 2021). The reported rates were 38% in mild, 41% in moderate, and 37% in severe stages, demonstrating minimal variation across the progression of dementia (Leung et al., 2021).

Studies suggest that both anxiety and depression are intricately linked with cognitive decline, creating a vicious cycle that exacerbates both conditions in individuals with cognitive impairment (Jain et al., 2020; Moon et al., 2017). In MCI, anxiety and depressive symptoms have been associated with accelerated cognitive decline and potentially higher risk of progression to dementia, particularly AD (Liew, 2020; Martin & Velayudhan, 2020; Moon et al., 2017). This interplay may stem from individuals' awareness of their cognitive decline, where fear of progression contributes to anxiety, which in turn worsens cognitive function (Martin & Velayudhan, 2020).

In dementia, this bidirectional interplay intensifies as neuropathological changes such as hippocampal atrophy and neurotransmitter imbalances exacerbate anxiety and depressive symptoms (Botto et al., 2022). A longitudinal cohort study revealed that higher levels of anxiety and vulnerability to stress were associated with a more rapid decline in global cognition, episodic memory, and working memory (Wilson et al., 2011). Therefore, managing anxiety and depression in individuals with cognitive impairment seems to be crucial, as effective coping strategies can help break this destructive cycle. By doing so, it may be possible to slow cognitive decline and improve the overall quality of life of this population.

The physiological mechanisms by which cognitive impairment leads to anxiety and depression are likely related to neuropathological changes in the brain and neurochemical imbalances (Botto et al., 2022). As dementia progresses, significant alterations occur in brain regions responsible for cognitive and emotional regulation, such as the hippocampus, amygdala, and prefrontal cortex (Brand & Markowitsch, 2008; Salzman & Fusi, 2010). The hippocampus, crucial for memory formation and emotional processing, undergoes atrophy, which can result in confusion and contribute to anxiety-related disorders (Femenía et al., 2012). The amygdala, involved in processing emotions, and the

prefrontal cortex, which regulates emotional responses, also deteriorate, impairing the individual's ability to manage stress and anxiety effectively (Salzman & Fusi, 2010). Neurochemical changes, including reduced levels of serotonin and norepinephrine (neurotransmitters critical for mood regulation) further exacerbate anxiety symptoms and trigger the development of depression (Ressler & Nemeroff, 2000; Zubenko et al., 1990). Neuroimaging studies suggest SCI is associated with hyperconnectivity between the insula and hippocampus, brain regions involved in processing uncertainty and emotions. This hyperactivity may intensify emotional distress, leading to higher anxiety and depressive symptoms in people with SCI (Attaallah et al., 2022).

Prevalence and manifestation of anxiety and depression vary across dementia subtypes and have distinct neuropathological and connectivity patterns in the brain (Zhao et al., 2024). In AD, anxiety and depression may arise from hippocampal degeneration, which disrupts emotional regulation and stress response pathways (Silva et al., 2019; Ghasemi et al., 2022). LBD often involves heightened anxiety and depression symptoms, possibly arising from disruption in the limbic system, particularly the amygdala, which is involved in emotional processing (Walker et al., 2015; Kwak et al., 2017). These symptoms are often exacerbated by the hallmark symptoms of LBD, such as visual hallucinations, fluctuating cognition, and motor disturbances, all of which contribute to emotional distress (Mosimann et al., 2006). Compared to AD, individuals with LBD are more likely to experience anxiety and depression, underscoring the unique challenges posed by this subtype (Sadak et al., 2014). In FTD, degeneration of the orbitofrontal cortex, the region for subjective perception of anxiety and emotional processing, could explain the prevalence of anxiety symptoms in this group (Charney & Deutch, 1996; Kenwood et al., 2022). Mixed dementia has combined features of AD and VaD, potentially leading to compounded effects of anxiety and depression due to both gradual neurodegeneration and acute vascular damage (Custodio et al., 2017). Understanding how anxiety and depression arise from distinct mechanisms highlights the potential for modifiable risk factors like physical activity or sleep quality to have differential associations with these symptoms across subtypes.

In addition to physiological mechanisms, several other factors contribute to the development of anxiety and depression in individuals with cognitive impairment. One primary factor is the progressive loss of cognitive abilities. People with MCI may experience heightened anxiety and depression as they become aware of subtle but persistent difficulties in memory, problem-solving, or language, often fearing progression to more severe impairment (Martin & Velayudhan, 2020). These

experiences can become even more challenging in dementia, where individuals often struggle to remember recent events, recognize familiar faces, or find the right words during conversations (Cerejeira et al., 2012). This cognitive disorientation can trigger anxiety and depression as individuals of both groups become increasingly aware of their declining abilities and the unpredictable nature of their condition (Seignourel et al., 2008). Similarly, people with SCI often experience higher anxiety and depression symptoms in response to perceived changes in their cognitive function. Heightened self-monitoring and persistent concerns about developing dementia lead to emotional distress and increase vulnerability to mood disturbances (Sabatini et al., 2022).

Another significant factor contributing to anxiety and depression in dementia is the loss of independence and autonomy (Orrell & Bebbington, 1996). As cognitive decline progresses, individuals may find themselves unable to perform everyday tasks such as managing finances, cooking, or personal hygiene, leading to increased dependence on caregivers (M. Brown et al., 2020). This loss of self-sufficiency can be distressing and contribute to feelings of helplessness, anxiety, and depression (Goyal et al., 2019). The fear of becoming a burden to loved ones and the uncertainty about the future further exacerbate these feelings (Boer et al., 2007).

Anxiety and depression have numerous negative effects on physical and mental health, increasing morbidity and mortality (Meier et al., 2016). Research highlights that anxiety and depression can worsen the course of chronic physical illnesses like gastrointestinal disorders, cancer, heart disease, and diabetes (Sobel & Markov, 2005). This is driven by both behavioral factors, like unhealthy lifestyle choices, disrupted sleep, and poor medical adherence, and biological mechanisms such as increased inflammation and disruption of the hypothalamic-pituitary-adrenal axis, which exacerbate adverse health outcomes (Sobel & Markov, 2005). Moreover, stress, anxiety, and depression have shown to be associated with a depressed immunological response, potentially increasing vulnerability to infections and other diseases (Cañas-González et al., 2020). A review by Ahmad et al. (2014) highlights that heightened anxiety and a constant state of worry and tension in adults can lead to sleep disturbances and cognitive decline, which in turn results in fatigue, low concentration, and diminished overall well-being (Ahmad et al., 2014). Also, older adults with anxiety disorders or even mild anxiety and depressive symptoms face increased disability, reduced quality of life, and higher utilization of health care services (Porensky et al., 2009; Brenes, 2007). This group often experiences significant impacts on their daily functioning, yet many do not receive appropriate or timely

treatment, highlighting a gap in health care for managing anxiety and depression in late life (Beurs et al., 1999).

Anxiety in people with dementia often manifests as heightened agitation and restlessness, as they struggle to communicate their needs and frustrations (Twelftree & Qazi, 2006). These symptoms, along with depressive symptoms and sleep disturbances, can increase the burden on caregivers, who must manage not only the physical care but also the emotional and psychological challenges associated with these behaviors (Wrede et al., 2025). Anxiety and depression are more prevalent in people with dementia compared to those without, and it is associated with greater limitations in activities of daily living, lower quality of life, and poorer neuropsychological performance (Seignourel et al., 2008; Lee & Ho Chung, 2022). Furthermore, physical complications of anxiety and depression, such as cardiovascular problems and a weakened immune system, can lead to a greater likelihood of nursing home placement, further affecting the life satisfaction of individuals with cognitive impairment (Kwak et al., 2017). Therefore, treating anxiety and depression in this population is crucial to enhance their quality of life and alleviate the significant burden on caregivers, ultimately promoting better health outcomes for both.

1.3 Treatments for Anxiety and Depression

Anxiety and depression are among the most common mental health conditions worldwide. According to the WHO, anxiety disorders affected approximately 301 million people in 2019, and an estimated 5% of adults suffer from depression on a global scale (WHO, 2023). Despite their high prevalence, anxiety and depression remain largely underrecognized and undertreated, particularly in older adults with cognitive impairment (Badrakalimuthu & Tarbuck, 2012; Dafsari & Jessen, 2020). Both pharmacological and non-pharmacological treatments can effectively manage anxiety and depressive symptoms, with pharmacological options often yielding stronger immediate effects (Bandelow et al., 2015). However, non-pharmacological approaches are recommended to be considered the first line of treatment for anxiety and depression in people with dementia and MCI, as they offer lower risks and are generally well-suited for long-term management (Lee et al., 2024). Non-pharmacological approaches emphasize addressing modifiable risk factors such as physical inactivity and poor sleep quality, which are linked to reductions in anxiety and depressive symptoms and may produce synergistic effects. As such, there is growing interest in non-pharmacological

interventions targeting modifiable risk factors such as physical activity and poor sleep quality (Su et al., 2021; Barham et al., 2022).

1.3.1 Pharmacological Treatments

Pharmacological interventions are often used as the first line of treatment for both anxiety disorders and depressive symptoms, with medications such as benzodiazepines and selective serotonin reuptake inhibitors being the most prescribed (Bandelow et al., 2017; Kovich et al., 2023). These medications have well-documented anxiolytic and antidepressive effects, making them effective in reducing anxiety and depression symptoms in the general population (Bandelow et al., 2017; Kovich et al., 2023). However, the effectiveness and safety of these medications in people with dementia are less clear and often controversial. A recent systematic review identified only seven randomized controlled trials since 1990 evaluating the effectiveness of antidepressants for reducing anxiety in people with dementia, with five reporting no benefits compared to placebo (Bingley et al., 2025). Also, such medications often have several side effects, including drowsiness, dizziness, increased hostility or aggression, cognitive impairment or impaired memory, etc. (Schnabel Jr, 1987). In people with dementia and MCI, these adverse effects are even more concerning because they can worsen cognitive function, potentially causing increased memory issues, disorientation, and confusion (McShane et al., 1997; Crowe & Stranks, 2018). Furthermore, the dizziness and drowsiness caused by these drugs can increase the risk of falls and fractures in this group, which further elevates care needs and healthcare costs (Lenze et al., 2003). Given these concerns, exploring non-pharmacological approaches for managing anxiety, depression, and distress becomes imperative in individuals with cognitive impairment.

1.3.2 Non-pharmacological Approaches

Non-pharmacological approaches provide low-risk alternatives or complements to medications to address both the physical and emotional symptoms of anxiety and depression (Lee et al., 2024; Burley et al., 2022). Examples of non-pharmacological interventions for anxiety and depression include cognitive behavioral therapy, music therapy, aromatherapy, and targeting modifiable risk factors such as physical activity and sleep quality. These interventions aim to reduce anxiety and depression symptoms by improving emotional resilience and addressing lifestyle factors that influence mental health.

Cognitive behavioral therapy is considered one of the most well-researched and effective psychotherapies for anxiety disorders and depressive symptoms (Servant, 2019; Lepping et al., 2017). This approach helps individuals recognize and modify negative thought patterns and behaviors that contribute to anxiety and depression. A recent systematic review of twelve publications suggested strong evidence on the association between cognitive behavioral therapy and improvements in anxiety, depression, and quality of life in people with MCI and dementia (Jin et al., 2021).

A crossover randomized control trial among 60 individuals with various dementia subtypes explored the effects of three non-pharmacological interventions, including music therapy, exercise, and aromatherapy with massage, on behavioral and psychological symptoms of dementia (Dimitriou et al., 2020). Participants were divided into six groups, and each intervention lasted five days, followed by a two-day washout period to minimize crossover effects. Anxiety, depression, and other neuropsychiatric symptoms were assessed using the Neuropsychiatric Inventory and other standardized measures, including the Geriatric Depression Scale (Dimitriou et al., 2020). Here, music therapy was the most effective intervention, with exercise following as the second most beneficial treatment. Aromatherapy and massage also showed positive but less substantial effects for both anxiety and depression. These findings highlight the potential of music therapy and exercise as effective, low-risk alternatives for managing anxiety and depression in people with dementia, although further research is needed to confirm these benefits across diverse settings and over extended durations (Dimitriou et al., 2020).

Improving sleep quality has also been associated with reductions in anxiety and depression. Scott et al. (2021) conducted a meta-analysis of randomized controlled trials that investigated interventions to improve sleep quality and their effects on mental health, including anxiety and depression. The study included a range of populations, such as adults with insomnia, older adults with chronic health conditions, and those with anxiety disorders. Interventions included cognitive behavioral therapy for insomnia, mindfulness-based therapies, and other structured behavioral approaches. The findings revealed that those interventions that effectively improved sleep quality had a statistically significant, small-to-medium effect on anxiety and depression (Scott et al., 2021).

Building on these approaches, research emphasizes the role of physical activity and sleep quality in managing anxiety in the general population, but the evidence regarding their effects in people with

dementia and MCI is limited. The following sections delve into existing studies on these interventions across different populations.

1.3.2.1 Physical Activity and Exercise

Physical activity refers to any movement that requires energy expenditure, such as walking, gardening, or doing household chores. It includes a wide range of activities that can be integrated into daily life and contribute to overall health. Exercise, on the other hand, is a structured and planned subset of physical activity, with specific goals to improve physical fitness, strength, and endurance (Caspersen et al., 1985). Both physical activity and exercise have been examined for effects on mental health, including their ability to reduce anxiety and depression. The evidence supporting benefits is variable but spans across different populations, including adults, older adults, and people with cognitive impairment.

In adults, numerous studies have demonstrated a relationship between physical activity and reduced anxiety and depression. A cross-sectional study by Khanzada et al. (2015) found that individuals who engaged in regular physical activity experienced lower levels of anxiety and depression compared to those who were physically inactive. Additionally, a synthesis of the systematic reviews of randomized controlled trials by Singh et al. (2023) confirmed that physical activity is associated with lower symptoms of anxiety and depression across a variety of populations, including healthy adults, individuals with mental health disorders, and those with various chronic diseases. The review also found that moderate-intensity physical activity was particularly effective in reducing anxiety symptoms compared to low-intensity activity (Singh et al., 2023). Similarly, a narrative review by Kandola et al. (2018) suggested that physical activity serves as a promising treatment option for people with anxiety disorders. However, the underlying mechanisms and most effective physical activity protocols need to be investigated (Kandola et al., 2018).

A meta-analysis of six randomized controlled trials, including 262 adults, revealed that aerobic exercise can substantially reduce anxiety symptoms in individuals with anxiety or stress-related disorders (Stubbs et al., 2017). Participants were randomized into exercise or control groups and participated in exercise one to seven times per week at moderate to high intensity. Anxiety was assessed using both clinician-rated and self-reported measures, with the results consistently showing that exercise reduced symptoms of anxiety, though study quality was variable (Stubbs et al., 2017). Also, a recent systematic review of 218 randomized controlled trials, including a total of 14,140

participants, assessed the effects of various exercise modalities and intensities on depression among adults with major depressive disorders (Noetel et al., 2024). The findings indicated that all forms of exercise resulted in moderate reductions in depressive symptoms compared to active control conditions. Notably, walking or jogging, yoga, and strength training produced moderate reductions in depression, with larger effect sizes than tai chi or mixed aerobic exercise. Moreover, the review suggested that higher-intensity exercise was associated with greater improvements in depressive symptoms, highlighting the potential dose-response relationship between physical activity intensity and mental health outcomes.

In older adults, both anxiety and depression are often underdiagnosed and undertreated, with anxiety being even less studied and less recognized than depression (Allan et al., 2014; Johnco et al., 2024). However, there is growing evidence for the relationship between increased physical activity and lower anxiety and depressive symptoms within this population, emphasizing its potential as a therapeutic intervention (Kazeminia et al., 2020; Bridle et al., 2012). A cross-sectional study of 200 older adults showed higher anxiety and depression levels in those who were sedentary compared to those who engaged in physical activities in a social center for the elderly (Oliveira et al., 2019). A recent randomized controlled trial by Ruiz-Comellas et al. (2022) explored the effects of a 4-month moderate physical activity program on depression and anxiety levels in 90 individuals aged 65 and older. The study found that walking just two days per week resulted in a 45% relative risk reduction in meeting the diagnostic threshold for anxiety and a 59% relative risk reduction for depression by the end of the trial, underscoring the effectiveness of moderate physical activity as a practical and accessible intervention for managing both anxiety and depression among older adults (Ruiz-Comellas et al., 2022).

While there is evidence that physical activity may reduce anxiety and depression symptoms in adults and older adult populations generally, studies focusing specifically on people with cognitive impairment are relatively limited and tend to focus more on cognitive outcomes rather than mental health, particularly anxiety and depression. However, several studies have explored the broader effects of physical activity on behavioral and psychological symptoms of dementia (BPSD) (Thuné-Boyle et al., 2012). These symptoms encompass a range of non-cognitive expressions among people with dementia, including anxiety and depression, but also agitation, delusions, hallucinations, wandering, and apathy (Cerejeira et al., 2012). These behaviors, at least in part, represent personal expression of needs or distress. While these symptoms can impact the individual's quality of life, they

also contribute to increased demands on caregivers, who must navigate both the emotional and practical aspects of providing support (Cerejeira et al., 2012).

The effects of physical activity on BPSD among people with dementia may vary by type of dementia. A study by Cristoforetti et al. (2011), involving 59 participants with AD, VaD, and mixed dementia, explored neuropsychiatric symptoms using the Neuropsychiatric Inventory. The study divided participants into two groups based on their physical activity levels over the past six months. Participants with AD and VaD who engaged in physical activity exhibited fewer neuropsychiatric symptoms compared to the sedentary group. However, no association between physical activity and neuropsychiatric symptoms was observed in participants with mixed dementia (Christofoletti et al., 2011). Additionally, a review by Thuné-Boyle et al. (2012) has shown the positive effects of exercise interventions in reducing some BPSD, notably depressed mood, agitation, and wandering, while also helping to improve night-time sleep. However, current evidence regarding the efficacy of exercise in alleviating specific symptoms, including anxiety, remains limited and requires further research to determine the impact of exercise (Thuné-Boyle et al., 2012).

Research among people with MCI is also limited. A recent scoping review on the effect of physical exercise in people with MCI highlights that various forms of exercise contribute to improved cognitive function and reduced anxiety (Stavrou et al., 2024). Exercise may mitigate anxiety through neurochemical changes, improved sleep quality, increased social interaction, and reduced brain inflammation (Stavrou et al., 2024). However, the evidence of reducing anxiety levels among people with MCI remains inconsistent, with some studies likely underpowered to detect an effect. A systematic review of 17 randomized controlled trials by Chen et al. (2024) investigated the effects of exercise on neuropsychiatric symptoms and quality of life in people with MCI. The review reported a small but statistically significant positive effect of exercise interventions, particularly mind-body exercise interventions, on depression. However, the evidence regarding the impact of exercise on anxiety and sleep disorders was uncertain and inconclusive, highlighting the need for further research in these areas (Chen & Kim, 2024).

1.3.2.2 Sleep Quality

In addition to physical activity, sleep quality has been introduced as a modifiable risk factor for mental health generally, and anxiety and depression specifically (Scott et al., 2021). Sleep is a

complex behavioral state that also influences cognitive function, emotional well-being, and physical resilience (Chakrabarty, 2023). However, as people age, sleep tends to become more fragmented, characterized by more frequent awakenings during the night and an increased tendency to sleep during the day (Turek et al., 1995).

Sleep disturbances are highly prevalent among people with cognitive impairment. Approximately 60 to 70% of people with dementia, and 63% of people with MCI, report poor sleep quality (Wennberg et al., 2017; McKinnon et al., 2014). Also, sleep disturbances are strongly associated with poorer disease prognosis among people with cognitive impairment (Wennberg et al., 2017).

Prevalence of sleep disturbances in dementia varies depending on the type and severity of cognitive impairment. Guarnieri et al. (2012) found that individuals with LBD and Parkinson's disease with dementia experience the highest rates of sleep disturbances, affecting 90% of the participants (Guarnieri et al., 2012). In the early stages, changes in sleep patterns are often more distinct across dementia types. As dementia advances, sleep changes start to converge across all types (Cipriani et al., 2015). For example, rapid eye movement sleep behavior disorder is frequently observed in early LBD, whereas insomnia and disrupted sleep are more characteristic of early AD. However, as dementia advances, these distinctions become less pronounced, with more severe dementias marked by generalized and severe sleep disruptions, including frequent nighttime awakenings and marked daytime drowsiness (Cipriani et al., 2015).

Among younger adults and those without cognitive impairment, relatively strong evidence suggests that poor sleep quality is associated with greater symptoms of anxiety and depression. For instance, a study of healthy young adults found that people who have deeper sleep report lower anxiety levels the following day (Simon et al. 2020). The authors suggested that a full night of deep sleep can restore the brain’s prefrontal mechanisms responsible for regulating emotions, lowering anxiety and diminishing emotional reactivity (Simon et al., 2020). Another study found that higher sleep quality was associated with lower rates of anxiety and depression among individuals experiencing chronic stress during the COVID-19 pandemic (Sullivan et al., 2023). Also, a systematic review of 65 randomized controlled trials in adults with different age ranges reported a medium effect of improved sleep on improving mental health and reducing anxiety and depression (Scott et al., 2021).

In comparison to adults without cognitive impairment, evidence on the effects of sleep quality on anxiety and depression in older adults with cognitive impairment remains limited and mostly preliminary, with anxiety being even less studied than depression. A study by Kabeshita et al. (2017) reported that 21% of individuals with AD experienced sleep disturbances, as measured by the nighttime behavior disturbance score. People who had sleep disturbances also had a higher prevalence of BPSDs in the early stages of AD (Kabeshita et al., 2017). Preliminary findings from a study involving 170 dyads of community-dwelling people with dementia and caregivers were presented at a conference. The results showed that subjective sleep impairments were associated with higher odds of anxiety and depressive symptoms among people with dementia, whereas objective sleep measures from actigraphy didn't show a statistically significant association (Hwang & Hodgson, 2020).

A cross-sectional study found that poor sleep quality partially mediates the relationship between cognitive decline and depression in older adults, suggesting that improving sleep quality may help reduce depressive symptoms associated with cognitive decline (Liu et al., 2022). Similarly, a longitudinal study in people with MCI suggested that sleep quality significantly correlates with cognitive function, and depressive symptoms fully mediated this association (Wang et al., 2024).

While some evidence links sleep quality to mental health symptoms in people with cognitive impairment, most studies are preliminary, often focus more on depression alone or BPSDs broadly, and rarely consider interactions with other modifiable factors such as physical activity.

1.4 Mechanisms Linking Physical Activity to Reduced Anxiety and Depression

The benefits of physical activity and exercise on anxiety and depression likely arise from a variety of physiological and psychological changes. From a psychological perspective, participating in regular physical activity can function as an effective distraction from negative thoughts and emotions, providing a cognitive break from daily worries and stressors (Bourdeaudhuij et al., 2002). Additionally, the sense of achievement and mastery gained from completing a workout can also enhance self-efficacy and self-esteem, further contributing to improved mental well-being (DeBoer et al., 2012).

Physiologically, physical activity increases the production of endorphins and monoamines, which are neurotransmitters that enhance mood and reduce feelings of anxiety and depression (Harber & Sutton, 1984). It also increases the availability and activity of neurotransmitters such as dopamine and

norepinephrine in the brain, both of which play crucial roles in mood regulation and emotional resilience. These neurochemical changes help alleviate depressive symptoms and are similar to mechanisms targeted by many antidepressant medications (Xue et al., 2025).

Exercise also raises body temperature, which is hypothesized to promote relaxation and decrease muscular tension by increasing the temperature in specific brain regions such as the brain stem (Petruzzello et al., 1993; deVries, 1981). Additionally, exercise modulates stress reactivity by regulating the release of corticotropin-releasing factor from the hypothalamus and adrenocorticotropic hormone from the anterior pituitary, thereby reducing the hyperactivity of the hypothalamic-pituitary-adrenal axis, which is often observed in anxiety and depression (Droste et al., 2003).

Physical activity may mitigate anxiety and depressive symptoms in MCI and dementia through mechanisms specifically counteracting dementia-related neurodegeneration. Structural MRI studies have demonstrated that physical activity is associated with larger brain volumes in regions vulnerable to dementia, including the hippocampus, temporal, and frontal lobes (Domingos et al., 2021). These areas, specifically the hippocampus, are also involved in emotional regulation (Femenía et al., 2012). Therefore, enhanced hippocampal volume and integrity through physical activity may help mitigate anxiety and depression.

Physical activity may also counteract key neuropathological features of dementia by reducing the accumulation of beta-amyloid plaques and tau tangles, which are hallmarks of AD. A narrative review by Brown et al. (2019) presents evidence, particularly strong in animal studies, that regular physical activity may reduce the buildup of these proteins, potentially alleviating neurodegeneration in areas critical for emotion regulation, such as the hippocampus and prefrontal cortex (Brown et al., 2019). A systematic review and meta-analysis further supported this, showing moderate evidence that middle-aged and older adults who engage in regular physical activity exhibit lower levels of beta-amyloid accumulation compared to those who are less active (Rodriguez-Ayllon et al., 2024). Thus, physical activity may serve not only as a general intervention for reducing anxiety and depression, but also as a potential modulator of neurodegenerative processes that contribute to these symptoms in people with cognitive impairment.

1.5 Mechanisms Linking Sleep Quality to Reduced Anxiety and Depression

There are multiple potential mechanisms underlying the relationship between sleep quality and anxiety in people with cognitive impairment. Poor sleep exacerbates cognitive impairment, increases irritability, and disrupts the brain's ability to regulate emotions, which could intensify anxiety and depression (Xu et al., 2020; Akpoveta et al., 2025). Moreover, neuroimaging studies suggest that deficits in default mode network connectivity may mediate the link between poor sleep quality and anxiety severity (Shen et al., 2024). The default mode network is a collection of interconnected brain regions, including the medial prefrontal cortex and posterior cingulate cortex, which is most active when the mind is at rest (Sormaz et al., 2018). When functioning properly, this network plays a crucial role in memory and emotional regulation. Deficits in default mode network connectivity, potentially resulting from poor sleep quality, may increase susceptibility to anxiety because the brain becomes less efficient at managing negative emotions and stress severity (Shen et al., 2024).

Fragmented sleep can also disrupt neurotoxin clearance. Sleep disturbances, such as sleep-disordered breathing, contribute to beta-amyloid buildup, neuroinflammation, and cerebrovascular damage (Ward & Pase, 2020). These physiological changes, along with frequent nighttime awakenings and confusion, further increase anxiety and depression (Wennberg et al., 2017; Cao et al., 2024). Therefore, addressing sleep disturbances may be an effective strategy to manage anxiety, depression, and cognitive decline in people with cognitive impairment.

1.6 Effects of Physical Activity on Sleep Quality

While both physical activity and sleep quality may be modifiable risk factors for anxiety and depression, they are not entirely independent. Research has shown the potential that physical activity can improve sleep quality across various populations, including older adults and people with cognitive impairments (Badami et al., 2019; Yang et al., 2012). Regular physical activity can enhance both the quantity and quality of sleep by increasing total sleep time, promoting slow-wave sleep (deep sleep), reducing rapid eye movement sleep, shortening sleep latency (the time it takes to fall asleep), and reducing wakefulness after sleep onset (Aritake-Okada & Uchida, 2019).

Both acute bouts and regular physical activity have demonstrated sleep-enhancing effects across adult age groups and sexes, with longer bouts showing more pronounced improvements (Kline et al., 2021). Specifically, aerobic exercises such as walking, cycling, and swimming have shown

considerable benefits in sleep duration and efficacy across various populations (Ghiasvand & Irandoust, 2024). The benefits are particularly pronounced in middle-aged and older adults, as well as those with chronic conditions like depression (Dolezal et al., 2017).

Physical activity improves sleep quality through several interconnected mechanisms. It helps regulate body temperature, reduce cortisol levels, and improve mood by increasing endorphin and serotonin production (Ghiasvand & Irandoust, 2024). The rise in core body temperature during exercise, followed by the cooling phase, signals the body that it is time to sleep, aiding in faster sleep onset and promoting deeper rest (Uchida et al., 2012). Additionally, by lowering cortisol, a key stress hormone, physical activity reduces stress, calming the nervous system and making it easier to relax before bedtime (Corazza et al., 2014). Physical activity is also thought to synchronize circadian rhythms, promoting more consistent sleep patterns and increasing the body's need for restorative sleep (Shen et al., 2023). Together, these effects lead to more restful and uninterrupted sleep, which enhances overall well-being and health.

2.0 Current Study

2.1 Rationale

Anxiety and depression are prevalent across the cognitive impairment spectrum, including people with SCI, MCI, and dementia (Hill et al., 2016; Ma, 2020; Cerejeira et al., 2012). Symptoms of anxiety and depression are associated with a range of negative outcomes, such as reduced quality of life, increased dependence on caregivers, and accelerated progression to dementia (Porensky et al., 2009; Brenes, 2007). Despite their high prevalence, anxiety and depression often remain underdiagnosed and undertreated in people with dementia and MCI. The effectiveness of the commonly prescribed medications for anxiety and depression is inconsistent in people with cognitive impairment, and they are frequently accompanied by adverse effects, such as exacerbating cognitive decline and increasing the risk of falls (Bingley et al., 2025). Therefore, exploring non-pharmacological approaches to serve as low-risk alternatives or complements to medications in people with cognitive impairment is crucial.

Physical activity and sleep quality have emerged as two promising modifiable factors to mitigate anxiety and depression in the general and younger populations (Singh et al., 2023); Scott et al., 2021). The association and effectiveness of these lifestyle factors in reducing the risk of anxiety and depression in older adults without cognitive impairment have also been researched to some extent. In older adults with cognitive impairment, however, the evidence is very limited, often preliminary, and mostly includes depression alone or broad neuropsychiatric symptoms. Furthermore, few studies have examined how physical activity and sleep quality may interact to reduce anxiety and depression in this population. Hence, further targeted research is needed to understand the independent and interactive relationships between physical activity and sleep quality with anxiety and depression among people with cognitive impairment.

2.2 Objectives and Hypothesis

Objective 1: To evaluate the association between physical activity and sleep quality with odds of having anxiety among older adults with MCI, SCI, dementia, and those without cognitive impairment.

a. **Hypothesis 1a:** Higher levels of physical activity will be associated with lower odds of anxiety.

b. **Hypothesis 1b:** Better subjective sleep quality will be associated with lower odds of anxiety.

c. **Hypothesis 1c:** The association between physical activity and sleep quality with anxiety will vary depending on cognitive status.

Objective 2: To evaluate the association between physical activity and sleep quality with odds of having depression among older adults with MCI, SCI, dementia, and those without cognitive impairment.

a. **Hypothesis 2a**: Higher levels of physical activity will be associated with lower odds of depression.

b. **Hypothesis 2b:** Better subjective sleep quality will be associated with lower odds of depression.

c. **Hypothesis 2c:** The association between physical activity and sleep quality with depression will vary depending on cognitive status.

Objective 3: To evaluate whether physical activity and sleep quality interact in their association with anxiety and depression among older adults with MCI, SCI, dementia, and those without cognitive impairment.

a. **Hypothesis 3a:** Physical activity will moderate the relationship between sleep quality and both anxiety and depression.

b. **Hypothesis 3b:** The moderating effect of physical activity on the association between sleep quality with anxiety and depression will vary by cognitive status.

Objective 4: To explore whether the relationship between physical activity and sleep quality with anxiety varies by dementia subtype.

Hypothesis 4: The association between physical activity and sleep quality with anxiety will differ by dementia type.

Objective 5: To explore whether the relationship between physical activity and sleep quality with depression varies by dementia subtype.

Hypothesis 5: The association between physical activity and sleep quality with depression will differ by dementia type.

3.0 Methods

3.1 Study Design

This study was an analysis of data from the Comprehensive Assessment of Neurodegeneration and Dementia (COMPASS-ND) cohort study, a Canadian initiative aimed at examining biological and clinical features of neurodegenerative diseases and dementia in older adults (Chertkow et al., 2019). COMPASS-ND is a longitudinal, observational cohort study that recruited participants aged 50 to 90 years from 31 sites across Canada. As of the most recent recruitment update, the COMPASS-ND cohort consisted of 1173 participants with baseline data, including individuals diagnosed with various neurodegenerative conditions such as AD, LBD, FTD, and mixed dementia. The cohort also included participants with MCI**,** SCI**,** as well as cognitively unimpaired (CU) older adults who served as a comparison group. Cognitive diagnoses and classifications were made by consensus among clinician-researchers based on the study data, including neuroimaging, and physical, clinical, and cognitive assessments (Chertkow et al., 2019). Exclusion criteria included the presence of significant known brain disease, drug or alcohol abuse, and a total score < 13 on the Montreal Cognitive Assessment (Nasreddine et al., 2005). The current study used data from the baseline assessment, which was conducted over a 2-year period from 2016 to 2018.

3.2 Participants

Participants with baseline data available in the COMPASS-ND study (n = 1,173) were included in these analyses. A total of 130 participants with missing data on key variables (anxiety, depression, physical activity, and sleep quality) and an additional 87 participants diagnosed with Parkinson's disease without cognitive impairment were removed from the sample. The final analytical sample included 956 participants.

Participants included 150 people without cognitive impairment, referred to as cognitively unimpaired (CU), 116 with SCI, 460 people with MCI, and 230 people with dementia. Dementia subtypes, including AD, LBD, FTD, and mixed dementia, were aggregated for subsequent analyses.

Participants reported their age, sex, and total years of education. Clinical and mental health history was comprehensively documented, capturing information on 47 physical and mental health conditions. The total number of comorbidities was calculated for each participant to account for the overall burden of health conditions. To avoid overadjustment and maintain conceptual clarity,

conditions related to the study outcomes (anxiety disorder and depression) were excluded from the comorbidities count. Table 2 describes the characteristics of participants by cognitive status

3.3 Assessments

All assessments in this study were based on self-report instruments that are widely used in older adult populations. These tools have demonstrated good validity and reliability in the general older adult population. However, despite their common use in people with cognitive impairment, formal validation studies among people with MCI or dementia are limited or lacking.

Physical Activity: Physical activity was assessed using the Physical Activity Scale for the Elderly (PASE), a validated self-report instrument for assessing physical activity frequency, intensity, and duration over the past week among older adults (Washburn et al., 1999). The PASE score is calculated as a weighted sum of various activities, including walking, household tasks, and recreational activities. Each activity in the questionnaire is assigned a weight based on its intensity (Washburn et al., 1993). The total PASE score is the sum of these weighted activity scores and can range from 0 to 793, with higher scores indicating greater physical activity levels (Logan et al., 2013).

Sleep Quality: Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a self-report questionnaire designed to evaluate sleep quality over the past month (Buysse et al., 1989). The PSQI consists of 19 items grouped into seven components: subjective sleep quality, sleep latency, duration, habitual sleep efficiency, disturbances, use of medication, and daytime dysfunction. Each component is scored on a scale from 0 to 3, with higher scores indicating greater impairment. The component scores are summed to generate a global score ranging from 0 to 21, where scores higher than 5 show a sensitivity of 89% to detect poor sleep quality (Buysse et al., 1989).

Anxiety: Anxiety symptoms were measured using the Generalized Anxiety Disorder 7-item (GAD-7) scale, a reliable and validated tool for assessing the severity of generalized anxiety symptoms over the past two weeks (Spitzer et al., 2006). Each of the seven items is scored from 0 to 3, yielding a total range of 0 to 21. Scores are categorized as follows: 5–9 for mild anxiety, 10–15 for moderate anxiety, and above 15 for severe anxiety. The GAD-7 has been shown to have excellent internal consistency (Cronbach's $\alpha = 0.92$) and good test-retest reliability (intraclass correlation = 0.83) among clinical populations (Spitzer et al., 2006). Originally, a cut-off score of 10 was suggested to rule out generalized anxiety disorder (Spitzer et al., 2006). However, a study by Wild et al. (2014) further evaluated the GAD-7 in an elderly population aged 58 to 82 years and suggested lowering the

cut-off scores for detecting generalized anxiety disorder from 10 to 5 for the GAD-7 to enhance sensitivity and specificity in older adults (Wild et al., 2014). In this study, anxiety scores will be dichotomized at 5 to classify individuals with anxiety disorder.

Depression: Depression symptoms were measured using the Geriatric Depression Scale (GDS). It is a self-reported instrument specifically developed to identify depressive symptoms in older adults. The GDS is composed of 30 items using a simple yes/no response format, making it more appropriate for individuals who may have cognitive or physical limitations (Yesavage et al., 1982). Scores ranging from 0 to 9 indicate normal range, 10-19 suggest mild depressive symptoms, and 20-30 indicate severe depressive symptoms. This scale has demonstrated good construct validity, excellent internal consistency (Cronbach's $\alpha = 0.94$), and strong test-retest reliability among older adults (Yesavage et al., 1982). The validity and reliability of the GDS-30 have been assessed in people with cognitive impairment. A study by Debruyne et al. (2009) reported a moderate and statistically significant correlation between the GDS and the Cornell scale for depression in dementia (Alexopoulos et al., 1988) among people with MCI, supporting its criterion validity in this group. However, only weak correlations were observed in individuals with AD, indicating limited validity of the GDS in more advanced cognitive impairment (Debruyne et al., 2009). In this study, depression scores are dichotomized at 10 to capture having at least mild depressive symptoms.

3.4 Data Analysis

All statistical analyses were conducted using R Statistical Software (v4.4.2; R Core Team 2024). Participants' characteristics are represented in Table 2 as mean (standard deviation) for continuous variables or percentage (n) for categorical variables.

The primary outcomes were anxiety and depression, defined as binary variables. Although the GAD-7 and GDS are not diagnostic tools, cutoff scores are commonly used in research to identify those who are likely to have at least mild anxiety or depression, as validated against clinical diagnoses. Therefore, in this thesis, participants were identified as having anxiety or depression if they screened positive for at least mild anxiety or depression based on the cutoffs provided.

The primary independent variables, physical activity (measured by PASE) and sleep quality (measured by PSQI), were analyzed as continuous variables. Cognitive status was included as a categorical variable, with older adults without cognitive impairment serving as the reference group.

3.4.1 Logistic Regression Model Framework

To address the study objectives, a series of logistic regression models was constructed to assess the odds of anxiety or depression.

For **Objective 1**, Model 1 was developed with **anxiety** as a binary outcome variable. The primary independent variables included physical activity, sleep quality, and cognitive status (categorized as no cognitive impairment, SCI, MCI, and dementia). Interaction terms between physical activity and cognitive status, as well as between sleep quality and cognitive status, were included to assess whether these relationships varied by cognitive status.

For **Objective 2**, a similar logistic regression model (Model 2) was constructed, this time with **depression** as the binary outcome variable. The model included the same set of predictors and interaction terms as in Model 1.

To examine **Objective 3**, which explored whether physical activity moderates the relationship between sleep quality and mental health outcomes, two additional models were developed: Model 3 for anxiety and Model 4 for depression. Both models included cognitive status, physical activity, sleep quality, and their two-way interaction (physical activity × sleep quality). Also, a three-way interaction between physical activity, sleep quality, and cognitive status was included to examine if the moderating effect of physical activity differs by cognitive status.

The secondary objectives of the study (**Objectives 4 and 5**) were to investigate the associations of physical activity and sleep quality with anxiety and depression across different types of dementia. Given the limited sample sizes within each subtype, separate logistic regression models were constructed for physical activity and sleep quality to preserve statistical power. For objective 4, two separate Models examined whether the association of physical activity (Model 5) and sleep quality (Model 6) with anxiety varied by dementia type. Similarly, for objective 5, two models assessed whether the association of physical activity (Model 7) and sleep quality (Model 8) with depression varied by dementia type.

3.4.2 Selection of Covariates

To determine the optimal set of covariates for the regression models, a backwards selection procedure was implemented in R. The initial models included all independent variables ─ PASE

scores, PSQI scores, cognitive status category, sex, age, education, income, smoking status, count of comorbidities, as well as interaction terms between cognitive status and both PASE and PSQI.

Smoking status and income were initially considered important predictors of anxiety based on prior literature. However, they were not retained in the final models after the backward selection. Most of the interaction terms were also removed due to a lack of statistical significance. The structure and key variables of all logistic regression models aligned with the study objectives are summarized in Table 1. Variables and interaction terms that were not retained in the final models following backward selection are shown in **red.**

Table 1. Summary of Logistic Regression Models by Study Objective

Objectives	Logistic Regression Models	Independent Variables	Outcome Variables	Retained Covariates
Objective 1: To evaluate the association between PA and SQ with **anxiety** among older adults with no cognitive impairment, MCI, SCI, and dementia.	Model 1	PA (PASE) Sleep (PSQI) Cog status PA * Cog status, Sleep * Cog status	Anxiety (GAD-7 ≥ 5)	Sex Age Education Comorbidities Income Smoking Status
Objective 2: To evaluate the association between PA and SQ with **depression** among older adults with no cognitive impairment, MCI, SCI, and dementia.	Model 2	PA (PASE) Sleep (PSQI) Cog status PA * Cog status, Sleep * Cog status	Depression (GDS ≥ 10)	
Objective 3: To evaluate whether PA **modifies** the relationship between SQ with anxiety and depression among older adults with no cognitive impairment, MCI, SCI, and dementia.	Models 3 & 4	PA (PASE) Sleep (PSQI) Cog status PA * Sleep PA * Sleep * Cog status	M3: Anxiety (GAD-7 ≥ 5) M4: Depression (GDS ≥ 10)	

Objective 4: To explore whether the relationship between PA and SQ with **anxiety** and depression varies by dementia type	Models 5 & 6	PA (PASE) Dementia Type PA * Dementia Type	Anxiety (GAD-7 ≥ 5)	
		Sleep (PSQI) Dementia Type Sleep * Dementia Type		
Objective 5: To explore whether the relationship between PA and SQ with anxiety and **depression** varies by dementia type	Models 7 & 8	PA (PASE) Dementia Type PA * Dementia Type	Depression (GDS ≥ 10)	
		Sleep (PSQI) Dementia Type Sleep * Dementia Type		

* Note: Variables shown in **red** were not retained in the final models following backward selection.

* PA: Physical Activity, SQ: Sleep Quality, PASE: Physical Activity Scale for Elderly, PSQI: Pittsburgh Sleep Quality Index,

3.4.3 Logistic Regression Assumption Checks

Assumptions required for logistic regression were examined as follows:

1. **Sample Size Adequacy:** The logistic regression models require a minimum of 10 cases per independent variable included in the analysis. In this study, 256 participants met the criteria for anxiety (GAD-7 ≥ 5), and 211 participants met the criteria for depression (GDS ≥ 10). Given these sample sizes, the models could accommodate up to 20 independent variables while maintaining adequate statistical power and ensuring reliable coefficient estimates.
2. **Binary Outcome Variable**: Anxiety (GAD-7 ≥ 5) and depression (GDS ≥ 10) were treated as binary dependent variables.
3. **Linearity of Continuous Predictors:** The Box-Tidwell test was employed to assess the linearity of continuous predictors with the logit transformation. The results indicated that PASE, PSQI, education, and comorbidities met the linearity assumption.
4. When depression was the outcome variable, all continuous predictors satisfied the linearity assumption. However, for anxiety, age did not exhibit a linear relationship with the logit

transformation. Attempts at logarithmic and square root transformations did not improve the model fit; therefore, age was retained in its original form due to its significance in the model. The results of the Box-Tidwell tests, as well as the linearity of the logit for age in the anxiety model, are included in Appendix A.

5. **Multicollinearity Assessment:** Variance inflation factor values were all below 5, indicating the absence of multicollinearity.
6. **Influential Observations:** Cook's distance values were below 0.5, suggesting no undue influence from outliers.
7. **Model Fit:** The Hosmer-Lemeshow goodness-of-fit test indicated satisfactory model fit for both anxiety ($\chi^2 = 2.74$, df = 8, $p = 0.95$) and depression ($\chi^2 = 5.37$, df = 8, $p = 0.72$).

4.0 Results

4.1 Descriptive Statistics

The final sample included 956 participants, comprising 230 people with dementia, 460 people with MCI, 116 people with SCI, and 150 people with no cognitive impairment. Among those with dementia, the majority had AD (n = 122), followed by LBD (n = 41), FTD (n = 36), and mixed dementia (n=31).

Average age increased progressively from SCI (*M* = 69.8, *SD* = 5.9) and cognitively unimpaired participants (*M* = 69.9, *SD* = 6) to those with MCI (*M* = 73.4, *SD* = 6.7) and dementia (*M* = 73.2, *SD* = 9), with individuals diagnosed with mixed dementia being the oldest on average (*M* = 78.1, *SD* = 6.8). Years of education were relatively high across all groups, but individuals with SCI reported the most years of education (*M* = 16.1, *SD* = 2.4).

Sex distribution also differed across cognitive groups. Females were overrepresented in the CU (F = 63.3%, M = 36.7%) and SCI (F = 64.7%, M = 53.3%) groups, while participants with dementia were predominantly male (F = 38.3%, M = 61.7%).

Anxiety and depression were more prevalent among people with dementia (anxiety: 30.4%; depression: 30.0%) and MCI (anxiety: 31.5%; depression: 25.2%) compared to those with SCI (anxiety: 13.8%; depression: 13.8%) and CU (anxiety: 16.7%; depression: 6.7%). Notably, individuals with LBD showed the highest rates (anxiety: 53.7%; depression: 61.0%). Overall, almost 27.0% of participants met the criteria for having anxiety (GAD-7 ≥ 5), and 22.0% met criteria for depression (GDS ≥ 10). Full descriptive statistics are summarized in Table 2.

Table 2. Participants' Characteristics by Cognitive Status

Characteristics		People with Dementia (N=230)	AD (N=122)	FTD (N=36)	LBD (N=41)	Mixed Dementia (N=31)	MCI (N=460)	SCI (N=116)	CU (N=150)	Total Sample (N=956)
Anxiety %(N) (GAD-7 > 5)		30.4% (70)	21.3% (26)	33.3% (12)	53.7% (22)	32.3% (10)	31.5% (145)	13.8% (16)	16.7% (25)	26.8 % (256)
Depression %(N) (GDS > 10)		30% (69)	21.3% (26)	36.1% (13)	61.0% (25)	16.1% (5)	25.2% (116)	13.8% (13)	6.67% (10)	22.1% (211)
Age Mean (SD)		73.2 (9)	73.8 (8.2)	65 (9.8)	74.8 (7.7)	78.1 (6.8)	73.4 (6.7)	69.8 (5.9)	69.9 (6)	72.4 (7.3)
Years of Education Mean (SD)		14.6 (3.2)	14.7 (3)	14.2 (3.2)	14.7 (3.8)	14.8 (3)	15 (3)	16.1 (2.4)	15.6 (2.4)	15.1 (2.9)
Comorbidities Mean (SD)		4.5 (2.9)	3.8 (2.4)	3.6 (2.6)	6.5 (2.8)	5.4 (3.4)	4.9 (2.8)	4.7 (2.9)	4.4 (2.4)	4.7 (2.8)
Sex% (N)	**Female**	38.3% (88)	47.5% (58)	41.7% (15)	12.2% (5)	32.3% (10)	40.4% (186)	64.7% (75)	63.3% (95)	46.4% (444)
	Male	61.7% (142)	52.5% (64)	58.3% (21)	87.8% (36)	67.7% (21)	59.6% (274)	35.3% (41)	36.7% (55)	53.6% (512)

AD: Alzheimer's Disease, FTD: Frontotemporal Dementia, LBD: Lewy body Dementia, MCI: Mild Cognitive Impairment, CU: Cognitively Unimpaired Older Adults, SCI: Subjective Cognitive Impairment, SD: Standard Deviation

4.2 The Association Between Physical Activity and Sleep Quality with Anxiety (Objective 1)

The results from Model 1 showed that poorer sleep quality (higher PSQI score) was associated with higher odds of anxiety (OR = 1.138, 95% CI [1.090 – 1.190], $p < 0.001$). These results suggest that for each unit increase in PSQI (indicating poorer sleep quality), the odds of anxiety increase by 13.8% when holding all other variables constant. In contrast, an unexpected finding emerged for physical activity. A small positive association was observed between PASE scores and anxiety (OR = 1.003, 95% CI [1.001 – 1.006], $p = 0.007$). Each one-point increase in PASE was associated with a 0.3% increase in the odds of anxiety. Although the effect size seems to be small, it's important to note that PASE is a large scale ranging from 0 to 793, and the odds ratio is based on a one-point increase in this scale. Therefore, cumulative changes over a broader range may result in more meaningful differences that warrant further investigation.

These results are based on the full sample, including participants across all cognitive groups. To assess whether the associations varied by cognitive status, interaction terms between variables and cognitive group were tested. No significant interactions were found, indicating that the associations between sleep quality, physical activity, and anxiety were consistent across cognitive groups. Consequently, interaction terms were removed, and the final model reflects main effects across the entire sample. Table 3 summarizes the logistic regression results for anxiety.

Table 3. Regression Results for the Odds of Anxiety (GAD ≥ 5)

Predictor	Odds Ratios (95% Confidence Intervals)	p-value
Physical Activity (PASE)	1.003 (1.001 - 1.006)	0.007
Sleep Quality (PSQI)	1.138 (1.090 - 1.190)	<0.001
Cognitive Status		
Cognitively Unimpaired Older Adults	Reference	
Dementia	3.546 (2.006 – 6.452)	<0.001
Mild Cognitive Impairment (MCI)	3.151 (1.896 – 5.424)	<0.001
Subjective Cognitive Impairment (SCI)	0.784 (0.376 – 1.597)	0.506
Age (50 - 90)	0.959 (0.936 – 0.981)	<0.001
Sex		
Sex (Female)	Reference	
Sex (Male)	0.675 (0.486 – 0.934)	0.018
Comorbidities	1.148 (1.082 – 1.218)	<0.001
Years of Education	0.963 (0.912 – 1.017)	0.179

4.3 The Association Between Physical Activity and Sleep Quality with Depression (Objective 2)

Results from Model 2 showed that poorer sleep quality was associated with greater odds of depression (OR = 1.355, 95% CI [1.137 – 1.646], $p = 0.001$). Each one-point increase in PSQI was associated with a 35.5% increase in the odds of depression, when holding other variables constant. Similarly, higher levels of physical activity were associated with lower odds of depression (OR = 0.997, 95% CI [0.994 – 0.999], $p = 0.038$). Every one-point increase in PASE score is associated with a 0.4% decrease in the odds of depression. As mentioned previously, although the per-unit association is small, the large range of PASE scores suggests that more substantial changes in physical activity may yield a more meaningful reduction in depression risk.

To capture whether the associations differ by cognitive status, interaction terms between predictors and cognitive group were tested. The interaction between sleep quality and dementia status was statistically significant (PSQI * Dementia: OR = 0.782, 95% CI [0.635 – 0.948], $p = 0.014$), suggesting that the relationship between sleep quality and depression was weaker among people with dementia compared to older adults without cognitive impairment. No significant interactions were

found for physical activity, indicating that the association between physical activity and depression was consistent across cognitive groups. Table 4 summarizes the regression model outputs for depression.

Table 4. Regression Results for the Odds of Depression (GDS ≥ 10)

Predictor	Odds Ratios (95% Confidence Intervals)	p-value
Physical Activity (PASE)	0.997 (0.994 - 0.999)	0.038
Sleep Quality (PSQI)	1.355 (1.137 - 1.646)	0.001
Cognitive Status		
Cognitively Unimpaired (CU) Older Adults	Reference	
Dementia	42.212 (8.366 - 321.839)	<0.001
Mild Cognitive Impairment (MCI)	19.443 (3.935 – 146.393)	0.001
Subjective Cognitive Impairment (SCI)	2.614 (0.280 – 28.012)	0.403
Age (50 – 90)	0.939 (0.916 – 0.963)	<0.001
Sex		
Sex (Female)	Reference	
Sex (Male)	1.069 (0.752 – 1.524)	0.711
Comorbidities	1.203 (1.130 – 1.283)	<0.001
Years of Education	1.000 (0.943 – 1.0610)	0.990
Variations in Sleep-Depression Associations by Cognitive Group		
Sleep Quality (PSQI) * CU	Reference	
Sleep Quality (PSQI) * Dementia	0.782 (0.635 – 0.948)	0.014
Sleep Quality (PSQI) * MCI	0.846 (0.690- 1.019)	0.087
Sleep Quality (PSQI) * SCI	0.963 (0.748 – 1.240)	0.769

4.4 Moderation Effect of Physical Activity (Objective 3)

Results from Model 3, which examined anxiety as the outcome variable, showed no significant interaction between physical activity and sleep quality (PASE*PSQI: OR = 1.000, 95% CI [0.999 - 1.001], $p = 0.332$), nor did this interaction vary across cognitive groups. This suggests that the association between sleep quality and anxiety is independent of physical activity levels.

Model 4 examined depression as the outcome variable. While the three-way interactions between physical activity, sleep quality, and cognitive status (specifically for MCI and dementia) reached statistical significance the absence of a significant two-way interaction between physical activity and sleep quality (PASE*PSQI: OR = 1.0001, 95% CI [0.999 - 1.0008], $p = 0.590$) raises concerns about

the reliability of these findings. Such patterns may result from overfitting, and therefore, these results should be interpreted with caution. Further research with more robust designs is necessary to clarify these relationships. The results from this analysis suggest that there is no moderation effect between physical activity and sleep quality in reducing the odds of anxiety or depression. Table 5 represents the regression results for the interactions between physical activity and sleep quality.

Table 5. Regression Results for the Moderation Effect of Physical Activity

	Anxiety (GAD-7 ≥ 5)		**Depression (GDS ≥ 10)**	
Predictor	**Odds Ratios (95% CI)**	**p-value**	**Odds Ratios (95% CI)**	**p-value**
Physical Activity (PASE)	1.002 (0.997 - 1.006)	0.435	0.999 (0.994 - 1.005)	0.970
Sleep Quality (PSQI)	1.110 (1.019 - 1.209)	0.016	1.205 (1.105 - 1.319)	<0.001
Cognitive Status				
Cognitively Unimpaired (CU)	**Reference**			
Dementia	5.197 (2.331 - 12.841)	<0.001	16.205 (5.981 -49.253)	<0.001
MCI	3.432 (1.605 - 8.222)	0.003	11.165 (4.279 - 32.934)	<0.001
SCI	0.673 (0.192 - 2.233)	0.520	2.492 (0.656 - 9.446)	0.174
Age (50-90)	0.956 (0.933 - 0.978)	<0.001	0.938 (0.914 - 0.962)	<0.001
Years of Education	0.963 (0.911 - 1.0169)	0.174	1.008 (0.950 - 1.069)	0.784
Sex				
Sex (Female)	**Reference**			
Sex (Male)	0.682 (0.491 - 0.946)	0.022	1.0512 (0.738 - 1.500)	0.782
Comorbidities	1.148 (1.082 - 1.219)	<0.001	1.200 (1.128 - 1.280)	<0.001
PA : SQ	1.000 (0.999 - 1.001)	0.332	1.0001 (0.999 - 1.0008)	0.590
Variations in the moderation effect by cognitive group				
PA : SQ : CU	**Reference**			

PA : SQ : Dementia	0.999 (0.998 - 0.998)	0.140	0.9991 (0.998 - 0.9999)	0.027
PA : SQ : MCI	0.999 (0.999 - 1.000)	0.898	0.99918 (0.998 - 0.9999)	0.021
PA : SQ : SCI	1.000 (0.999 - 1.001)	0.737	0.9997 (0.998 - 1.000)	0.665

MCI: Mild Cognitive Impairment, SCI: Subjective Cognitive Impairment, CU: Cognitively Unimpaired

CI: Confidence Interval, PA: Physical Activity, SQ: Sleep Quality

PASE: Physical Activity Scale for Elderly, PSQI: Pittsburgh Sleep Quality Index

4.5 Differential Association of Physical Activity and Sleep Quality with Anxiety and Depression Across Dementia Subtypes (Objectives 4 & 5)

Among the 230 participants diagnosed with dementia, 70 exhibited at least mild anxiety (GAD-7 > 5), and 69 met the criteria for at least mild depression (GDS > 10). To preserve statistical power within each dementia subtype, four separate logistic regression models were conducted to examine the association between physical activity and sleep quality with anxiety and depression outcomes.

No statistically significant interactions were found between dementia subtype and either physical activity or sleep quality in predicting anxiety or depression. These findings suggest that the associations between physical activity, sleep quality, and mental health outcomes were similar across dementia types within this sample. However, it is important to note that these exploratory analyses were limited by small sample sizes within dementia subtypes, which may have reduced the ability to detect meaningful differences. Further studies with larger and more diverse dementia populations are needed to better understand potential differences in these associations across dementia types. Tables 6 to 9 present the results of the exploratory logistic regression models across dementia subtypes.

Table 6. Regression Results for the Association Between Physical Activity and Odds of Anxiety (GAD-7 ≥ 5) Across Dementia Subtypes

Predictor	Odds Ratios (95% Confidence Intervals)	p-value
Physical Activity (PASE)	1.003 (0.995 - 1.011)	0.471
Dementia Type		
Alzheimer's Disease (AD)	Reference	
Frontotemporal Dementia (FTD)	1.665 (0.279 - 9.244)	0.564
Lewy Body Dementia (LBD)	3.205(0.784 – 12.934)	0.100
Mixed Dementia	4.940 (0.711 - 37.484)	0.109
Age	0.976 (0.935 - 1.018)	0.257
Sex		
Sex (Female)	Reference	
Sex (Male)	0.550 (0.271 - 1.099)	0.093
Comorbidities	1.178 (1.048 - 1.333)	0.007
Years of Education	0.977 (0.882 – 1.083)	0.660
Variations in Physical Activity-Anxiety Association by dementia Type		
Physical Activity (PASE)* AD	Reference	
Physical Activity (PASE)* FTD	0.999 (0.984 - 1.0136)	0.878
Physical Activity (PASE)* LBD	1.003 (0.991 - 1.016)	0.665
Physical Activity (PASE)* Mixed Dementia	0.985 (0.957 - 1.009)	0.251

Table 7. Regression Results for the Association Between Sleep Quality and Odds of Anxiety (GAD-7 ≥ 5) Across Dementia Subtypes

Predictor	Odds Ratios (95% Confidence Intervals)	p-value
Sleep Quality (PSQI)	1.138 (1.005 - 1.298)	0.045
Dementia Type		
Alzheimer's Disease (AD)	Reference	
Frontotemporal Dementia (FTD)	3.423 (0.748 - 15.018)	0.104
Lewy Body Dementia (LBD)	1.405 (0.193 - 8.188)	0.717
Mixed Dementia	2.451 (0.445 - 12.066)	0.280
Age	0.976 (0.938 - 1.015)	0.240
Sex		
Sex (Female)	Reference	
Sex (Male)	0.581 (0.289 - 1.156)	0.122
Comorbidities	1.131 (0.998 - 1.289)	0.058
Years of Education	1.012 (0.909 – 1.128)	0.829
Variations in Sleep Quality-Anxiety Association by dementia Type		
Sleep Quality (PSQI)* AD	Reference	
Sleep Quality (PSQI)* FTD	0.846 (0.684 - 1.036)	0.112
Sleep Quality (PSQI)* LBD	1.142 (0.882 - 1.554)	0.349
Sleep Quality (PSQI)* Mixed Dementia	0.936 (0.693 - 1.274)	0.665

Table 8. Regression Results for the Association Between Physical Activity and Odds of Depression (GDS ≥ 10) Across Dementia Subtypes

Predictor	Odds Ratios (95% Confidence Intervals)	p-value
Physical Activity (PASE)	1.001 (0.993 - 1.009)	0.774
Dementia Type		
Alzheimer's Disease (AD)	Reference	
Frontotemporal Dementia (FTD)	1.315 (0.224 – 7.153)	0.754
Lewy Body Dementia (LBD)	5.138 (1.383 - 20.047)	0.015
Mixed Dementia	3.174 (0.307 - 31.429)	0.318
Age	0.937 (0.896 - 0.978)	0.003
Sex		
Sex (Female)	Reference	
Sex (Male)	1.167 (0.571 - 2.405)	0.673
Comorbidities	1.208 (1.071 - 1.372)	0.003
Years of Education	1.009 (0.909 – 1.123)	0.854
Variations in Physical Activity-Depression Association by dementia Type		
Physical Activity (PASE)* AD	Reference	
Physical Activity (PASE)* FTD	1.000 (0.986 - 1.015)	0.992
Physical Activity (PASE)* LBD	0.997 (0.986 - 1.008)	0.597
Physical Activity (PASE)* Mixed Dementia	0.973 (0.935 - 1.004)	0.127

Table 9. Regression Results for the Association Between Sleep Quality and Odds of Depression (GDS ≥ 10) Across Dementia Subtypes

Predictor	Odds Ratios (95% Confidence Intervals)	p-value
Sleep Quality (PSQI)	1.053 (0.929 - 1.197)	0.411
Dementia Type		
Alzheimer's Disease (AD)	Reference	
Frontotemporal Dementia (FTD)	2.308 (0.528 - 9.717)	0.256
Lewy Body Dementia (LBD)	2.720 (0.495 - 14.099)	0.237
Mixed Dementia	0.554 (0.055 - 3.688)	0.571
Age	0.944 (0.905 - 0.982)	0.005
Sex		
Sex (Female)	Reference	
Sex (Male)	1.130 (0.559 - 2.315)	0.734
Comorbidities	1.195 (1.049 - 1.371)	0.008
Years of Education	1.028 (0.923 - 1.147)	0.616
Variations in Sleep Quality-Depression Association by dementia Type		
Sleep Quality (PSQI)* AD	Reference	
Sleep Quality (PSQI)* FTD	0.909 (0.741 - 1.111)	0.352
Sleep Quality (PSQI)* LBD	1.047 (0.828 - 1.359)	0.709
Sleep Quality (PSQI)* Mixed Dementia	1.021 (0.694 - 1.480)	0.913

5.0 Discussion

This analysis of the COMPASS-ND study examined the association between physical activity and sleep quality with odds of anxiety or depression among older adults with varying cognitive statuses. Poorer sleep quality was associated with a higher odds of anxiety and depression. However, the relationship between sleep quality and depression was weaker among people with dementia compared to people without cognitive impairment. As expected, greater physical activity was associated with lower odds of depression. However, an unexpected positive relationship was observed for anxiety, suggesting that greater physical activity was associated with higher odds of anxiety. Neither these behaviours (i.e., sleep, physical activity) nor dementia type moderates the relationship between physical activity or sleep quality and odds of anxiety or depression. Overall, the consistent associations observed between poor sleep quality and increased risk of mental health outcomes underscore the need to prioritize sleep interventions in older adults across the cognitive impairment spectrum.

The most surprising finding from this study was that people with greater physical activity also had higher odds of having anxiety. This finding is inconsistent with most controlled trials among adults and older adults without cognitive impairment, which most often suggest a small, positive effect on anxiety symptoms (Stubbs et al., 2017; Ruiz-Comellas et al., 2022). It should be noted, however, that randomized controlled trial results are not consistent. For example, a 2024 systematic review of 25 recent randomized controlled trials among adults and older adults with anxiety as the primary outcome suggested inconsistent and uncertain results on the effectiveness of physical activity in reducing anxiety symptoms (Stonerock et al., 2024). The review reported that 18 out of 25 trials either had ambiguous results or did not improve anxiety. The authors pointed out that methodological limitations, such as small sample sizes, lack of control for placebo effect, and lack of blinding, limit interpretability. While it is possible that physical activity has a neutral or negative effect on anxiety, recent clinical guidelines cautiously recommend exercise for treating anxiety. For example, the Canadian guidelines for the assessment and treatment of anxiety in older adults made a conditional recommendation of aerobic exercise and strength training for reducing anxiety symptoms, and mentioned that the certainty of evidence is very low (Iaboni et al., 2025).

On the other hand, it is possible that physical activity has a positive effect (as is suggested in some trials), but that this effect is hidden in this observational study. This could occur if older adults with

early stages of cognitive impairment who are more physically active were also more aware of their functional decline, and this could lead to a higher likelihood of anxiety. Alternatively, individuals with anxiety may use physical activity as a coping mechanism. Indeed, during the COVID-19 pandemic, 80% of community-dwelling older adults engaged in walking or home-based physical activities as a coping behavior (Ejiri et al., 2021). Physical activity may reduce anxiety by providing distraction or "time out" from stressors (Anderson & Shivakumar, 2013), and health-related concerns may motivate some individuals to be more active to prevent future health decline (Buman et al., 2010). Future research should also explore potential moderators influencing the relationship between physical activity and anxiety in older adults with cognitive impairment. Factors such as physical activity dose (frequency, intensity, and type), baseline anxiety levels, cognitive status, and anxiety sensitivity may alter the direction or strength of these associations. For instance, individuals with high anxiety sensitivity may interpret normal physiological responses to exercise, such as elevated heart rate or shortness of breath, as symptoms of anxiety, potentially increasing rather than reducing anxiety (Farris et al., 2019).

Other main effects between physical activity, sleep quality, anxiety and depression were in the expected directions. That is, greater physical activity was associated with reduced odds of depression, and poorer sleep quality was associated with increased odds of anxiety and depression, in line with most prior literature (Noetel et al., 2024; Scott et al., 2021). However, contrary to hypotheses, only the relationship between sleep quality and depression appeared to be modified with cognitive status, where the relationship was weaker among people with dementia than among people without cognitive impairment. People with dementia often use sedatives, antipsychotics, or antidepressants (Byeon et al., 2025), which can mask depressive symptoms or alter sleep patterns. Also, symptoms of anxiety and depression often overlap with neuropsychiatric symptoms of dementia over time (Cerejeira et al., 2012), making it more difficult to differentiate or diagnose depression and to find a relationship between sleep and depression. Furthermore, sleep tends to become more disrupted and fragmented with more awakening periods as cognitive impairment progresses (Mukherjee et al., 2024). Therefore, in people with dementia, sleep quality is generally reduced, and neuropsychiatric symptoms are present in up to 90% of individuals (Cerejeira et al., 2012). This widespread prevalence results in limited variability in both sleep quality and symptoms of anxiety and depression, potentially leading to less ability to find differences in this population. This could explain the weaker relationship between sleep quality and depression in people with dementia compared to older adults without

cognitive impairment. Though the difference was not significant for people with MCI versus those without cognitive impairment, the difference approached statistical significance (OR = 0.846, 95% CI [0.690 - 1.019], $p = 0.087$), suggesting that the relationship between sleep quality and depression might become weaker with increasing severity of cognitive impairment. This preliminary observation warrants further investigation with larger sample sizes.

Other subgroup analyses suggested that there is no effect modification by cognitive status. The association between physical activity and anxiety or depression, and sleep quality and anxiety, remained consistent across cognitive groups. Most of the interactions with cognitive status had odds ratios between 0.9 and 1.1 and p-values greater than 0.1, with relatively narrow confidence intervals that included 1. As a result, the lack of effect modification is likely to be unrelated to sample power.

Physical activity was also investigated as a moderator of the relationship between sleep quality and anxiety and depression, with no significant effect modification observed. In other samples, the evidence for a moderating effect by physical activity is currently limited and inconsistent. Of the three relevant studies, two identified a statistically significant moderating effect of physical activity in the relationship between sleep quality and depressive symptoms (Cheval et al., 2022; Yang et al., 2023). Cheval et al. (2022) found that physical inactivity strengthened the link between poor sleep quality and depressive symptoms in over 79,000 European adults aged 50 and above. Similarly, Yang et al. (2023) reported that greater physical activity was associated with lower depression risk, but only among those with good or moderate sleep in a population of 11,423 Chinese university students. In contrast, a doctoral dissertation among 14,093 American older adults aged 55 and above by Wickersham (2022) found no significant interaction between self-reported physical activity and insomnia with depressive symptoms (Wickersham, 2022). Our findings align with this latter body of evidence.

These inconsistent results suggest that the moderating effect of physical activity may vary depending on population characteristics or methodology. For example, the absence of a moderation effect in our analysis may reflect the biological nature of sleep disruptions in older adults with cognitive impairment. While poor sleep in younger populations is often behavioral and responsive to lifestyle interventions like physical activity (S. Brand et al., 2010), sleep disturbances in older adults with cognitive impairment are more likely driven by circadian dysregulation or neurodegenerative changes (Ju et al., 2014), which may limit the moderating role of physical activity.

The analyses by dementia subtype revealed no significant interaction between dementia subtype with either physical activity or sleep quality on mental health outcomes. This null finding contradicts our hypothesis and could be attributed to small and uneven sample sizes, which limited the statistical power. Each subtype of dementia has distinct neuropathological characteristics, and it is expected that physical activity and sleep show different mental health outcomes in each group based on different physiological mechanisms (De la Rosa et al., 2020; Silva et al., 2019). The relationship between sleep quality and anxiety in FTD approached statistical significance (OR = 0.829, 95% CI [0.672 - 1.012], $p = 0.071$), which may reflect a true difference that was not detected due to limited statistical power. If this observed trend reflects an underlying difference, it could suggest sleep has a weaker association with anxiety in FTD compared to AD, potentially due to differences in neuropathology of each subtype, though more study is needed with greater sub-samples by dementia type. Additionally, the self-reported tools used in this study may not have been sensitive enough to detect subtle associations with mental health across dementia subtypes, particularly given that their validity and psychometric properties are not well established in people with dementia. Therefore, the null findings of subgroup analysis across dementia types may be due to either low statistical power or methodological limitations.

5.1 Strengths and Limitations

This analysis offers valuable insights into the associations between physical activity and sleep quality with symptoms of anxiety and depression among older adults with different cognitive statuses. A major strength of this study is the use of a large cohort of participants across the full cognitive impairment spectrum, including older adults without cognitive impairment as a comparison group. Importantly, the categorization of cognitive impairment and dementia subtypes was based on clinician-confirmed diagnosis, enhancing the reliability and robustness of subgroup classification.

However, a few limitations should be considered when interpreting the results. First, it's important to note that the cross-sectional design of this study cannot determine the direction of causality (if any), and all the associations are only correlational rather than explaining the direction of the relationships.

Second, all key variables, including anxiety, depression, physical activity, and sleep quality, were assessed through self-reported questionnaires, which may be subject to recall inaccuracies. This can be even more concerning in people with cognitive impairment, where memory deficits and reduced

self-awareness may affect the validity of responses. Additionally, while the measures used in this study (PASE, PSQI, GAD-7, and GDS) are widely used in older adults with and without cognitive impairment, most have not been specifically validated in dementia populations, raising concerns about their accuracy and interpretability in this context.

Third, the power to detect significant associations within subgroups, especially dementia subtypes, may have been limited due to small and uneven sample sizes. Limited power may therefore explain the absence of statistically significant findings in some subgroup analyses. Future research with larger, more balanced samples is needed to clarify potential group-specific relationships. Also, no data were available for individuals with VaD, the second most common dementia subtype, which limits the ability to generalize findings across the full spectrum of dementia subtypes.

Finally, the participants of the COMPASS-ND study might not fully represent the broader Canadian population. Recruitment was primarily conducted through memory clinics, stroke clinics, movement disorder clinics, and research groups, mostly in urban areas. Further, the COMPASS-ND sample lacks ethnoracial diversity, with approximately 90% of participants identifying as White (Compass-ND - CCNA - CCNV 2025). In addition, more than 81% of the participants had education beyond a high school diploma. These factors limit the generalizability of the findings as they may be more representative of highly educated, urban-dwelling, White individuals. Lower-educated individuals or those from lower ethnoracial minority groups often face barriers to care and underreport mental health symptoms due to stigma or lack of awareness (Lin, 2023). Nevertheless, the prevalence rates of anxiety and depression in this analysis were mostly aligned with previous research, averaging around 30% in older adults with cognitive impairment (Zhang et al., 2012).

5.2 Conclusion and Future Directions

Taken together, the findings from this thesis highlight the potential role of sleep quality in influencing symptoms of anxiety and depression in older adults with different cognitive statuses. Poor sleep emerged as a consistent factor associated with worse mental health outcomes, which underscores the need to prioritize development of effective sleep interventions as part of the holistic care for people with and without cognitive impairment. Physical activity also emerged as a promising lifestyle approach for managing depression. However, its unexpected positive association with anxiety suggests a more complex relationship that should be approached more cautiously for treatment of mental health conditions. The overall consistency between these associations across the cognitive

impairment spectrum suggests that interventions to improve mental health need not be entirely distinct for people of different cognitive abilities. Future longitudinal and intervention-based studies are needed to build on this work and clarify the potential direction of these associations. Additionally, studies with larger and more balanced samples across dementia subtypes are warranted to better understand potential subgroup differences.

References

Ahmad, S., Ahmad, H. I., Khan, F. A., Ali, F., & Hussain, A. (2014). *Full Length Review Article A STUDY OF EFFECTS OF IZTERAB - E - NAFSANI (ANXIETY) AND ITS MANAGEMENT WITH REFERENCE TO UNANI SYSTEM OF MEDICINE: A REVIEW*. https://www.semanticscholar.org/paper/Full-Length-Review-Article-A-STUDY-OF-EFFECTS-OF-E-Ahmad-Ahmad/a1fca03f3b82048baa6744f2734aa9e7b31adb7a

Akpoveta, E. D., Okpete, U. E., & Byeon, H. (2025). Sleep disorders and mental health: Understanding the cognitive connection. *World Journal of Psychiatry*, *15*(6), 105362. https://doi.org/10.5498/wjp.v15.i6.105362

Alexopoulos, G. S., Abrams, R. C., Young, R. C., & Shamoian, C. A. (1988). Cornell scale for depression in dementia. *Biological Psychiatry*, *23*(3), 271–284. https://doi.org/10.1016/0006-3223(88)90038-8

Allan, C. E., Valkanova, V., & Ebmeier, K. P. (2014). Depression in older people is underdiagnosed. *The Practitioner*, *258*(1771), 19–22, 2–3.

Anderson, E., & Shivakumar, G. (2013). Effects of Exercise and Physical Activity on Anxiety. *Frontiers in Psychiatry*, *4*, 27. https://doi.org/10.3389/fpsyt.2013.00027

Aretouli, E., & Brandt, J. (2010). Everyday functioning in mild cognitive impairment and its relationship with executive cognition. *International Journal of Geriatric Psychiatry*, *25*(3), 224–233. https://doi.org/10.1002/gps.2325

Aritake-Okada, S., & Uchida, S. (n.d.). Physical Activity and Sleep. In *Oxford Research Encyclopedia of Psychology*. Retrieved September 19, 2024, from https://oxfordre.com/psychology/display/10.1093/acrefore/9780190236557.001.0001/acrefore-9780190236557-e-204

Aritake-Okada, S., & Uchida, S. (2019, March). *Physical Activity and Sleep*. Oxford University Press. https://doi.org/10.1093/acrefore/9780190236557.013.204

Attaallah, B., Petitet, P., Slavkova, E., Turner, V., Saleh, Y., Manohar, S. G., & Husain, M. (2022). Hyperreactivity to uncertainty is a key feature of subjective cognitive impairment. *eLife*, *11*, e75834. https://doi.org/10.7554/eLife.75834

Bademli, K., Lok, N., Canbaz, M., & Lok, S. (2019). Effects of Physical Activity Program on cognitive function and sleep quality in elderly with mild cognitive impairment: A randomized controlled trial. *Perspectives in Psychiatric Care*, *55*(3), 401–408. https://doi.org/10.1111/ppc.12324

Badrakalimuthu, V. R., & Tarbuck, A. F. (2012). Anxiety: A hidden element in dementia. *Advances in Psychiatric Treatment*, *18*(2), 119–128. https://doi.org/10.1192/apt.bp.110.008458

Bai, W., Chen, P., Cai, H., Zhang, Q., Su, Z., Cheung, T., Jackson, T., Sha, S., & Xiang, Y.-T. (2022). Worldwide prevalence of mild cognitive impairment among community dwellers aged 50 years and older: A meta-analysis and systematic review of epidemiology studies. *Age and Ageing*, *51*(8), afac173. https://doi.org/10.1093/ageing/afac173

Bandelow, B., Michaelis, S., & Wedekind, D. (2017). Treatment of anxiety disorders. *Dialogues in Clinical Neuroscience*, *19*(2), 93–107. https://doi.org/10.31887/DCNS.2017.19.2/bbandelow

Bandelow, B., Reitt, M., Röver, C., Michaelis, S., Görlich, Y., & Wedekind, D. (2015). Efficacy of treatments for anxiety disorders: A meta-analysis. *International Clinical Psychopharmacology*, *30*(4), 183. https://doi.org/10.1097/YIC.0000000000000078

Barham, W. T., Buysse, D. J., Kline, C. E., Kubala, A. G., & Brindle, R. C. (2022). Sleep health mediates the relationship between physical activity and depression symptoms. *Sleep & Breathing = Schlaf & Atmung*, *26*(3), 1341–1349. https://doi.org/10.1007/s11325-021-02496-9

Bayles, K. A., Kaszniak, A. W., & Tomoeda, C. K. (1987). *Communication and cognition in normal aging and dementia* (pp. xvi, 400). College-Hill Press/Little, Brown & Co.

Ben Simon, E., Rossi, A., Harvey, A. G., & Walker, M. P. (2020). Overanxious and underslept. *Nature Human Behaviour*, *4*(1), 100–110. https://doi.org/10.1038/s41562-019-0754-8

Beurs, E. de, Beekman, A. T. F., Balkom, A. J. L. M. van, Deeg, D. J. H., Dyck, R. van, & Tilburg, W. van. (1999). Consequences of anxiety in older persons: Its effect on disability, well-being and use of health services. *Psychological Medicine*, *29*(3), 583–593. https://doi.org/10.1017/S0033291799008351

Bingley, J., Young, A., & Chong, T. W. H. (2025). What is the evidence for using antidepressants to reduce anxiety for people with dementia? *Archives of Gerontology and Geriatrics Plus*, *2*(1), 100108. https://doi.org/10.1016/j.aggp.2024.100108

Boer, M. E. de, Hertogh, C. M. P. M., Dröes, R.-M., Riphagen, I. I., Jonker, C., & Eefsting, J. A. (2007). Suffering from dementia – the patient's perspective: A review of the literature. *International Psychogeriatrics*, *19*(6), 1021–1039. https://doi.org/10.1017/S1041610207005765

Botto, R., Callai, N., Cermelli, A., Causarano, L., & Rainero, I. (2022). Anxiety and depression in Alzheimer's disease: A systematic review of pathogenetic mechanisms and relation to cognitive decline. *Neurological Sciences*, *43*(7), 4107–4124. https://doi.org/10.1007/s10072-022-06068-x

Brand, M., & Markowitsch, H. (2008). *Brain structures involved in dementia.: An Demenz beteiligte Hirnstrukturen.* https://www.semanticscholar.org/paper/Brain-structures-involved-in-dementia.%3A-An-Demenz-Brand-Markowitsch/93db9df0eb4f8bfe7a32df69fec8054c62adc46f

Brand, S., Gerber, M., Beck, J., Hatzinger, M., Pühse, U., & Holsboer-Trachsler, E. (2010). High exercise levels are related to favorable sleep patterns and psychological functioning in adolescents: A comparison of athletes and controls. *The Journal of Adolescent Health: Official Publication of the Society for Adolescent Medicine*, *46*(2), 133–141. https://doi.org/10.1016/j.jadohealth.2009.06.018

Brenes, G. A. (2007). Anxiety, Depression, and Quality of Life in Primary Care Patients. *Primary Care Companion to The Journal of Clinical Psychiatry*, *9*(6), 437–443. https://doi.org/10.4088/pcc.v09n0606

Bridle, C., Spanjers, K., Patel, S., Atherton, N. M., & Lamb, S. E. (2012). Effect of exercise on depression severity in older people: Systematic review and meta-analysis of randomised controlled trials. *The British Journal of Psychiatry*, *201*(3), 180–185. https://doi.org/10.1192/bjp.bp.111.095174

Brown, B. M., Peiffer, J., & Rainey-Smith, S. R. (2019). Exploring the relationship between physical activity, beta-amyloid and tau: A narrative review. *Ageing Research Reviews*, *50*, 9–18. https://doi.org/10.1016/j.arr.2019.01.003

Brown, M., Tolson, D., & Ritchie, L. (2020). Changing needs in advanced dementia. *Nursing Older People*. https://doi.org/10.7748/nop.2020.e1204

Buman, M. P., Daphna Yasova, L., & Giacobbi, P. R. (2010). Descriptive and narrative reports of barriers and motivators to physical activity in sedentary older adults. *Psychology of Sport and Exercise*, *11*(3), 223–230. https://doi.org/10.1016/j.psychsport.2010.02.002

Burley, C. V., Burns, K., Lam, B. C. P., & Brodaty, H. (2022). Nonpharmacological approaches reduce symptoms of depression in dementia: A systematic review and meta-analysis. *Ageing Research Reviews*, *79*, 101669. https://doi.org/10.1016/j.arr.2022.101669

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4

Byeon, G., Kang, D. W., Kim, Y., Kim, G. H., Kim, K. W., Kim, H.-J., Na, S., Park, K. H., Park, Y. H., Suh, J., Shin, J. H., Shim, Y., Yang, Y., Um, Y. H., Oh, S.-I., Wang, S.-M., Yoon, B., Lee, S. M., Lee, J., … Korean Dementia Association's Quality Management Committee. (2025). Clinical Practice Guidelines for Dementia: Recommendations for the Pharmacological Treatment of Behavioral and Psychological Symptoms. *Dementia and Neurocognitive Disorders*, *24*(1), 24–43. https://doi.org/10.12779/dnd.2025.24.1.24

Cañas-González, B., Fernández-Nistal, A., Ramírez, J. M., & Martínez-Fernández, V. (2020). Influence of Stress and Depression on the Immune System in Patients Evaluated in an Anti-aging Unit. *Frontiers in Psychology*, *11*, 1844. https://doi.org/10.3389/fpsyg.2020.01844

Cao, D., Zhao, Y., Wang, Y., Wei, D., Yan, M., Su, S., Pan, H., & Wang, Q. (2024). Effects of sleep deprivation on anxiety-depressive-like behavior and neuroinflammation. *Brain Research*, *1836*, 148916. https://doi.org/10.1016/j.brainres.2024.148916

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports*, *100*(2), 126.

Cerejeira, J., Lagarto, L., & Mukaetova-Ladinska, E. (2012a). Behavioral and Psychological Symptoms of Dementia. *Frontiers in Neurology*, *3*. https://doi.org/10.3389/fneur.2012.00073

Cerejeira, J., Lagarto, L., & Mukaetova-Ladinska, E. (2012b). Behavioral and Psychological Symptoms of Dementia. *Frontiers in Neurology*, *3*. https://doi.org/10.3389/fneur.2012.00073

Cerejeira, J., Lagarto, L., & Mukaetova-Ladinska, E. B. (2012c). Behavioral and Psychological Symptoms of Dementia. *Frontiers in Neurology*, *3*. https://doi.org/10.3389/fneur.2012.00073

Chakrabarty, K. (2023). The Role of Sleep in Maintaining Mental and Physical Health. *Journal of Community Health Provision*, *3*(3), Article 3. https://doi.org/10.55885/jchp.v3i3.306

Charney, D. S., & Deutch, A. (1996). A functional neuroanatomy of anxiety and fear: Implications for the pathophysiology and treatment of anxiety disorders. *Critical Reviews in Neurobiology*, *10*(3–4), 419–446. https://doi.org/10.1615/critrevneurobiol.v10.i3-4.70

Chen, L., & Kim, S. M. (2024). Exercise effects on neuropsychiatric symptoms and quality of life in mild cognitive impairment: A systematic review and meta-analysis. *Frontiers in Neurology*, *15*. https://doi.org/10.3389/fneur.2024.1447734

Chertkow, H., Borrie, M., Whitehead, V., Black, S. E., Feldman, H. H., Gauthier, S., Hogan, D. B., Masellis, M., McGilton, K., Rockwood, K., Tierney, M. C., Andrew, M., Hsiung, G.-Y. R., Camicioli, R., Smith, E. E., Fogarty, J., Lindsay, J., Best, S., Evans, A., … Rylett, R. J. (2019). The Comprehensive Assessment of Neurodegeneration and Dementia: Canadian Cohort Study. *Canadian Journal of Neurological Sciences*, *46*(5), 499–511. https://doi.org/10.1017/cjn.2019.27

Cheval, B., Maltagliati, S., Sieber, S., Cullati, S., Sander, D., & Boisgontier, M. P. (2022). Physical inactivity amplifies the negative association between sleep quality and depressive symptoms. *Preventive Medicine*, *164*, 107233. https://doi.org/10.1016/j.ypmed.2022.107233

Christofoletti, G., Oliani, M. M., Bucken-Gobbi, L. T., Gobbi, S., Beinotti, F., & Stella, F. (2011). Physical activity attenuates neuropsychiatric disturbances and caregiver burden in patients with dementia. *Clinics*, *66*, 613–618. https://doi.org/10.1590/S1807-59322011000400015

Cipriani, G., Lucetti, C., Danti, S., & Nuti, A. (2015). Sleep disturbances and dementia. *Psychogeriatrics: The Official Journal of the Japanese Psychogeriatric Society*, *15*(1), 65–74. https://doi.org/10.1111/psyg.12069

Collins, J. D., Henley, S. M. D., & Suárez-González, A. (2023). A systematic review of the prevalence of depression, anxiety, and apathy in frontotemporal dementia, atypical and young-onset Alzheimer's disease, and inherited dementia. *International Psychogeriatrics*, *35*(9), 457–476. https://doi.org/10.1017/S1041610220001118

Compass-ND - CCNA - CCNV. CCNA. (2025, July 25). https://ccna-ccnv.ca/compass-nd-study/

Corazza, D. I., Sebastião, É., Pedroso, R. V., Andreatto, C. A. A., de Melo Coelho, F. G., Gobbi, S., Teodorov, E., & Santos-Galduróz, R. F. (2014). Influence of chronic exercise on serum cortisol levels in older adults. *European Review of Aging and Physical Activity*, *11*(1), 25–34. https://doi.org/10.1007/s11556-013-0126-8

Crowe, S. F., & Stranks, E. K. (2018). The Residual Medium and Long-term Cognitive Effects of Benzodiazepine Use: An Updated Meta-analysis. *Archives of Clinical Neuropsychology*, *33*(7), 901–911. https://doi.org/10.1093/arclin/acx120

Custodio, N., Montesinos, R., Lira, D., Herrera-Pérez, E., Bardales, Y., & Valeriano-Lorenzo, L. (2017). Mixed dementia: A review of the evidence. *Dementia & Neuropsychologia*, *11*, 364–370. https://doi.org/10.1590/1980-57642016dn11-040005

Dafsari, F. S., & Jessen, F. (2020). Depression—An underrecognized target for prevention of dementia in Alzheimer's disease. *Translational Psychiatry*, *10*, 160. https://doi.org/10.1038/s41398-020-0839-1

De Bourdeaudhuij, I., Crombez, G., Deforche, B., Vinaimont, F., Debode, P., & Bouckaert, J. (2002). Effects of distraction on treadmill running time in severely obese children and adolescents. *International Journal of Obesity*, *26*(8), 1023–1029. https://doi.org/10.1038/sj.ijo.0802052

De la Rosa, A., Olaso-Gonzalez, G., Arc-Chagnaud, C., Millan, F., Salvador-Pascual, A., García-Lucerga, C., Blasco-Lafarga, C., Garcia-Dominguez, E., Carretero, A., Correas, A. G., Viña, J., & Gomez-Cabrera, M. C. (2020). Physical exercise in the prevention and treatment of Alzheimer's disease. *Journal of Sport and Health Science*, *9*(5), 394–404. https://doi.org/10.1016/j.jshs.2020.01.004

de Oliveira, L. da S. S. C. B., Souza, E. C., Rodrigues, R. A. S., Fett, C. A., & Piva, A. B. (2019). The effects of physical activity on anxiety, depression, and quality of life in elderly people living in the community. *Trends in Psychiatry and Psychotherapy*, *41*, 36–42. https://doi.org/10.1590/2237-6089-2017-0129

DeBoer, L. B., Powers, M. B., Utschig, A. C., Otto, M. W., & Smits, J. A. (2012). Exploring exercise as an avenue for the treatment of anxiety disorders. *Expert Review of Neurotherapeutics*, *12*(8), 1011–1022. https://doi.org/10.1586/ern.12.73

Debruyne, H., Van Buggenhout, M., Le Bastard, N., Aries, M., Audenaert, K., De Deyn, P. P., & Engelborghs, S. (2009). Is the geriatric depression scale a reliable screening tool for depressive symptoms in elderly patients with cognitive impairment? *International Journal of Geriatric Psychiatry*, *24*(6), 556–562. https://doi.org/10.1002/gps.2154

deVries, H. A. (1981). Tranquilizer Effect of Exercise: A Critical Review. *The Physician and Sportsmedicine*, *9*(11), 46–55. https://doi.org/10.1080/00913847.1981.11711206

Dhakal, A., & Bobrin, B. D. (2025). Cognitive Deficits. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK559052/

Dimitriou, T.-D., Verykouki, E., Papatriantafyllou, J., Konsta, A., Kazis, D., & Tsolaki, M. (2020). Non-Pharmacological interventions for the anxiety in patients with dementia. A cross-over randomised controlled trial. *Behavioural Brain Research*, *390*, 112617. https://doi.org/10.1016/j.bbr.2020.112617

Dolezal, B. A., Neufeld, E. V., Boland, D. M., Martin, J. L., & Cooper, C. B. (2017). Interrelationship between Sleep and Exercise: A Systematic Review. *Advances in Preventive Medicine*, *2017*(1), 1364387. https://doi.org/10.1155/2017/1364387

Domingos, C., Pêgo, J. M., & Santos, N. C. (2021). Effects of physical activity on brain function and structure in older adults: A systematic review. *Behavioural Brain Research*, *402*, 113061. https://doi.org/10.1016/j.bbr.2020.113061

Dong, L., Freedman, V. A., & Mendes de Leon, C. F. (2020). The association of comorbid depression and anxiety symptoms with disability onset in older adults. *Psychosomatic Medicine*, *82*(2), 158–164. https://doi.org/10.1097/PSY.0000000000000763

Droste, S. K., Gesing, A., Ulbricht, S., Müller, M. B., Linthorst, A. C. E., & Reul, J. M. H. M. (2003). Effects of Long-Term Voluntary Exercise on the Mouse Hypothalamic-Pituitary-Adrenocortical Axis. *Endocrinology*, *144*(7), 3012–3023. https://doi.org/10.1210/en.2003-0097

Duong, S., Patel, T., & Chang, F. (2017). Dementia: What pharmacists need to know. *Canadian Pharmacists Journal : CPJ*, *150*(2), 118. https://doi.org/10.1177/1715163517690745

Ejiri, M., Kawai, H., Kera, T., Ihara, K., Fujiwara, Y., Watanabe, Y., Hirano, H., Kim, H., & Obuchi, S. (2021). Exercise as a coping strategy and its impact on the psychological well-being of Japanese community-dwelling older adults during the COVID-19 pandemic: A longitudinal study. *Psychology of Sport and Exercise*, *57*, 102054. https://doi.org/10.1016/j.psychsport.2021.102054

Farris, S. G., Legasse, A. J., Uebelacker, L. A., Brown, R. A., Price, L. H., & Abrantes, A. M. (2019). Anxiety Sensitivity is Associated with Lower Enjoyment and an Anxiogenic Response to Physical Activity in Smokers. *Cognitive Therapy and Research*, *43*(1), 78–87. https://doi.org/10.1007/s10608-018-9948-z

Femenía, T., Gómez-Galán, M., Lindskog, M., & Magara, S. (2012). Dysfunctional hippocampal activity affects emotion and cognition in mood disorders. *Brain Research*, *1476*, 58–70. https://doi.org/10.1016/j.brainres.2012.03.053

Ghasemi, M., Navidhamidi, M., Rezaei, F., Azizikia, A., & Mehranfard, N. (2022). Anxiety and hippocampal neuronal activity: Relationship and potential mechanisms. *Cognitive, Affective, & Behavioral Neuroscience*, *22*(3), 431–449. https://doi.org/10.3758/s13415-021-00973-y

Ghiasvand, P., & Irandoust, K. (2024). Moving for Better Sleep: A Narrative Review of Exercise and Sleep Quality. *International Journal of Sport Studies for Health*, *7*(3), 25–32. https://doi.org/10.61838/kman.intjssh.7.3.4

Goyal, A. R., Engedal, K., & Eriksen, S. (2019). Clinicians' experiences of anxiety in patients with dementia. *Dementia*, *18*(1), 80–93. https://doi.org/10.1177/1471301216659770

Guarnieri, B., Adorni, F., Musicco, M., Appollonio, I., Bonanni, E., Caffarra, P., Caltagirone, C., Cerroni, G., Concari, L., Cosentino, F. I. I., Ferrara, S., Fermi, S., Ferri, R., Gelosa, G., Lombardi, G., Mazzei, D., Mearelli, S., Morrone, E., Murri, L., … Sorbi, S. (2012). Prevalence of sleep disturbances in mild cognitive impairment and dementing disorders: A multicenter Italian clinical cross-sectional study on 431 patients. *Dementia and Geriatric Cognitive Disorders*, *33*(1), 50–58. https://doi.org/10.1159/000335363

Harber, V. J., & Sutton, J. R. (1984). Endorphins and Exercise. *Sports Medicine*, *1*(2), 154–171. https://doi.org/10.2165/00007256-198401020-00004

Harvey, P. D. (2019). Domains of cognition and their assessment. *Dialogues in Clinical Neuroscience*, *21*(3), 227–237. https://doi.org/10.31887/DCNS.2019.21.3/pharvey

Hwang, Y., & Hodgson, N. (2020). How Is Sleep Related to Anxiety or Depression in Older Adults With Dementia? *Innovation in Aging*, *4*(Suppl 1), 619. https://doi.org/10.1093/geroni/igaa057.2106

Iaboni, A., Flint, A., Goodarzi, Z., Gough, A., Juola, H., Neil-Sztramko, S., Reynolds, K., Trenaman, S., Ameringen, M. V., Weir, E., Whitmore, C., Yeung, A., & Grenier, S. (2025). 4. CANADIAN GUIDELINES FOR THE ASSESSMENT AND TREATMENT OF ANXIETY IN OLDER ADULTS. *The American Journal of Geriatric Psychiatry*, *33*(10), S3–S4. https://doi.org/10.1016/j.jagp.2025.04.007

Ismail, Z., Elbayoumi, H., Fischer, C. E., Hogan, D. B., Millikin, C. P., Schweizer, T., Mortby, M. E., Smith, E. E., Patten, S. B., & Fiest, K. M. (2017). Prevalence of Depression in Patients With Mild Cognitive Impairment: A Systematic Review and Meta-analysis. *JAMA Psychiatry*, *74*(1), 58–67. https://doi.org/10.1001/jamapsychiatry.2016.3162

Jain, S., Chauhan, N., Sharma, S., Reddy, K. R., Sadhu, V., & Kulkarni, R. V. (2020). 12 - The link between anxiety and Alzheimer's disease: Critical facts. In S. Kanchi & D. Sharma (Eds.), *Nanomaterials in Diagnostic Tools and Devices* (pp. 331–349). Elsevier. https://doi.org/10.1016/B978-0-12-817923-9.00012-2

Jessen, F., Amariglio, R. E., Buckley, R. F., van der Flier, W. M., Han, Y., Molinuevo, J. L., Rabin, L., Rentz, D. M., Rodriguez-Gomez, O., Saykin, A. J., Sikkes, S. A. M., Smart, C. M., Wolfsgruber, S., & Wagner, M. (2020). The characterisation of subjective cognitive decline. *The Lancet. Neurology*, *19*(3), 271–278. https://doi.org/10.1016/S1474-4422(19)30368-0

Jessen, F., Wiese, B., Bachmann, C., Eifflaender-Gorfer, S., Haller, F., Kölsch, H., Luck, T., Mösch, E., van den Bussche, H., Wagner, M., Wollny, A., Zimmermann, T., Pentzek, M., Riedel-Heller, S. G., Romberg, H.-P., Weyerer, S., Kaduszkiewicz, H., Maier, W., Bickel, H., & German Study on Aging, Cognition and Dementia in Primary Care Patients Study Group. (2010). Prediction of dementia by subjective memory impairment: Effects of severity and temporal association with cognitive impairment. *Archives of General Psychiatry*, *67*(4), 414–422. https://doi.org/10.1001/archgenpsychiatry.2010.30

Jin, J. W., Nowakowski, S., Taylor, A., Medina, L. D., & Kunik, M. E. (2021). Cognitive Behavioral Therapy for Mood and Insomnia in Persons With Dementia: A Systematic Review. *Alzheimer Disease & Associated Disorders*, *35*(4), 366. https://doi.org/10.1097/WAD.0000000000000454

Johnco, C. J., Matovic, D., & Wuthrich, V. M. (2024). Anxiety Disorders in Later Life. *Psychiatric Clinics of North America*, *47*(4), 741–752. https://doi.org/10.1016/j.psc.2024.04.015

Jongsiriyanyong, S., & Limpawattana, P. (2018). Mild Cognitive Impairment in Clinical Practice: A Review Article. *American Journal of Alzheimer's Disease & Other Dementias®*, *33*(8), 500–507. https://doi.org/10.1177/1533317518791401

Ju, Y.-E. S., Lucey, B. P., & Holtzman, D. M. (2014). Sleep and Alzheimer disease pathology—A bidirectional relationship. *Nature Reviews. Neurology*, *10*(2), 115–119. https://doi.org/10.1038/nrneurol.2013.269

Jutkowitz, E., MacLehose, R. F., Gaugler, J. E., Dowd, B., Kuntz, K. M., & Kane, R. L. (2017). Risk Factors Associated With Cognitive, Functional, and Behavioral Trajectories of Newly Diagnosed Dementia Patients. *The Journals of Gerontology: Series A*, *72*(2), 251–258. https://doi.org/10.1093/gerona/glw079

Kabeshita, Y., Adachi, H., Matsushita, M., Kanemoto, H., Sato, S., Suzuki, Y., Yoshiyama, K., Shimomura, T., Yoshida, T., Shimizu, H., Matsumoto, T., Mori, T., Kashibayashi, T., Tanaka, H., Hatada, Y., Hashimoto, M., Nishio, Y., Komori, K., Tanaka, T., … Kazui, H. (2017). Sleep disturbances are key symptoms of very early stage Alzheimer disease with behavioral and psychological symptoms: A Japan multi-center cross-sectional study (J-BIRD). *International Journal of Geriatric Psychiatry*, *32*(2), 222–230. https://doi.org/10.1002/gps.4470

Kandola, A., Vancampfort, D., Herring, M., Rebar, A., Hallgren, M., Firth, J., & Stubbs, B. (2018). Moving to Beat Anxiety: Epidemiology and Therapeutic Issues with Physical Activity for Anxiety. *Current Psychiatry Reports*, *20*(8), 63. https://doi.org/10.1007/s11920-018-0923-x

Kazeminia, M., Salari, N., Vaisi-Raygani, A., Jalali, R., Abdi, A., Mohammadi, M., Daneshkhah, A., Hosseinian-Far, M., & Shohaimi, S. (2020). The effect of exercise on anxiety in the elderly worldwide: A systematic review and meta-analysis. *Health and Quality of Life Outcomes*, *18*(1), 363. https://doi.org/10.1186/s12955-020-01609-4

Kenwood, M. M., Kalin, N. H., & Barbas, H. (2022). The prefrontal cortex, pathological anxiety, and anxiety disorders. *Neuropsychopharmacology*, *47*(1), 260–275. https://doi.org/10.1038/s41386-021-01109-z

Khanzada, F. J., Soomro, N., & Khan, S. Z. (2015). Association of Physical Exercise on Anxiety and Depression Amongst Adults. *Journal of the College of Physicians and Surgeons--Pakistan: JCPSP*, *25*(7), 546–548.

Kline, C. E., Hillman, C. H., Bloodgood Sheppard, B., Tennant, B., Conroy, D. E., Macko, R. F., Marquez, D. X., Petruzzello, S. J., Powell, K. E., & Erickson, K. I. (2021). Physical activity and sleep: An

updated umbrella review of the 2018 Physical Activity Guidelines Advisory Committee report. *Sleep Medicine Reviews*, *58*, 101489. https://doi.org/10.1016/j.smrv.2021.101489

Knopman, D. S., & Petersen, R. C. (2014). Mild Cognitive Impairment and Mild Dementia: A Clinical Perspective. *Mayo Clinic Proceedings*, *89*(10), 1452–1459. https://doi.org/10.1016/j.mayocp.2014.06.019

Kovich, H., Kim, W., & Quaste, A. M. (2023). Pharmacologic Treatment of Depression. *American Family Physician*, *107*(2), 173–181.

Kwak, Y. T., Yang, Y., & Koo, M.-S. (2017). Anxiety in Dementia. *Dementia and Neurocognitive Disorders*, *16*(2), 33–39. https://doi.org/10.12779/dnd.2017.16.2.33

Lee, A. T. C., Mok, V. C. T., & Lam, L. C. W. (2024). Anxiety in Dementia. In J. S. Kim (Ed.), *Neuropsychiatric Manifestations in Neurological Diseases* (pp. 71–75). Springer Nature. https://doi.org/10.1007/978-981-97-1821-4_7

Lee, S., & Ho Chung, J. (2022). The association between subjective cognitive decline and quality of life: A population-based study. *Journal of Clinical Neuroscience*, *98*, 60–65. https://doi.org/10.1016/j.jocn.2022.01.037

Lenze, E. J., Pollock, B. G., Shear, M. K., Mulsant, B. H., Bharucha, A., & Reynolds, C. F. (2003). Treatment Considerations for Anxiety in the Elderly. *CNS Spectrums*, *8*(S3), 6–13. https://doi.org/10.1017/S1092852900008221

Lepping, P., Whittington, R., Sambhi, R. S., Lane, S., Poole, R., Leucht, S., Cuijpers, P., McCabe, R., & Waheed, W. (2017). Clinical relevance of findings in trials of CBT for depression. *European Psychiatry*, *45*, 207–211. https://doi.org/10.1016/j.eurpsy.2017.07.003

Leung, D. K. Y., Chan, W. C., Spector, A., & Wong, G. H. Y. (2021). Prevalence of depression, anxiety, and apathy symptoms across dementia stages: A systematic review and meta-analysis. *International Journal of Geriatric Psychiatry*, *36*(9), 1330–1344. https://doi.org/10.1002/gps.5556

Liew, T. M. (2020). Subjective cognitive decline, anxiety symptoms, and the risk of mild cognitive impairment and dementia. *Alzheimer's Research & Therapy*, *12*(1), 107. https://doi.org/10.1186/s13195-020-00673-8

Lin, S. (Lamson). (2023). Inequities in Mental Health Care Facing Racialized Immigrant Older Adults With Mental Disorders Despite Universal Coverage: A Population-Based Study in Canada. *The Journals of Gerontology: Series B*, *78*(9), 1555–1571. https://doi.org/10.1093/geronb/gbad036

Liu, X., Xia, X., Hu, F., Hao, Q., Hou, L., Sun, X., Zhang, G., Yue, J., & Dong, B. (2022). The mediation role of sleep quality in the relationship between cognitive decline and depression. *BMC Geriatrics*, *22*, 178. https://doi.org/10.1186/s12877-022-02855-5

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

Lovell, M. A. (2010). Similarities and differences between mild cognitive impairment and Alzheimer's disease. *Journal of Alzheimer's Disease: JAD*, *19*(1), 219. https://doi.org/10.3233/JAD-2010-1263

Ma, L. (2020). Depression, Anxiety, and Apathy in Mild Cognitive Impairment: Current Perspectives. *Frontiers in Aging Neuroscience*, *12*. https://doi.org/10.3389/fnagi.2020.00009

Martin, E., & Velayudhan, L. (2020). Neuropsychiatric Symptoms in Mild Cognitive Impairment: A Literature Review. *Dementia and Geriatric Cognitive Disorders*, *49*(2), 146–155. https://doi.org/10.1159/000507078

McKinnon, A., Terpening, Z., Hickie, I. B., Batchelor, J., Grunstein, R., Lewis, S. J. G., & Naismith, S. L. (2014). Prevalence and Predictors of Poor Sleep Quality in Mild Cognitive Impairment. *Journal of Geriatric Psychiatry and Neurology*, *27*(3), 204–211. https://doi.org/10.1177/0891988714527516

McShane, R., Keene, J., Gedling, K., Fairburn, C., Jacoby, R., & Hope, T. (1997). Do neuroleptic drugs hasten cognitive decline in dementia? Prospective study with necropsy follow up. *BMJ*, *314*(7076), 266. https://doi.org/10.1136/bmj.314.7076.266

Meier, S. M., Mattheisen, M., Mors, O., Mortensen, P. B., Laursen, T. M., & Penninx, B. W. (2016). Increased mortality among people with anxiety disorders: Total population study. *British Journal of Psychiatry*, *209*(3), 216–221. https://doi.org/10.1192/bjp.bp.115.171975

Moon, B., Kim, S., Park, Y. H., Lim, J.-S., Youn, Y. C., Kim, S., Jang, J.-W., & Alzheimer's Disease Neuroimaging Initiative. (2017). Depressive Symptoms are Associated with Progression to

Dementia in Patients with Amyloid-Positive Mild Cognitive Impairment. *Journal of Alzheimer's Disease: JAD*, *58*(4), 1255–1264. https://doi.org/10.3233/JAD-170225

Mosimann, U. P., Rowan, E. N., Partington, C. E., Collerton, D., Littlewood, E., O'Brien, J. T., Burn, D. J., & McKeith, I. G. (2006). Characteristics of Visual Hallucinations in Parkinson Disease Dementia and Dementia With Lewy Bodies. *The American Journal of Geriatric Psychiatry*, *14*(2), 153–160. https://doi.org/10.1097/01.JGP.0000192480.89813.80

Mukherjee, U., Sehar, U., Brownell, M., & Reddy, P. H. (2024). Sleep deprivation in dementia comorbidities: Focus on cardiovascular disease, diabetes, anxiety/depression and thyroid disorders. *Aging*, *16*(21), 13409–13429. https://doi.org/10.18632/aging.206157

Müller-Spahn, F. (2003). Behavioral disturbances in dementia. *Dialogues in Clinical Neuroscience*, *5*(1), 49–59.

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A Brief Screening Tool For Mild Cognitive Impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Noetel, M., Sanders, T., Gallardo-Gómez, D., Taylor, P., del Pozo Cruz, B., van den Hoek, D., Smith, J. J., Mahoney, J., Spathis, J., Moresi, M., Pagano, R., Pagano, L., Vasconcellos, R., Arnott, H., Varley, B., Parker, P., Biddle, S., & Lonsdale, C. (2024). Effect of exercise for depression: Systematic review and network meta-analysis of randomised controlled trials. *The BMJ*, *384*, e075847. https://doi.org/10.1136/bmj-2023-075847

Orrell, M., & Bebbington, P. (1996). Psychosocial stress and anxiety in senile dementia. *Journal of Affective Disorders*, *39*(3), 165–173. https://doi.org/10.1016/0165-0327(95)00094-1

Petersen, R. C., Caracciolo, B., Brayne, C., Gauthier, S., Jelic, V., & Fratiglioni, L. (2014). Mild cognitive impairment: A concept in evolution. *Journal of Internal Medicine*, *275*(3), 214. https://doi.org/10.1111/joim.12190

Petruzzello, S. J., Landers, D. M., & Salazar, W. (1993). Exercise and Anxiety Reduction: Examination of Temperature as an Explanation for Affective Change. *Journal of Sport & Exercise Psychology*, *15*(1), 63–76. https://doi.org/10.1123/jsep.15.1.63

Pippenger, M. A. (2023). Incidence of subjective cognitive decline in a private practice memory clinic. *Alzheimer's & Dementia*, *19*(S8), e064508. https://doi.org/10.1002/alz.064508

Porensky, E. K., Dew, M. A., Karp, J. F., Skidmore, E., Rollman, B. L., Shear, M. K., & Lenze, E. J. (2009). The Burden of Late-Life Generalized Anxiety Disorder: Effects on Disability, Health-Related Quality of Life, and Healthcare Utilization. *The American Journal of Geriatric Psychiatry : Official Journal of the American Association for Geriatric Psychiatry*, *17*(6), 473. https://doi.org/10.1097/jgp.0b013e31819b87b2

Porter, V. R., Buxton, W. G., Fairbanks, L. A., Strickland, T., O'Connor, S. M., Rosenberg-Thompson, S., & Cummings, J. L. (2003). Frequency and characteristics of anxiety among patients with Alzheimer's disease and related dementias. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *15*(2), 180–186. https://doi.org/10.1176/jnp.15.2.180

Rabins, P. V., Mace, N. L., & Lucas, M. J. (1982). The Impact of Dementia on the Family. *JAMA*, *248*(3), 333–335. https://doi.org/10.1001/jama.1982.03330030039022

Ressler, K. J., & Nemeroff, C. B. (2000). Role of serotonergic and noradrenergic systems in the pathophysiology of depression and anxiety disorders. *Depression and Anxiety*, *12*(S1), 2–19. https://doi.org/10.1002/1520-6394(2000)12:1+<2::AID-DA2>3.0.CO;2-4

Roberts, R., & Knopman, D. S. (2013). Classification and Epidemiology of MCI. *Clinics in Geriatric Medicine*, *29*(4), 753–772. https://doi.org/10.1016/j.cger.2013.07.003

Rodriguez-Ayllon, M., Solis-Urra, P., Arroyo-Ávila, C., Álvarez-Ortega, M., Molina-García, P., Molina-Hidalgo, C., Gómez-Río, M., Brown, B., Erickson, K. I., & Esteban-Cornejo, I. (2024). Physical activity and amyloid beta in middle-aged and older adults: A systematic review and meta-analysis. *Journal of Sport and Health Science*, *13*(2), 133–144. https://doi.org/10.1016/j.jshs.2023.08.001

Röhr, S., Pabst, A., Riedel-Heller, S. G., Jessen, F., Turana, Y., Handajani, Y. S., Brayne, C., Matthews, F. E., Stephan, B. C. M., Lipton, R. B., Katz, M. J., Wang, C., Guerchet, M., Preux, P.-M., Mbelesso, P., Ritchie, K., Ancelin, M.-L., Carrière, I., Guaita, A., … for Cohort Studies of Memory in an International Consortium (COSMIC). (2020). Estimating prevalence of subjective cognitive decline in and across international cohort studies of aging: A COSMIC study. *Alzheimer's Research & Therapy*, *12*(1), 167. https://doi.org/10.1186/s13195-020-00734-y

Rotenberg, S., & Dawson, D. R. (2022). Characterizing Cognition in Everyday Life of Older Adults With Subjective Cognitive Decline. *Otjr*, *42*(4), 269–276. https://doi.org/10.1177/15394492221093310

Rotenberg, S., Maeir, A., & Dawson, D. R. (2020). Changes in Activity Participation Among Older Adults With Subjective Cognitive Decline or Objective Cognitive Deficits. *Frontiers in Neurology*, *10*. https://doi.org/10.3389/fneur.2019.01393

Ruiz-Comellas, A., Valmaña, G. S., Catalina, Q. M., Baena, I. G., Mendioroz Peña, J., Roura Poch, P., Sabata Carrera, A., Cornet Pujol, I., Casaldàliga Solà, À., Fusté Gamisans, M., Saldaña Vila, C., Vázquez Abanades, L., & Vidal-Alaball, J. (2022). Effects of Physical Activity Interventions in the Elderly with Anxiety, Depression, and Low Social Support: A Clinical Multicentre Randomised Trial. *Healthcare*, *10*(11), Article 11. https://doi.org/10.3390/healthcare10112203

Sabatini, S., Woods ,Robert T., Ukoumunne ,Obioha C., Ballard ,Clive, Collins ,Rachel, & and Clare, L. (2022). Associations of subjective cognitive and memory decline with depression, anxiety, and two-year change in objectively-assessed global cognition and memory. *Aging, Neuropsychology, and Cognition*, *29*(5), 840–866. https://doi.org/10.1080/13825585.2021.1923634

Sadak, T. I., Katon, J., Beck, C., Cochrane, B. B., & Borson, S. (2014). Key neuropsychiatric symptoms in common dementias: Prevalence and implications for caregivers, clinicians, and health systems. *Research in Gerontological Nursing*, *7*(1), 44–52. https://doi.org/10.3928/19404921-20130918-01

Salzman, C. D., & Fusi, S. (2010). Emotion, Cognition, and Mental State Representation in Amygdala and Prefrontal Cortex. *Annual Review of Neuroscience*, *33*(Volume 33, 2010), 173–202. https://doi.org/10.1146/annurev.neuro.051508.135256

Schnabel Jr, T. (1987). Evaluation of the safety and side effects of antianxiety agents. *The American Journal of Medicine*, *82*(5), 7–13. https://doi.org/10.1016/0002-9343(87)90197-5

Scott, A. J., Webb, T. L., Martyn-St James, M., Rowse, G., & Weich, S. (2021a). Improving sleep quality leads to better mental health: A meta-analysis of randomised controlled trials. *Sleep Medicine Reviews*, *60*, 101556. https://doi.org/10.1016/j.smrv.2021.101556

Scott, A. J., Webb, T. L., Martyn-St James, M., Rowse, G., & Weich, S. (2021b). Improving sleep quality leads to better mental health: A meta-analysis of randomised controlled trials. *Sleep Medicine Reviews*, *60*, 101556. https://doi.org/10.1016/j.smrv.2021.101556

Seignourel, P. J., Kunik, M. E., Snow, L., Wilson, N., & Stanley, M. (2008a). Anxiety in dementia: A critical review. *Clinical Psychology Review*, *28*(7), 1071–1082. https://doi.org/10.1016/j.cpr.2008.02.008

Seignourel, P. J., Kunik, M. E., Snow, L., Wilson, N., & Stanley, M. (2008b). Anxiety in dementia: A critical review. *Clinical Psychology Review*, *28*(7), 1071–1082. https://doi.org/10.1016/j.cpr.2008.02.008

Servant, D. (2019). [Non-pharmacological treatment for anxiety disorders]. *La Revue Du Praticien*, *69*(9), 985–987.

Shen, B., Ma, C., Wu, G., Liu, H., Chen, L., & Yang, G. (2023). Effects of exercise on circadian rhythms in humans. *Frontiers in Pharmacology*, *14*. https://doi.org/10.3389/fphar.2023.1282357

Shen, Z., Yang, X., She, T., Zhao, G., Dou, Z., Luo, Y., Lin, W., Dang, W., & Yu, S. (2024). Deficits in brain default mode network connectivity mediate the relationship between poor sleep quality and anxiety severity. *Sleep*, *47*(3), zsad296. https://doi.org/10.1093/sleep/zsad296

Silva, M. V. F., Loures, C. de M. G., Alves, L. C. V., de Souza, L. C., Borges, K. B. G., & Carvalho, M. das G. (2019). Alzheimer's disease: Risk factors and potentially protective measures. *Journal of Biomedical Science*, *26*(1), 33. https://doi.org/10.1186/s12929-019-0524-y

Singh, B., Olds, T., Curtis, R., Dumuid, D., Virgara, R., Watson, A., Szeto, K., O'Connor, E., Ferguson, T., Eglitis, E., Miatke, A., Simpson, C. E., & Maher, C. (2023). Effectiveness of physical activity interventions for improving depression, anxiety and distress: An overview of systematic reviews. *British Journal of Sports Medicine*, *57*(18), 1203–1209. https://doi.org/10.1136/bjsports-2022-106195

Sobel, R. M., & Markov, D. (2005). The impact of anxiety and mood disorders on physical disease: The worried not-so-well. *Current Psychiatry Reports*, *7*(3), 206–212. https://doi.org/10.1007/s11920-005-0055-y

Sormaz, M., Murphy, C., Wang, H., Hymers, M., Karapanagiotidis, T., Poerio, G., Margulies, D. S., Jefferies, E., & Smallwood, J. (2018). Default mode network can support the level of detail in experience during active task states. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(37), 9318. https://doi.org/10.1073/pnas.1721259115

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A Brief Measure for Assessing Generalized Anxiety Disorder: The GAD-7. *Archives of Internal Medicine*, *166*(10), 1092–1097. https://doi.org/10.1001/archinte.166.10.1092

Stavrou, V. T., Vavougios, G. D., Hadjigeorgiou, G. M., Bargiotas, P., Stavrou, V. T., Vavougios, G., Hadjigeorgiou, G. M., & Bargiotas, P. (2024). The Effect of Physical Exercise on Patients With Mild Cognitive Impairment: A Scoping Review. *Cureus*, *16*. https://doi.org/10.7759/cureus.73265

Stonerock, G. L., Gupta, R. P., & Blumenthal, J. A. (2024). Is exercise a viable therapy for anxiety? Systematic review of recent literature and critical analysis. *Progress in Cardiovascular Diseases*, *83*, 97–115. https://doi.org/10.1016/j.pcad.2023.05.006

Stubbs, B., Vancampfort, D., Rosenbaum, S., Firth, J., Cosco, T., Veronese, N., Salum, G. A., & Schuch, F. B. (2017). An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: A meta-analysis. *Psychiatry Research*, *249*, 102–108. https://doi.org/10.1016/j.psychres.2016.12.020

Su, Y., Wang, S.-B., Zheng, H., Tan, W.-Y., Li, X., Huang, Z.-H., Hou, C.-L., & Jia, F.-J. (2021). The role of anxiety and depression in the relationship between physical activity and sleep quality: A serial multiple mediation model. *Journal of Affective Disorders*, *290*, 219–226. https://doi.org/10.1016/j.jad.2021.04.047

Sullivan, E. C., James, E., Henderson, L.-M., McCall, C., & Cairney, S. A. (2023). The influence of emotion regulation strategies and sleep quality on depression and anxiety. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *166*, 286–305. https://doi.org/10.1016/j.cortex.2023.06.001

Thuné-Boyle, I. C. V., Iliffe, S., Cerga-Pashoja, A., Lowery, D., & Warner, J. (2012). The effect of exercise on behavioral and psychological symptoms of dementia: Towards a research agenda. *International Psychogeriatrics*, *24*(7), 1046–1057. https://doi.org/10.1017/S1041610211002365

Turek, F. W., Penev, P., Zhang, Y., van Reeth, O., & Zee, P. (1995). Effects of age on the circadian system. *Neuroscience & Biobehavioral Reviews*, *19*(1), 53–58. https://doi.org/10.1016/0149-7634(94)00030-5

Twelftree, H., & Qazi, A. (2006). Relationship between anxiety and agitation in dementia. *Aging & Mental Health*, *10*(4), 362–367. https://doi.org/10.1080/13607860600638511

Uchida, S., Shioda, K., Morita, Y., Kubota, C., Ganeko, M., & Takeda, N. (2012). Exercise Effects on Sleep Physiology. *Frontiers in Neurology*, *3*, 48. https://doi.org/10.3389/fneur.2012.00048

Walker, Z., Possin, K. L., Boeve, B. F., & Aarsland, D. (2015). Lewy body dementias. *The Lancet*, *386*(10004), 1683–1697. https://doi.org/10.1016/S0140-6736(15)00462-6

Wang, J., Chen, S., & Xue, J. (2024). Depressive symptoms mediate the longitudinal relationships between sleep quality and cognitive functions among older adults with mild cognitive impairment: A cross-lagged modeling analysis. *Scientific Reports*, *14*(1), 21242. https://doi.org/10.1038/s41598-024-72159-8

Ward, S. A., & Pase, M. P. (2020). Advances in pathophysiology and neuroimaging: Implications for sleep and dementia. *Respirology*, *25*(6), 580–592. https://doi.org/10.1111/resp.13728

Washburn, R. A., McAuley, E., Katula, J., Mihalko, S. L., & Boileau, R. A. (1999). The Physical Activity Scale for the Elderly (PASE): Evidence for Validity. *Journal of Clinical Epidemiology*, *52*(7), 643–651. https://doi.org/10.1016/S0895-4356(99)00049-9

Washburn, R. A., Smith, K. W., Jette, A. M., & Janney, C. A. (1993). The Physical Activity Scale for the Elderly (PASE): Development and evaluation. *Journal of Clinical Epidemiology*, *46*(2), 153–162. https://doi.org/10.1016/0895-4356(93)90053-4

Wennberg, A. M. V., Wu, M. N., Rosenberg, P. B., & Spira, A. P. (2017). Sleep Disturbance, Cognitive Decline, and Dementia: A Review. *Seminars in Neurology*, *37*, 395–406. https://doi.org/10.1055/s-0037-1604351

Wickersham, C. E. (2022). *The Role of Physical Activity and Gender as Moderators for the Relationship between Insomnia and Depression* [Ph.D., University of Massachusetts Boston]. https://www.proquest.com/docview/2681823300/abstract/3387B480E3004E14PQ/1

Wild, B., Eckl, A., Herzog, W., Niehoff, D., Lechner, S., Maatouk, I., Schellberg, D., Brenner, H., Müller, H., & Löwe, B. (2014). Assessing generalized anxiety disorder in elderly people using the GAD-7 and GAD-2 scales: Results of a validation study. *The American Journal of Geriatric Psychiatry: Official Journal of the American Association for Geriatric Psychiatry*, *22*(10), 1029–1038. https://doi.org/10.1016/j.jagp.2013.01.076

Wilson, R. S., Begeny, C. T., Boyle, P. A., Schneider, J. A., & Bennett, D. A. (2011). Vulnerability to Stress, Anxiety, and Development of Dementia in Old Age. *The American Journal of Geriatric Psychiatry*, *19*(4), 327–334. https://doi.org/10.1097/JGP.0b013e31820119da

Wrede, N., Töpfer, N. F., Wilz, G., & Pfeiffer, K. (2025). Decomposing the association between caregiver burden and depressive symptoms in family caregivers of older adults: A network analysis. *Journal of Affective Disorders*, *387*, 119547. https://doi.org/10.1016/j.jad.2025.119547

Xu, W., Tan, C.-C., Zou, J.-J., Cao, X.-P., & Tan, L. (2020). Sleep problems and risk of all-cause cognitive decline or dementia: An updated systematic review and meta-analysis. *Journal of Neurology, Neurosurgery, and Psychiatry*, *91*(3), 236–244. https://doi.org/10.1136/jnnp-2019-321896

Xue, P., Du, X., & Kong, J. (2025). Age-dependent mechanisms of exercise in the treatment of depression: A comprehensive review of physiological and psychological pathways. *Frontiers in Psychology*, *16*. https://doi.org/10.3389/fpsyg.2025.1562434

Yang, P.-Y., Ho, K.-H., Chen, H.-C., & Chien, M.-Y. (2012). Exercise training improves sleep quality in middle-aged and older adults with sleep problems: A systematic review. *Journal of Physiotherapy*, *58*(3), 157–163. https://doi.org/10.1016/S1836-9553(12)70106-6

Yang, Y., Zhang, Z., Liu, J., & Cao, H. (2023). Interactive effects of sleep and physical activity on depression among rural university students in China. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1240856

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1982). Development and validation of a geriatric depression screening scale: A preliminary report. *Journal of Psychiatric Research*, *17*(1), 37–49. https://doi.org/10.1016/0022-3956(82)90033-4

Zhang, M., Wang, H., Li, T., & Yu, X. (2012). Prevalence of Neuropsychiatric Symptoms across the Declining Memory Continuum: An Observational Study in a Memory Clinic Setting. *Dementia and Geriatric Cognitive Disorders Extra*, *2*(1), 200–208. https://doi.org/10.1159/000338410

Zhao, K., Xie, H., Fonzo, G. A., Carlisle, N. B., Osorio, R. S., & Zhang, Y. (2024). Dementia Subtypes Defined Through Neuropsychiatric Symptom–Associated Brain Connectivity Patterns. *JAMA Network Open*, *7*(7), e2420479. https://doi.org/10.1001/jamanetworkopen.2024.20479

Zu, B., Wang, N., Fan, L., Huang, J., Zhang, Y., Wu, Y., & Du, M. (2025). A study on the impact of chronic diseases and depressive symptoms comorbidity on the risk of cognitive impairment in

middle-aged and older adults people based on the CHARLS database. *Frontiers in Public Health*, *13*. https://doi.org/10.3389/fpubh.2025.1558430

Zubenko, G. S., Moossy, J., & Kopp, U. (1990). Neurochemical correlates of major depression in primary dementia. *Archives of Neurology*, *47*(2), 209–214. https://doi.org/10.1001/archneur.1990.00530020117023

Appendices

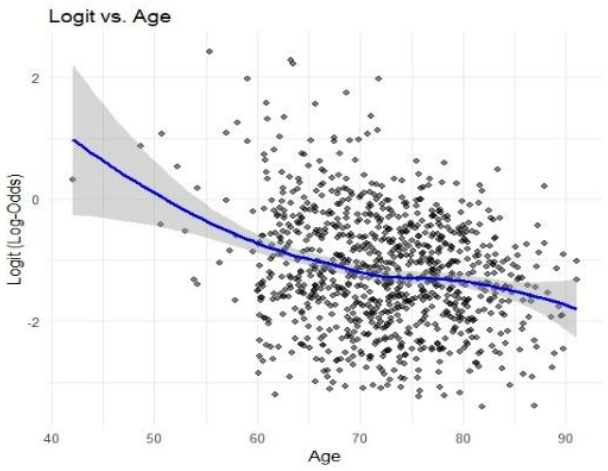
Appendix A: Box-Tidwell Test Results

Summary of the Box-Tidwell Test for the Anxiety Model

Variable	Interaction Term	p-value	Interpretation
Physical Activity	PASE:logPASE	0.5090	✅ Linearity holds
Sleep Quality	PSQI:logPSQI	0.2428	✅ Linearity holds
Age	Age:logAge	0.0418	❌ Linearity violated
Years of Education	Years.of.education:logEducation	0.7531	✅ Linearity holds
Comorbidities	Comorbidities:logComorbidities	0.4679	✅ Linearity holds

PASE: Physical Activity Scale for Elderly, PSQI: Pittsburgh Sleep Quality Index

Visualization of Linearity Assumption for Age in Anxiety Model



Appendix B: Questionnaires

Geriatric Depression Scale (GDS) 30 items

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Patient _____ Examiner_____ Date_____

Directions to Patient: Please choose the best answer for how you have felt over the past week.
Directions to Examiner: Present questions VERBALLY. Circle answer given by patient. Do not show to patient.

1.	Are you basically satisfied with your life?	yes	**no** (1)
2.	Have you dropped many of your activities and interests?	**yes** (1)	no
3.	Do you feel that your life is empty?	**yes** (1)	no
4.	Do you often get bored?	**yes** (1)	no
5.	Are you hopeful about the future?	yes	**no** (1)
6.	Are you bothered by thoughts you can't get out of your head?	**yes** (1)	no
7.	Are you in good spirits most of the time?	yes	**no** (1)
8.	Are you afraid that something bad is going to happen to you?	**yes** (1)	no
9.	Do you feel happy most of the time?	yes	**no** (1)
10.	Do you often feel helpless?	**yes** (1)	no
11.	Do you often get restless and fidgety?	**yes** (1)	no
12.	Do you prefer to stay at home rather than go out and do things?	**yes** (1)	no
13.	Do you frequently worry about the future?	**yes** (1)	no
14.	Do you feel you have more problems with memory than most?	**yes** (1)	no
15.	Do you think it is wonderful to be alive now?	yes	**no** (1)
16.	Do you feel downhearted and blue?	**yes** (1)	no
17.	Do you feel pretty worthless the way you are now?	**yes** (1)	no
18.	Do you worry a lot about the past?	**yes** (1)	no
19.	Do you find life very exciting?	yes	**no** (1)
20.	Is it hard for you to get started on new projects?	**yes** (1)	no
21.	Do you feel full of energy?	yes	**no** (1)
22.	Do you feel that your situation is hopeless?	**yes** (1)	no
23.	Do you think that most people are better off than you are?	**yes** (1)	no
24.	Do you frequently get upset over little things?	**yes** (1)	no
25.	Do you frequently feel like crying?	**yes** (1)	no
26.	Do you have trouble concentrating?	**yes** (1)	no
27.	Do you enjoy getting up in the morning?	yes	**no** (1)
28.	Do you prefer to avoid social occasions?	**yes** (1)	no
29.	Is it easy for you to make decisions?	yes	**no** (1)
30.	Is your mind as clear as it used to be?	yes	**no** (1)

TOTAL: Please sum all bolded answers (worth one point) for a total score. _____

Scores: **0 - 9 Normal** **10 - 19 Mild Depressive** **20 - 30 Severe Depressive**

Source: www.stanford.edu/~ yesavage

Source: Dermatol Nurs © 2002 Jannetti Publications, Inc.

Generalized Anxiety Disorder-7 item (GAD-7)

		Not at all	Several days	More than half the days	Nearly everyday
1	Feeling nervous, anxious or on edge	0	1	2	3
2	Not being able to stop or control worrying	0	1	2	3
3	Worrying too much about different things	0	1	2	3
4	Trouble relaxing	0	1	2	3
5	Being so restless that is hard to sit still	0	1	2	3
6	Becoming easily annoyed or irritable	0	1	2	3
7	Feeling afraid as if something awful might happen	0	1	2	3

Pittsburgh Sleep Quality Index (PSQI)

Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month.
Please answer all questions.

1. During the past month, what time have you usually gone to bed at night? .
2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night? __
3. During the past month, what time have you usually gotten up in the morning? ___
4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) ___

5. During the past month, how often have you had trouble sleeping because you…	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
a. Cannot get to sleep within 30 minutes				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe:				
6. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
	No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
8. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?				
	Very good	Fairly good	Fairly bad	Very bad
9. During the past month, how would you rate your sleep quality overall?				

	No bed partner or room mate	Partner/room mate in other room	Partner in same room but not same bed	Partner in same bed
10. Do you have a bed partner or room mate?				
	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
If you have a room mate or bed partner, ask him/her how often in the past month you have had:				
a. Loud snoring				
b. Long pauses between breaths while asleep				
c. Legs twitching or jerking while you sleep				
d. Episodes of disorientation or confusion during sleep				
e. Other restlessness while you sleep, please describe:				

PASE SCORING FORM

PASE Item	Type of Activity	Activity Weight	Activity Frequency	Frequency
1.	Leisure time Activity			
2.	Walk outside home	20	a.	
3.	Light sport / recreational activities	21	a.	
4.	Moderate sport / recreational activities	23	a.	
5.	Strenuous sport / recreational activities	23	a.	
6.	Muscle strength / endurance exercises	30	a.	
7.	Light housework	25	b.	
8.	Heavy housework or chores	25	b.	
9a.	Home repairs	30	b.	
9b.	Lawn work or yard care	36	b.	
9c.	Outdoor gardening	20	b.	
9d.	Caring for another person	35	b.	
10.	Work for pay or as volunteer	21	c.	
			PASE SCORE:	

Activity Frequency Values:

a. Use hours per day conversion table below
b. 1 = activity reported in past week, 0 = activity not reported
c. Divide work hours reported in Item 10.1 by seven; if no work hours or if job involves mainly sitting with slight arm movements (Item 10.2 = 1), then activity frequency = 0.

ACTIVITY TIME TO HOURS PER DAY
CONVERSION TABLE

Days of Activity	Hours Per Day of Activity	Hours Per Day
0. Never		0
1. Seldom	1. Less than 1 hour	.11
	2. 1-2 hours	.32
	3. 2-4 hours	.64
	4. More than 4 hours	1.07
2. Sometimes	1. Less than 1 hour	.25
	2. 1-2 hours	.75
	3. 2-4 hours	1.50
	4. More than 4 hours	2.50
3. Often	1. Less than 1 hour	.43
	2. 1-2 hours	1.29
	3. 2-4 hours	2.57
	4. More than 4 hours	4.29