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Consideration of Executive Functioning for Physiotherapy Rehabilitation: Studies of Physiotherapists’ Knowledge, Normative Data, and a Practice Application

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Abstract

Executive functioning (EF) refers to a family of cognitive abilities involved in decision-making and self-regulation and can be impaired in many patients referred for physiotherapy, including older adults and people living with chronic pain. Physiotherapists may need to recognize impairments in EF so that rehabilitation can be adjusted to maximize a patient's ability while minimizing their limitations. This dissertation aimed to determine what physiotherapists understood about EF, to summarize normative data for application in physiotherapy practice, and to provide an assessment of feasibility for studying EF impairments in people living with chronic pain. Study one, an online survey, examined what physiotherapists understood about EF as a concept, what EF assessments they used clinically, and if this was influenced by their primary area of practice (i.e., musculoskeletal, neurological, cardiorespiratory, or multi-systems). Respondents (N = 262) subjectively reported that they understood what EF is, but this only moderately correlated with objective understanding, r = 0.43 ($p < 0.001$). A physiotherapist's primary area of practice impacted their knowledge of EF and their experience assessing EF ($p < 0.01$). Physiotherapists reported an awareness of some measures of EF; however, were unsure about interpreting patient scores among the multiple sets of available normative data. Study two presented summarized normative data for three common assessments of EF in older adults (i.e., trail-making, verbal fluency, and clock drawing tests) based on a systematic review. Methodological quality of 35 studies meeting the inclusion criteria were assessed. Normative data were found for trail-making in 19 studies, 34 studies for verbal fluency, and five studies for clock drawing tests. Normative data were stratified by age, education, and sex in summary tables for accessible referencing by physiotherapists. Finally, study three described the feasibility of virtual recruitment and data collection in females living with Chronic Pelvic Pain, a musculoskeletal chronic pain condition not examined in previous EF research. Results (N = 35) indicated impaired EF, and high central sensitization, pain catastrophizing, depression, anxiety, and stress. These findings demonstrated impaired EF in a chronic pain population treated by physiotherapists, revealing a potentially overlooked variable that may impact physiotherapy rehabilitation outcomes.

Keywords

Executive Function, Physical Therapy, Physiotherapy, Cognition, Older Adults, Chronic Pain, Surveys and Questionnaires, Systematic Review, Pilot Study

Summary for Lay Audience

Executive functioning (EF) is a complex ability of the human brain responsible for decision-making and self-management. Many patients of physiotherapists, such as older adults and people living with chronic pain, potentially have impairments in EF. It is possible that patients may not reach their full potential with physiotherapy rehabilitation if impairment in EF is not considered. This dissertation presents the results of three studies that investigated what physiotherapists understood about EF, summarized scores from three commonly used EF assessments for application by physiotherapists, and a study of EF impairments in people living with chronic pain. The first study surveyed physiotherapists about their understanding of EF as a concept. A total of 262 respondents completed the survey and reported that they understood what EF was, but when they were asked to identify the correct components of EF more specifically, they were only moderately accurate. Respondents also reported an awareness of some assessment tools that measure EF; however, were unsure about how to interpret their patients' scores. Therefore, in the second study, 35 published papers were reviewed that presented "normal" scores (i.e., scores that characterize what is usual in a defined population) on three assessment tools measuring EF (e.g., tests called trail-making, verbal fluency, and clock drawing tests). Normal scores were found for a trail-making test in 19 studies, 34 studies for a fluency test, and five studies for a clock drawing test. Data were summarized by age, education, and sex. In the third study, a total of 35 females living with a condition called Chronic Pelvic Pain were recruited to participate in an interview and complete several questionnaires. Chronic Pelvic Pain is a condition that has not been examined in previous EF research. The study aimed to describe the feasibility (i.e., the degree to which future studies could be conveniently completed) of virtual recruitment and EF data collection in these participants. Results were indicative of impaired EF, and high central sensitization, pain catastrophizing, depression, anxiety, and stress. These findings demonstrate impaired EF in a patient population treated by physiotherapists, revealing an overlooked variable with the potential to impact physiotherapy rehabilitation outcomes.

Co-Authorship Statement

Chapter two represents a peer-reviewed manuscript currently in press with *Physiotherapy Canada* undertaken in collaboration with co-authors. Chapter three has been submitted for publication with *Ageing Research Reviews*. Nicole Guitar was the primary investigator across all articles in thesis and took the lead role in all aspects of the research and writing. References for these two studies are provided below, in the order in which they appear within the dissertation.

Guitar, N. A., Connelly, D. M., Murray, L. & Hunter, S. W. (2021 in press). A survey of Canadian physiotherapists and physiotherapy students' knowledge and use of executive functioning assessments in clinical practice. Accepted to *Physiotherapy Canada*. ID: PTC-2021-0020.

Guitar, N. A., Connelly, D. M., Murray, L. & Hunter, S. W. (2021). A systematic review of normative data for the interpretation of executive functioning in older adults: Clock Drawing Tests, Verbal Fluency Tests and Trail-Making Tests. Submitted to *Aging Research Reviews*.

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Chapter 1

Introduction

Executive functioning (EF; also called executive control or cognitive control) refers to a family of cognitive abilities involved in decision-making and self-regulation. These abilities allow for control of one's behaviour in pursuit of long-term goals (Lezak, Howieson & Loring, 2004; Barkley, 2012). Impairment in EF, a concept also referred to as executive dysfunction, is common in many patient populations seen by physiotherapists, such as older adults (Caetano et al., 2018; Muir, Gopaul & Montero-Odasso, 2012; Buracchio et al., 2011; Kearney et al., 2013) and people living with chronic pain (Bunk et al., 2019; Berryman et al., 2014).

While EF impairment is prevalent in patient populations seen by physiotherapists, previous research highlights physiotherapists' lack of knowledge about impairment in EF, current physiotherapy practices for modifications to implement during rehabilitation for people living with EF impairments, and the negative impact of EF impairment on rehabilitation (Blackwood & Martin, 2017; Cossette et al., 2016; Hayes, Donnellan & Stokes, 2015; Struder, 2007). Measures of EF are strongly related to daily functioning and can predict future functional dependence after discharge from physiotherapy rehabilitation (Hanks et al., 1999). It is essential for physiotherapists to understand how a person's EF can impact physiotherapy rehabilitation, and for the physiotherapist to understand the potential use of remedial and compensatory intervention approaches. These compensatory approaches include providing structure, feedback and routine or assisting the patient to compensate for reduced abilities by using other intact cognitive functions and/or modifying their environment (Blackwood & Martin, 2017; O'Sullivan et al., 2014; Studer, 2007). Physiotherapists need to understand the impact of EF impairments on rehabilitation to develop strategies to minimize that impact through appropriate instruction, cues, and interdisciplinary collaboration.

According to the most recent 'Description of Physiotherapy in Canada' published by the Canadian Physiotherapy Association (CPA, 2012), the scope of physiotherapy assessment in Canada includes, but is not limited to, examination of joint integrity and mobility, gait and balance, muscle performance, motor function, cardiorespiratory function, neuromotor and sensorimotor development, cardiovascular capacity, pain, cognition, and mental status across all body systems (ACCPAP, Alliance, CPA, CCPUP, 2009). A physiotherapists' practice may involve clients of all ages in a variety of settings providing health services in a variety of contexts from wellness, health promotion and prevention, acute care and rehabilitation to disability and disease management (CPA, 2012). Physiotherapists in Canada assess clients with actual or potential impairments, pain, limitations, or other health related conditions using detailed history taking, specific tests and measures for screening, establishing diagnoses and/or monitoring. The biopsychosocial model, in which physiotherapists practice, allows for the co-existence of the biological, psychological, and social branches of ill-health, and the interplay between these (Engel, 1979; 2012). This person-centered approach enables a physiotherapist to step into the world of the individual, embrace the person's lived experience and begin to understand their unique lifeworld (i.e., all that makes up the world of the individual; Dahlberg, Todres, & Galvin, 2009; Jones, Edwards, & Gifford, 2002; Langendoen, 2004; Solvang & Fougner, 2016).

1.1 Defining Executive Functioning

EF is considered the use of self-directed actions to choose goals and to select, enact and sustain actions across time toward those goals (Barkley, 2013). As such, EF includes the abilities that allow us to plan, judge, reason, solve problems and organize (Hankee et al., 2013; Wang et al., 2014). EF allows us to think before we act, meet unanticipated challenges, and stay focused (Diamond, 2013). To illustrate the everyday importance of EF, assessment measures that can identify impairments in EF (i.e., clock drawing and letter cancellation tests) have been employed as screening tests for adults aged 80 years and older renewing their driver's license in the province of Ontario since 2017 (Ministry of Transportation, 2017). EF is also considered part of what is referred to as "functional cognition", which is cognition required for daily living that is also influential on the initiation and performance of physical exercise (Donovan et al., 2008).

Historically, the concept of EF predates the actual term by more than a century (Harlow, 1848; 1868). The concept was first defined, by default, as the function of the human brains' prefrontal lobes (Pribram, 1973; 1976). However, it is now understood that EF is not exclusively a function of any single brain region. EF is largely controlled by frontal regions of the brain, most notably the prefrontal cortex (PFC) in the frontal lobe; however, the PFC has various connections to other brain regions including the basal ganglia, amygdala, and cerebellum (Watson et al., 2010; Morris et al., 2016).

For the purposes of this dissertation, the abilities considered integral parts of EF, that are considered core executive functions, include: inhibition, working memory and cognitive flexibility (Lehto et al., 2003; Miyake et al., 2000). These have also been referred to as inhibition, updating, and shifting, respectively. The Unity and Diversity theory of EF states that these EF variables are related to one another, but not so closely as to represent the same construct (Miyake et al., 2012). Inhibition involves not acting on impulse and is commonly considered self-control. Working memory and updating involve holding information in the mind and working with it on the "mental blackboard" (i.e., our temporary workspace that makes possible the examination and manipulation of information). Cognitive flexibility and shifting involve changing perspective to solve a problem and/or adjusting to new priorities. In combination, these three abilities allow for reasoning, problem solving and planning (Collins & Koechlin, 2012; Lunt et al., 2012). For the purposes of this dissertation, *executive function* is a superordinate term inclusive of multiple components and types of *executive functions*, those components, systems, and processes that are often measured in tests of *executive functioning* (Royall et al., 2002).

1.2 Executive Functioning Impairments in Patients of Physiotherapy

1.2.1 Aging and Chronic Disease

Impairments in EF are seen in older adults (Caetano et al., 2018; Muir, Gopaul & Montero-Odasso, 2012; Buracchio et al., 2011; Kearney et al., 2013). By the year 2050, the worldwide proportion of individuals aged 60 and over is expected to double, and the proportion of adults over the age of 80 is expected to triple (United Nations, 2015). In Canada, it is expected that one in four people will be ≥ 65 years of age by the year 2030 (Statistics Canada, 2014). Older adults increasingly account for most patient populations across the continuum of health care from community to acute and post-acute practice settings (Canadian Physiotherapy Association, 2021). This trend is likely to increase with the rapidly aging population. Older adults are treated by physiotherapists for a variety of musculoskeletal, neurological, and cardiorespiratory conditions and diseases associated with aging. The Seniors Health Division of the Canadian Physiotherapy Association (CPA) was established in 1985 to highlight the need to develop specialized expertise in the comprehensive assessment and treatment of older adults with complex health conditions.

EF declines with age, even in those without overt disease or risk factors for disease associated with cognitive decline, who are successfully maintaining their autonomy, physical and cognitive functions (Bowling & Dieppe, 2005; Annele et al., 2019). This is due, in part, to the frontal brain regions' vulnerability to white matter change, neuron atrophy and neurotransmitter depletion with aging (Buckner, 2004). The white matter of the brain functions to channel communication between different brain regions and the rest of the body (Buckner, 2004). Aging contributes to problems with white matter integrity that are associated with declines in memory, processing speed, and EF (Gunning-Dixon et al., 2009). These changes have been demonstrated using Diffusion Tensor Imaging (DTI) of white matter integrity (Madden et al., 2012; Le Bihan et al., 2001; Neil et al., 2002). In fact, diffuse decline in white matter is the most common observation in older adults' frontal lobes, and one estimate states that 65% of people over the age of 75 will show statistically significant white matter abnormalities in this region (Ylikoski et al., 1995). These change in the frontal brain regions have been proposed to be the most likely cause of impaired EF in healthy aging older adults (Buckner, 2004) and underlie early cognitive difficulties in aging that are the most apparent on tasks demanding high levels of attention and controlled processing (i.e., EF). The Frontal-Lobe Hypothesis states that age-related changes should be observable in tasks that involve EF rather than tasks with lesser executive demands (Constantinidou et al., 2012).

Cognitive reserve is the ability to use alternate cognitive strategies to optimize performance on a task (Baldivia, Andrade, & Bueno, 2008), and is believed to be built by experience with cognitively demanding and stimulating experiences (e.g., more years of formal education; Reed et al., 2010). Cognitive reserve allows for brain resilience – cognition maintenance despite neuropathological damage (Livingston et al., 2020). High cognitive reserve allows individuals to cope with the cognitive changes associated with aging by promoting more flexible use of cognitive processes, such as the development of new strategies (Giogkaraki, Michaelides & Constantinidou, 2013). As such, cognitive reserve can moderate the relationship between brain pathology and the expression of that pathology (Brickman et al., 2011; Singh-Manoux et al., 2011), providing a possible explanation as to why some older adults experience decline in EF that affects their functional abilities while others do not.

Impairments in EF have also been documented in people who are living with conditions considered to be associated with aging, such as dementia (Pérès et al., 2008), Parkinson's disease (Muslimović et al., 2005), and stroke (Hayes, Donnellan & Stokes, 2011). In research investigating EF after stroke, EF impairment was negatively associated with abilities that were considered integral to physiotherapy rehabilitation by physiotherapists such as balance, mobility, rehabilitation participation, and activities of daily living (ADLs). The researchers highlighted physiotherapists' lack of knowledge about impairments in EF, current physiotherapy practices regarding EF impairment, and the negative impact of EF impairment on physiotherapy rehabilitation (Hayes, Donnellan & Stokes, 2015). In this study people with impairments in EF were observed to require more physical assistance during physiotherapy and were more often dependent on one-to-one physiotherapy sessions when compared to people who had experienced a stroke but who did not have EF impairments. The authors suggested that impairments in EF have negative implications for physiotherapy rehabilitation in this population. Further, they suggested that physiotherapists need to develop strategies to minimize the impact of EF impairments on rehabilitation through interdisciplinary collaboration with occupational therapists and clinical neuropsychologists. The authors concluded that EF impairment can strongly impact rehabilitation success (Hayes, Donnellan & Stokes, 2011).

Further research involving people living with acquired brain injuries (ABI) also suggests impaired EF in this patient group (Riepe et al., 2003; Montenigro et al., 2017; Chung et al., 2013). ABI is a significant problem for older adults, with people ≥ 75 years of age having the highest rates of ABI-related hospitalization and death (Thompson et al., 2006). Previous research shows that abilities integral to physiotherapy rehabilitation, such as gait fluidity and speed, differ between teenagers with and without impairments in EF who are living with an ABI (Cossette et al., 2016). Additionally, EF impairments account for 47%

of the variance in instrumental activities of daily living (IADL; e.g., preparing meals, managing money, grocery shopping, and/or using a telephone; Wattmo et al., 2016) scores for those living with an ABI. Low IADL scores are associated with lower quality of life secondary to the detrimental effects of chronic illness and low functional independence. As a result, having low IADL scores increases a persons' requirements for help from health services (Cahn-Weiner et al., 2002).

1.2.2 Chronic Pain

Another common physiotherapy patient population living with EF impairment is people, of all ages, living with chronic pain (McRae & Hancock, 2017). Meta-analyses support that people living with chronic pain have impairments in EF (Bunk et al., 2019; Berryman et al., 2014). Pain is treated so often in physiotherapy practice that the Pain Science Division of the CPA was established in 2008 to facilitate bidirectional knowledge translation between pain research and clinical practice.

In this dissertation, "chronic pain" includes the use of the term "persistent" pain. Estimates suggest that 10-20% of the globe's population reports living with chronic pain (Sturgeon, 2010). Chronic pain is defined by the International Association for the Study of Pain (IASP) as "… pain that persists beyond normal healing time…" for which three months is the conventionally used duration assigned to “normal healing time” (IASP, 1986, p. S5). A biopsychosocial approach to patient treatment maintains that the experience of pain is determined by the interaction between biological (e.g., bone, tendon, or ligament), psychological (e.g., cognition, behaviour, or mood) and social (e.g., cultural and relationship) factors (Asmundson et al., 2014). The experience of chronic pain can result in structural, functional, and chemical changes within the brain and central nervous system that result in hypersensitivity of the central nervous system and increased amplification of pain signaling to the brain (Apkarian, Baliki, & Geha, 2009; Farmer, Baliki, & Apkarian, 2012; Farmer et al., 2011; Moseley & Flor, 2012; Tracey & Bushnell, 2009; Wand et al., 2011). These changes have been observed in neural networks common to both pain and cognitive performance, including those networks in the PFC involved in EF (Elliot, 2003; Seminowicz & Davis, 2007; Wiech et al., 2005). The Neurocognitive Model of Attention to Pain (Legrain, et al., 2009) was developed to explain the relationship between sensory input and the actual perception or interpretation of pain in the brain. This model is founded on the idea that pain experiences are profoundly affected by cognitive factors, such as the EF processes of the brain (Tracey & Mantyh 2007) and supports the growing body of evidence that suggests chronic pain is associated with impaired EF. As a result of chronic pain, the nervous system goes through a process that creates a state of high reactivity that triggers a prolonged increase in the excitability and synaptic efficacy of neurons in central nociceptive pathways (Woolf, 2011). These changes contribute to increased symptoms and predispose people to the development of additional chronic conditions (Binshtok et al., 2008).

Meta-analyses suggest people living with chronic pain have impaired EF (Berryman et al., 2014). Twenty-two studies suggested mild to moderate impairment in EF among adults living with chronic pain. The diagnoses of participants included “chronic pain, chronic low back pain, fibromyalgia, rheumatoid arthritis, chronic non-malignant pain, osteoarthritis, [and] temporomandibular disorder” (Berryman et al., 2014, p. 568). A cross-sectional study of 234 community-dwelling older adults, defined as being greater than or equal to 65 years of age, indicated that chronic musculoskeletal (MSK) pain interferes with EF, including processing speed measured through semantic fluency (Murata et al., 2017). In this research, chronic MSK pain was defined as having moderate or severe pain (i.e., a score of ≥ 4 on the 11-point Numerical Pain Rating Scale [NPRS]) lasting > 3 months in at least one of the following locations: neck, low back, shoulder, elbow, wrist, finger, hip, knee, ankle and/or feet (Murata et al., 2017). Evidence also suggests that people (n = 20) living with chronic pain from hip osteoarthritis have reduced prefrontal cortex volumes, the brain region primarily responsible for EF control processes (Buckner, 2004), when compared to people without pain (Rodriguez-Raecke et al., 2013). Additionally, people living with chronic pain often self-report signs of impaired EF, such as poor concentration and memory, and problems with attention (Farmer et al., 2011; Moseley & Flor, 2012; Wand et al., 2011; Eccleston & Crombez, 1999).

According to The Conference Board of Canada's 2017 publication on the Role of Physiotherapy in Canada, MSK physiotherapy is the predominant area of physiotherapy practice. MSK physiotherapists comprise approximately 40% of all practicing physiotherapists in Canada (The Conference Board of Canada, 2017). Physiotherapists working in MSK physiotherapy focus on restoring function to the musculoskeletal system, including joints, tendons, muscles, ligaments, and bones. MSK physiotherapy intervention can reduce pain and improve ADLs in patients living with chronic MSK pain (Nakandala et al., 2020; Nazari et al., 2019; Lorås et al., 2015). Further, physiotherapy assessment and treatment are recommended as an alternative to opioids for pain control by the Centers for Disease Control and Prevention (Dowell, Haegerich & Chou, 2016). Given the evidence to suggest chronic MSK pain interferes with EF (Murata et al., 2017), it is important that physiotherapists practicing in MSK physiotherapy understand the implications of EF impairment in their patients so they can modify treatment approaches to minimize these limitations.

1.3 Overview of Current Studies

Despite the impact EF can have on physiotherapy rehabilitation (Hayes, Donnellan & Stokes, 2015 & 2011; Cossette et al., 2016), it was unknown what Canadian physiotherapists and physiotherapy students understood about EF as a clinical concept. The first study, which has been accepted for publication (see Guitar et al., 2021 in press), was designed to understand physiotherapists and physiotherapy students understanding and knowledge of EF assessments in clinical practice. The primary objective of this study was to investigate physiotherapists' and physiotherapy students' understanding of EF as a concept and its utility in clinical physiotherapy practice. The second objective was to discover which EF measures are used in physiotherapy practice and why. The final objective was to explore whether primary areas of physiotherapy practice influenced EF assessment, since some practice settings may offer greater support and more frequent opportunities to access empirical literature when compared to other practice settings.

To assist clinicians when assessing the EF of older adults, it is important to understand the implications of an individual score through comparison with normative data (Busch, & Chapin, 2008). There are numerous sets of normative data available for various EF assessment measures. This presents a challenge for clinicians to find normative data that they can use to assess and screen their patients. When applying normative data to assist in the interpretation of assessment scores in clinical practice, clinicians must determine the similarity between their patient and the characteristics of the individuals in the normative group, including relevant demographic characteristics such as age, sex (Mitrushina et al., 2005; Strauss, Sherman, & Spreen, 2006; Steinberg & Bieliauskas, 2005) and contextual factors (e.g., sample sizes; Busch, Chelune, & Suchy, 2005; Mitrushina et al., 2005). Study two presented the results of a systematic review focused on providing a summary of available normative data for three tests used to measure EF in older adults (i.e., people ≥ 65 years of age). The objective of study 2 was to produce a comprehensive review, assessment, and summary for application by clinicians of available normative data for clock drawing, verbal fluency, and trail-making tests in older adults. This included identification of descriptive characteristics of study participants and relevant information to inform clinical application (e.g., education levels, gender, and geographic location).

We aimed to determine what age-, education-, and sex-matched data the currently available published normative data provides for these EF assessments.

Lastly, Study 3 was a cross-sectional pilot study focused on assessing EF in females living with Chronic Pelvic Pain (CPP). CPP is defined by the International Continence Society as constant or intermittent pain in the pelvic region of at least six months in duration (Doggweiler et al., 2017) that features abdominal or pelvic pain, hypersensitivity or discomfort often associated with elimination changes of the bowel or bladder, and sexual dysfunction often in the absence of organic etiology. It is a common MSK condition that has not been examined in previous research examining EF and MSK pain, including previous systematic reviews and meta-analyses on this topic (Murata et al., 2017; Berryman et al., 2014). CPP affects approximately 26% of females according to the 2021 clinical practice recommendations update on CPP in females from the American College of Obstetricians and Gynecologists (ACOG; Arnold et al., 2021). The Women's Health Division of the CPA was established in 1994 to provide information on women's health to physiotherapists including but not limited to bone health, domestic violence, and pelvic floor dysfunction related to continence or sexual function. CPP is associated with significant central nervous system changes when compared to healthy, pain-free females

(Brawn et al., 2014). In females living with CPP, alterations of brain structures involved in EF, like the PFC, seen on Magnetic Resonance Imaging (MRI) and DTI, suggest there may be structural changes in regions of the brain responsible for EF because of chronic pain (Huang et al., 2020); however, to our knowledge, there is no research describing EF in females living with CPP. The primary objective of study 3 was to determine the feasibility of recruitment and EF data collection from females living with CPP. We also aimed to determine if scores on EF assessment measures emerge that suggest the presence of EF impairments in this sample, and finally, if scores for pain catastrophizing, central sensitization, depression, anxiety, and stress are indicative of impairments in this sample.

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2 Chapter 2

A survey of Canadian physiotherapists and physiotherapy students' knowledge and use of executive functioning assessments in clinical practice[1]

2.1 Introduction

Executive functioning (EF) refers to a set of cognitive skills involved in decision-making and self-regulation (i.e., control of one's behaviour in pursuit of long-term goals; Lezak, Howieson & Loring, 2004; Barkley, 2012), including the ability to plan, reason, and problem solve (Hankee et al., 2013; Wang et al., 2014). EF is part of what is referred to as "functional cognition" (i.e., cognition required for daily activities that is also influential on the initiation and performance of physical exercise; Donovan et al., 2008). EF impairment is a feature of many client populations seen in physiotherapy practice including, but not limited to, older adults at risk for falls (Muir, Gopaul & Montero Odasso, 2012; Burachhio et al., 2011; Kearney et al, 2013), people living with chronic

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pain (Berryman et al., 2014), people who have been diagnosed with dementia (Pérès et al., 2008), acquired brain injuries (Chung et al., 2013), stroke (Riepe et al., 2004), and Parkinson's disease (Muslimović et al., 2005).

Physiotherapists report that, from their perspective, EF impairments in people after a stroke have negative implications for balance, mobility, and activities of daily living in rehabilitation (Hayes, Connellan & Stokes, 2015). The same researchers highlighted physiotherapists' lack of knowledge about impairments in EF, current physiotherapy practices regarding EF impairment, and the negative impact of EF impairment on rehabilitation post-stroke (Hayes et al., 2015). People with impairments in EF required more physical assistance during physiotherapy and were more often dependent on one-to-one physiotherapy sessions when compared to people who had experienced a stroke but did not have EF impairments (Hayes et al., 2015). The authors also suggested that impairments in EF have negative implications for physiotherapy rehabilitation. Further, they suggested that physiotherapists need to develop strategies to minimize the impact of EF impairments on rehabilitation through interdisciplinary collaboration.

In addition to disease-defined patient groups, changes in EF are associated with aging and the number of older adults (i.e., those ≥ 65 years of age) is increasing in Canada (Hedden et al., 2004; Fuster, 1989; Albert & Kaplan, 2014; Pearson, St-Arnaud & Geran, 2015). Researchers have demonstrated that poor EF scores can predict functional decline and mortality in older adults (Johnson, Lui & Yaffe, 2007; Herman et al. 2010). Findings from systematic reviews and meta-analyses in both healthy older adults and older adults living with cognitive impairments suggest that physical exercise can improve scores on measures of EF (Nagamatsu et al., 2012; Liu-Ambrose et al., 2010; Liu-Ambrose et al., 2012; Scherder et al., 2005; Colcombe & Kramer, 2003; Smith et al., 2010; Guitar et al., 2018).

The National Physiotherapy Advisory Group (NPAG) publishes the Competency Profile for Physiotherapists in Canada (NPAG, 2017) with the Canadian Alliance of Physiotherapy Regulators (CAPR), Canadian Council of Physiotherapy University Programs (CCPUP), and Canadian Physiotherapy Association (CPA). It is a foundational document that describes the essential competencies required of a physiotherapist in Canada. This document describes physiotherapists as health care providers that "contribute to keeping people productive throughout their lives by maximizing function and improving quality of life" (p. 5). EF is highly related to functional abilities, as demonstrated by the correlation between scores on measures of EF and Instrumental

Activities of Daily Living scores (IADLs; Marshall et al., 2011). IADLs include abilities such as meal preparation, money management, grocery shopping, and/or using a telephone (Wattmo et al., 2016), are reflective of functional status, and are often used in physiotherapy assessments (Graf, 2008). Further, scores on measures of EF are significant and independent correlates of functional status, and neither a normal baseline global cognition score nor a stable global cognition score over time preclude functionally significant changes in EF (Royall et al., 2004). Low IADL scores are associated with lower quality of life secondary to the detrimental effects of chronic illness, resulting in lower functional independence and increased requirements for help from health services (Cahn-Weiner et al., 2002). As a result, the EF of a patient is highly relevant in physiotherapy practice.

Within the Competency Profile for Physiotherapists in Canada there are seven core domains, including physiotherapy expertise. An integral component of physiotherapy expertise is conducting a client assessment that includes obtaining relevant information about a client's status from other sources, identifying comordbities that impact an approach to assessment, and selecting and performing appropriate tests and outcome measures. Therefore, physiotherapists should understand how a person's EF impacts their status and how it may be necessary to screen EF in their patients.

Understanding the patterns of use and the factors that influence assessment practices for EF could inform guidelines for professional development in different practice settings. The first aim of this study was to investigate physiotherapists' and physiotherapy students' understanding about EF as a concept and its utility in clinical practice. The second aim was to discover which EF measures are used in physiotherapy practice and why. Lastly, we sought to explore whether primary areas of physiotherapy practice influence EF assessment since some practice settings may offer greater support and more frequent opportunities to access empirical literature when compared to other practice settings (Morris et al., 2011; Rappolt & Tassone, 2002).

2.2 Method

2.2.1 Survey Design and Development

Qualtrics XM (Provo, UT) software was used to conduct the survey. The survey could be completed online on a computer or smartphone and was accessible between late February 2019 and early April 2020. Ethical approval for the study was obtained from The University of Western Ontario's Internal Review Board (see Appendix A). The Checklist for Reporting Results of Internet E-Surveys (CHERRIES) was used in the writing of this manuscript (Eysenbach, 2004). No translations from English were distributed. No incentives were provided for completion of the survey. Responses were securely stored on a firewall protected computer.

Survey items followed a forced-choice format, multiple choice format with some instances of optional text-box sections for written responses, Likert scales, and True/False selections. Non-response options (i.e., “other”) were provided for questions that forced a response. Question content and organization was developed iteratively using The Tailored Design Method, which includes guidelines for web questionnaire design and implementation (Dillman, Smyth & Christian, 2014). The Tailored Design Method includes guidelines on a variety of internet survey considerations including congruence in viewing the survey across different devices, platforms, and browsers (guideline 9.3); optimization for mobile devices (guideline 9.4); allowing respondents to navigate backward in the survey (guideline 9.9); not including a graphical progress indicator (guideline 9.13); and avoiding forced responses unless necessary (guideline 9.10). The first author (NG) composed a set of items and designed the order of these items within the survey. The second author (DC) suggested revisions on the order of items and survey selections, as well as the wording of the items, then reviewed the initial draft. Once this process was completed, the third and fourth authors (LM and SH) reviewed the survey draft and offered comment. Both reviewers have extensive clinical experience in their fields and are based at The University of Western Ontario's Faculty of Health and Rehabilitation Sciences, one in The School of Physical Therapy, and the other in The School of Communication Sciences and Disorders. Two doctoral students also trialed the completion of the survey prior to recruitment.

The survey was divided into eight question blocks (Appendix B). Blocks 1 and 2 contained the letter of information (see Appendix C), instructions, and consent form. Block 3 determined if a respondent was a physiotherapist or a physiotherapy student, which dictated if a respondent would be prompted with section 8a or 8b for demographic characteristic information later in the survey. "Block 4: Understanding & Knowledge" elicited information about respondents' self-reported, or subjective, current understanding and knowledge of EF (Q5-Q7), and objective understanding and knowledge of EF by asking respondents which of nine cognitive skills/components were involved in EF (Q9-17). "Block 5: Assessment Practices" asked questions related to administering and assessing EF in physiotherapy practice. "Block 6: Beliefs About Executive Functioning" prompted respondents to consider their own views about the utility of assessing EF for the clinical management of their patients. “Block 7: Assessment Experiences” prompted respondents to identify which assessments, or types of assessments, of EF they have experience administering. In this section, the choice of assessments listed in the survey was based on the findings of a review of instruments for the assessment of EF and the research experience of the authors (Chan et al., 2008). Respondents were provided with an “other” option where they used free-form text to add any EF assessment measure(s) that were not listed. Block 8 elicited information about respondents’ demographic characteristics. Section 8a asked demographic information questions from physiotherapy students, and Section 8b asked the same of practicing physiotherapists.

Adaptive questioning was used throughout the survey such that certain items were conditionally displayed based on responses to other items. For Blocks 4-8 of the survey, the number of questions per page ranged from 2-4 and the number of pages ranged from 8-12. The total number of questions that were presented to respondents ranged from 34–60. A completeness check was performed for each respondent, and respondents were not able to navigate backward within the survey. No time cut-off for completion of the survey was used.

2.2.2 Sample and Recruitment

Recruitment was completed through an open invitation e-mail explaining the purpose of the study and inviting potential respondents to volunteer to participate. The e-mail provided information for accessing the survey and the expected time commitment. This e-mail was distributed through the Canadian Physiotherapy Association's (CPA) National Rounds in February and September of 2019, which was received by approximately 14000 members, the provincial college of Physiotherapy of Ontario (the number of members who receive this communication is not known), Yukon (received by approximately 35 members), British Colombia (received by approximately 4400 members) and Nova Scotia (received by approximately 780 members) in February 2019. It was also distributed by the Ontario Physiotherapy Association (received by approximately 5300 members), the East Coast Physiotherapy Association (received by approximately 800 members) inclusive of Newfoundland, Prince Edward Island, New Brunswick and Nova Scotia, and the Acupuncture, Global Health, Oncology, Pediatric, Orthopedic and Pain Division e-newsletters of the CPA between August and September of 2019. In addition, the directors of the schools of Physical Therapy at Western and Dalhousie University distributed the survey to their staff and students. Lastly, the survey was also shared by the National Student Assembly of the CPA in October of 2019 via their Facebook social media channel. Physiotherapy students were included in this study to gain access to the broad spectrum of knowledge accompanied by changing curricula. No direct contact was made with potential respondents and survey responses were anonymized. IP addresses were manually cross-referenced to ensure all respondents were unique. Cookies were not used because there were no user identifiers. No other log file analyses were used to identify possible multiple entries.

2.2.2.1 Sample Size Calculation

Given an approximate sample size of 14000 physiotherapists who are members of the CPA, using G*Power version 3.1 (Faul et al., 2009), an *a priori* power analysis indicated that a sample size of n = 260 was required to have sufficient power for running a multivariate analysis of variance (MANOVA) examining the effect of primary area of practice on survey responses. In this power analysis, it was assumed that the distribution of the sample means was normal (i.e., the normality assumption). It was also assumed that the primary practice area groups had the same common variance. The use of non-probabilistic sampling, due to the physical constraints of obtaining nationwide access to individual contact information, prevented the calculation of a participation rate (Couper, 2000; American Association for Public Opinion Research, 2010).

2.2.3 Data Management and Statistical Analyses

Data were exported from Qualtrics and organized within Excel software. Data analyses were completed using SPSS Version 25 (IBM Corp, 2017). The level of significance used for all analyses was $p < 0.05$. *A priori* it was determined that only questionnaires that were 100% complete would be analyzed. Descriptive statistics were used to analyze respondent characteristics and to address the first and second aims. In addition, a Pearson product-moment correlation was used to determine the strength of the relationship between *subjective* and *objective EF understanding and knowledge* to address the study's first aim. For graphical presentation of the data on *subjective EF understanding and knowledge*, the 7-point Likert scale (*strongly agree* to *strongly disagree*) items were collapsed. Therefore, responses of *strongly agree* and *agree* became an overarching *agree* classification, and *strongly disagree* and *disagree* became an overarching *disagree* classification.

To address the third study aim, physiotherapists were stratified by their self-indicated primary area of practice: musculoskeletal, neurological, cardiorespiratory, or multi-systems. Four dependent variables were created *a posteriori* from 16 survey questions for a MANOVA analysis: *subjective EF understanding and knowledge, objective EF* *understanding and knowledge, experience assessing EF,* and *views toward EF*. All questions that composed these dependent variables were scored on 7-point Likert scales (where strongly disagree = 1, strongly agree = 7), apart from the *objective EF understanding and knowledge* dependent variable, which was scored on a 3-point Likert scale: *agree* to *unsure* to *disagree*. To determine if survey questions could reasonably be combined to create the above listed dependent variables, Cronbach's alpha was calculated. A Cronbach's alpha > 0.70 defines adequate internal consistency to confirm that combined survey questions measure the same underlying construct (Cortina, 1993; DeVellis, 2016).

2.3 Results

A total of 334 individuals responded to the survey, but 72 surveys were incomplete and therefore excluded from the data analysis. Accordingly, the total number of respondents who completed the survey was n = 262 (n = 219 physiotherapists; n = 43 physiotherapy students; completion rate = 78.4%; see Table 1).

Table 1. *Respondent characteristics.*

	All Respondents	Physiotherapists	Physiotherapy Students
Respondents	262	219	43

Age, Mean *(SD)* Age, Minimum-Maximum	42.67[a] (*13.49*) 22-82	46.1 (*11.89*) 26-82	24.8 (*2.95*) 22-35
Gender, % female	82.3%[b]	81.2%[b]	88.3%
% with training on EF	27.4%	37.7%	27.9%
Years of practice, Mean *(SD)* Range	Not applicable	21.18 (*12.09*) 0.5-60	0.17 (*0.20*) 0-0.59
Description of status	Not applicable	Clinician 70.6% Academic 2.3% Both 10.7%	1st year 60.4% 2nd year 39.6%
Current practice setting	Not applicable	OP Community 34.2% OP 31.0% Home Care/LTC 16.4% Acute IP 11.8% Inpatient Rehab 6.3%	OP Community 20.9% OP 34.9% Home Care/LTC 0.04% Acute IP 20.9% Inpatient Rehab 23.2%
Current primary area of practice	Not applicable	Musculoskeletal 41.6% Neurological 15.3% Cardiorespiratory 3.1% Multi-systems 23.7%	Not applicable

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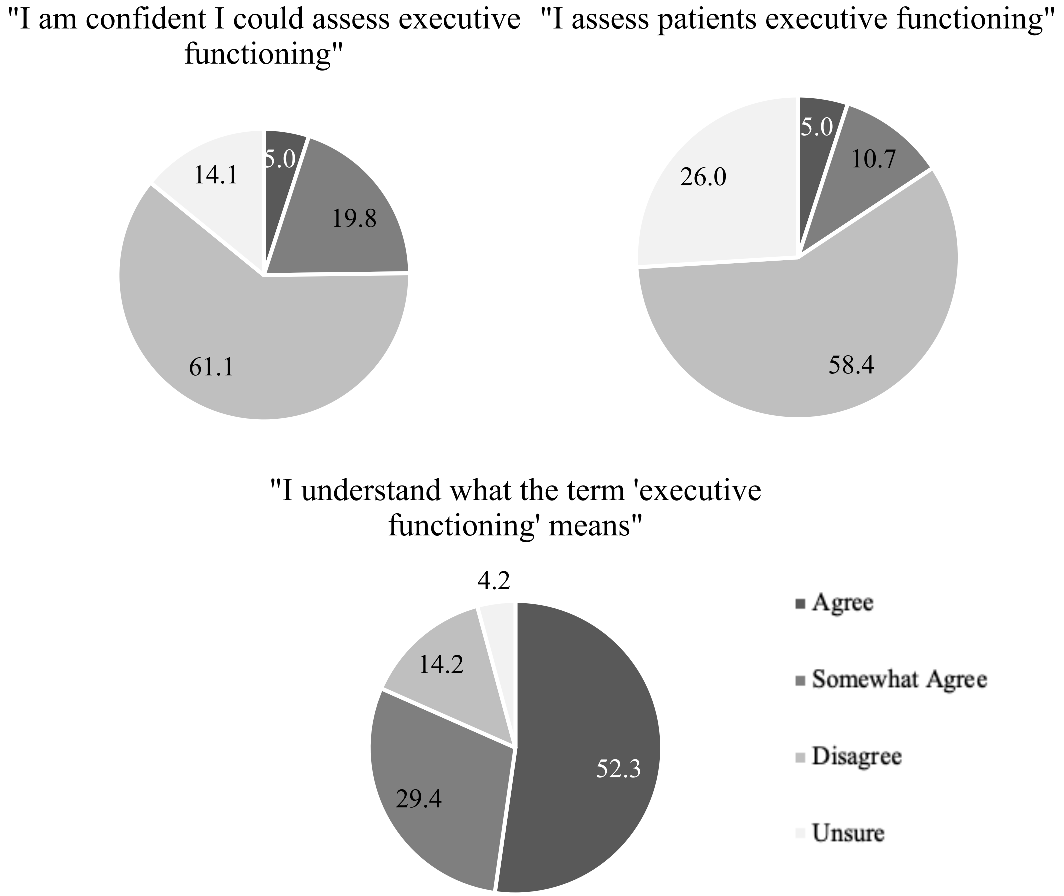
Note. SD = standard deviation; [a]one physiotherapist reported their age as "0" and was not included in the average; [b]0.8% of physiotherapists also reported their gender as "other"; OP = outpatient; IP = inpatient; LTC = long-term care; Rehab = rehabilitation.

2.3.1 Aim 1: Understanding of Executive Functioning as a Concept and Utility in Clinical Practice

For respondents' *subjective EF understanding and knowledge*, most respondents (81.7%, n = 214) agreed that they understood what the term "executive functioning" means; however, only 24.8% (n = 64) of respondents agreed that they felt confident they could assess a patient's EF (see Figure 1). Further, only 15.6% (n = 40) of respondents indicated that they assess EF in patients. Most respondents (n = 117) indicated that Occupational Therapists were typically responsible for administering cognitive assessments in Question 22, followed by Psychologists (n = 50), Medical Doctors (n =

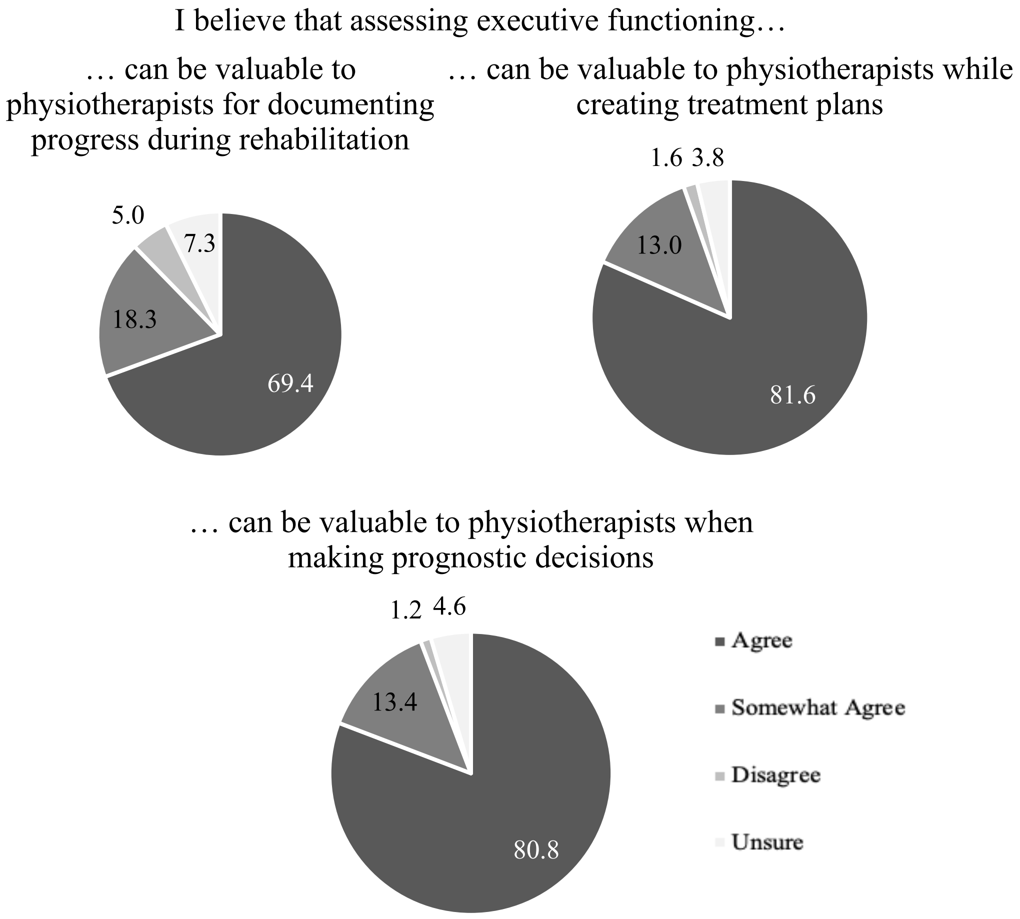
44), Speech-Language Pathologists (n = 35), Social Workers (n = 23), Nurses (n = 17), or “Other” (n = 11) and three indicated that their health care team does not administer cognitive assessments. For *objective EF understanding and knowledge,* respondents

Figure 1. *Respondent’s subjective EF understanding and knowledge (%).*



correctly classified each of nine skills/components as part of EF 60.6% of the time on average (Relative SD = 19.8%). There was a statistically significant, moderate positive correlation between *subjective* and *objective EF understanding and knowledge*, r = 0.43

Figure 2. *Respondent's experience assessing executive function (%).*



(95% CI = 0.32, 0.54; n = 260; $p < 0.001$). On the same 7-point Likert scale ranging from *strongly agree* to *strongly disagree*, 87.8% (n = 230) of respondents agreed that assessing EF can be valuable to physiotherapists for documenting progress during rehabilitation, 94.6% (n = 247) agreed that assessing EF can be valuable to physiotherapists while creating treatment plans, and 94.3% (n = 247) agreed that assessing EF can be valuable to physiotherapists when making prognostic decisions (see Figure 2). Most respondents, 95.4% (n = 249), also agreed that problems with a patient's EF are relevant to their work as a physiotherapist. Additionally, 98.1% (n = 257) of respondents indicated that they expect that problems with a patient's EF would have an impact on functional recovery during rehabilitation, and 72.1% (n = 188) of respondents indicated that they have a lower expectation for a positive rehabilitation outcome for patients with EF impairments.

2.3.2 Aim 2: Executive Functioning Outcome Measures Used in Clinical Practice

Most respondents (64.9%, n = 170) reported that they were a member of a health care team (i.e., working with other health care professionals) and of those respondents, 81.2% (n = 138) reported that another team member (e.g., psychologist) was typically responsible for administering cognitive assessments. Responses to "Where have you ever heard about executive functioning?" indicated that other health care team members were their most common source of information (56.8%, n = 148). One participant said, “I can rely on my interdisciplinary team… to complete these assessments and update me on how it would affect my practice… likewise, I can provide them with what I am observing in clinic.” Course work (46.0%, n = 120), journal articles (37.7%, n = 98), presentations (30.5%, n = 79) and clinical placements (22.5%, n = 58) followed in frequency. Only 16% (n = 42) of all respondents indicated that they had never learned anything about EF.

Respondents who indicated that they believed EF was not relevant to their work as a physiotherapist in Q23 (5.7%, n = 15) said they did not use EF scores in their practice because of a lack of training on how to administer these assessments (60.0%, n = 9), a lack of time available for administering these assessments (20.0%, n = 3), and a lack of access to them in Q26 (20.0%, n = 3). One respondent indicated that there was a lack of utility of the results and two others noted that they did not see patients with EF deficits in their practice (e.g., “I dont [sic] think I see anyone with these deficits in my practice” and “I don't treat patients with cognitive impairments”).

When asked which EF assessments they had ever administered (32.4%, n = 85) respondents provided 159 responses with 12 different assessments selected from the list in Q30. Of the 85 respondents who selected any outcome measure from this list, 71

(83.5%) indicated they had administered a clock drawing test (CDT), 20 (23.5%) indicated they had administered a trail-making-test (TMT), and 14 (16.4%) indicated they had administered a verbal fluency test. However, among the 71 respondents who reported having administered a CDT, seven (9.8%) also stated that they had administered the Montreal Cognitive Assessment (MOCA) and Mini-Mental State Examination (MMSE), which are measures of global cognition not EF, even though they do include some items specific to EF. Overall, 18 (22.0%) respondents provided an answer in the "other" section of Q30 that was a measure of global cognition.

2.3.3 Aim 3: The Influence of Primary Areas of Practice on Executive Functioning Assessment

The first dependent variable, *subjective EF understanding and knowledge*, was created using the mean response values of questions Q5-Q7 and had adequate internal consistency, Cronbach's alpha = 0.749. The second dependent variable, *objective EF understanding and knowledge,* was created by summing the responses of questions Q9-Q17; for these questions, *unsure* responses were classified as *disagree* for analysis purposes to capture whether respondents know which cognitive skills were a part of EF (e.g., if they agreed they were indicating they knew a skill was or was not part of EF). Therefore, respondents with correct knowledge of the components involved in EF would correctly identify all nine components/skills listed (i.e., they would agree to all nine questions; see Table 2) and have accurate objective knowledge of EF.

Table 2. *Percentage of responses to survey Q9-17 regarding whether the following cognitive skills/ components are involved in executive functioning.*

	Response		
Abbreviated skills/components	Agree	Unsure	Disagree
9. Cognitive Shifting*	73.7%	23.3%	3.1%
10. Problem-Solving*	89.7%	7.3%	3.1%
11. Language	56.1%	21%	22.9%
12. Mental Switching*	74.4%	23.7%	1.9%
13. Reference Memory	41.6%	37.8%	20.6%
14. Inhibition*	72.9%	18.7%	8.4%
15. Planning*	92.7%	6.9%	0.4%
16. Knowledge	51.9%	19.1%	29.0%
17. Working Memory*	70.2%	21.8%	8.0%

Note. *denotes the skills/components that actually are involved in executive function.

The third dependent variable, *views toward EF assessment,* was created using the mean values of questions Q27-Q29, which also had adequate internal consistency, Cronbach's alpha = 0.867. The fourth dependent variable, *experience assessing EF*, consisted of only question Q18, and therefore did not require an internal consistency assessment. As a result, the dependent variables are considered ordinal approximations of continuous data (Sullivan & Artino, 2013). A fifth construct, *views toward executive functioning relevance*, consisted of three questions (Q23-25). The variable created by the mean of these questions had an unacceptable level of internal consistency, Cronbach’s alpha = 0.28, and was therefore not used in the multivariate analysis (Cortina, 1993; DeVillis, 2016).

The data met assumptions required for a MANOVA and t-test analyses (e.g., Shapiro-Wilk test and Mahalanobis distance). A series of independent samples *t*-tests were completed to determine if there were differences in scores between physiotherapists and physiotherapy students for these four dependent variables. There were no significant differences between physiotherapist and physiotherapy student respondents on the four dependent variables in the MANOVA: *subjective EF understanding and knowledge*, *t*(260) = -0.611, *p* = ns; MD = 0.12, 95% CI = 0.51, 0.26, *objective EF understanding and knowledge, t*(260) = 1.60, *p* = ns; MD = 0.47, 95% CI = -0.10, 1.06, *views toward EF assessment, t*(260) = 0.76, *p* = ns; MD = 0.11, 95% CI = -0.18, 0.41, and *experience assessing EF, t*(260) = 1.38, *p* = ns; MD = 0.25, 95% CI = -0.11, 0.61, so data for physiotherapists and physiotherapists was combined in the MANOVA (see Table 3).

Table 3. *Summary mean Likert-scale scores foreach dependent variable for each practice group, mean (SD).*

	Musculoskeletal	Neurological	Multi-systems	Cardio-respiratory
Subjective EF understanding and knowledge	3.56 (1.25)	4.13 (1.03)	4.06 (1.16)	3.67 (0.85)
Objective EF understanding and knowledge	5.02 (1.98)	6.35 (1.54)	5.44 (1.60)	5.25 (1.98)
Views toward EF assessment	5.97 (0.76)	5.87 (1.37)	5.99 (0.83)	5.75 (1.02)

Experience assessing EF	3.98 (1.03)	3.72 (1.15)	3.70 (1.28)	4.75 (0.71)

Note. EF = executive functioning; strongly disagree = 1, strongly agree = 7.

There was a statistically significant difference between primary area of practice on the four dependent variables (F12, 555.89 = 2.29, $p < 0.01$; Wilks' $\Lambda = 0.880$; partial $\eta^2 = 0.042$), in *subjective EF understanding and knowledge* scores (F3,213 = 3.51, $p < 0.05$; partial $\eta^2 = 0.047$), *objective EF understanding and knowledge* scores (F3,213 = 5.32, $p < 0.001$; partial $\eta^2 = 0.070$), and in *experience assessing EF* scores (F3,213 = 3.33, $p < 0.05$; partial $\eta^2 = 0.036$). There was no statistically significant difference in *views toward EF assessment* scores among respondents with different primary areas of practice (F3,213 = 0.253, p = ns; partial $\eta^2 = 0.004$).

Tukey post-hoc tests showed that for *subjective EF understanding and knowledge*, respondents in a musculoskeletal primary area of practice had significantly lower mean scores (i.e., less agreeance on the Likert scale) than respondents in neurological ($p < 0.05$) or multi-systems ($p < 0.05$) primary areas of practice; those in cardiorespiratory primary areas of practice did not significantly differ from those in musculoskeletal (p = ns). For *objective EF understanding and knowledge*, respondents in a musculoskeletal primary area of practice had significantly lower mean scores than respondents in neurological primary areas of practice ($p < 0.001$), whereas those in cardiorespiratory and multi-systems primary areas of practice did not significantly differ from those in musculoskeletal (*p* = ns).

2.4 Discussion

The results of this survey indicated that respondents believe they have sufficient knowledge about what EF is, which was corroborated by a moderate positive correlation between their *subjective* and *objective EF understanding and knowledge*. Respondents reported that assessing EF can be valuable for documenting progress, creating treatment plans, and informing prognostic decisions in physiotherapy. There does, however, appear to be a misunderstanding that tests of global cognition (e.g., MOCA) measure EF, which may explain why the correlation between subjective and objective EF knowledge was only moderate. These tests include some items that assess EF but are not measures of EF.

These results are consistent with a previous national survey of Canadian occupational therapists (n = 663) working in stroke rehabilitation, which found that less than 1% use EF assessments in their clinical practice (Korner-Bitensky, Barrett-Bernstein & Poulin, 2011). Instead, occupational therapists reported that they use measures like the MMSE in cognitive assessments of patients who have had a stroke, because they thought these assessments would measure EF. Similar findings have been reported in Australia (Koh et al., 2009). The findings in the present study suggested that since respondents report that they know what EF is and believe it is relevant to their practice, there is a barrier to understanding which outcome measures assess EF.

Our findings indicated that respondents practicing in musculoskeletal physiotherapy report less *subjective* and *objective knowledge and understanding*, and experience with EF assessments than respondents in neurological, cardiorespiratory, or multi-systems primary areas of practice. Understanding that a physiotherapists' current primary area of practice influences their EF understanding and knowledge could be relevant to informing the provision of mentorship in clinical settings, workforce planning, and guidelines for professional development in clinical settings. It is possible that respondents working primarily in musculoskeletal areas of practice are unaware that they treat people living with impaired EF (e.g., people living with chronic pain; Marshall et al., 2001; Berryman et al., 2014).

The results of this study indicate that there is a need for change within National Physiotherapy Entry-to-Practice Curriculum Guidelines (2019) from the Canadian Council of Physiotherapy University Programs (CCPUP). These current guidelines indicate that physiotherapists need to be able to assess cognition, but do not include EF or specify any assessment tools used to measure it. When treating a person living with cognitive dysfunction, the focus for the physiotherapist should be on understanding how the impairment is manifested clinically, and how examination and treatment could be adjusted to maximize a patient's ability while minimizing their limitations. Awareness of the possibility and nature of cognitive deficits should signal the therapist to redirect the method of testing, particularly the instructional sets and cues (O'Sullivan, Schmitz & Fulk, 2019). Failure to do so may result in denying access to opportunities for rehabilitation to patients with impairments in EF and contribute to the increased risk of care home admission and poor quality of life (Goodwin & Allan, 2018). Modified treatment approaches involve providing structure while gradually transferring these responsibilities to the patient, while compensatory treatment approaches allow the therapist to assist the patient to offset their limited abilities by using other intact cognitive functions and/or modifying their environment. Physiotherapists need to develop strategies that minimize the impact of EF impairments on rehabilitation through interdisciplinary collaboration with other health care providers such as occupational therapists and clinical neuropsychologists (Reeves et al., 2013; Thistlewaite, 2012). Having a structure for assessment practices that includes the completion of cognitive assessments prior to physiotherapy interventions would be beneficial.

This is the first survey of this topic among physiotherapists and physiotherapy students. It is important that physiotherapists understand how EF can impact their clients and their ability to participate in a rehabilitation program. This knowledge should be foundational within training for physiotherapy students and post-professional courses. Additionally, within health professional programs, curricula should include understanding the various components of cognition.

This study is limited by the fact that multiple methods of recruitment were used and, as a result, the number of people exposed to the invitation to participate, and the number of invitations to which they were exposed, are unknown. Further, not all the CPA divisions, and provincial colleges of physiotherapy across Canada, were able to distribute this survey. As a result of the recruitment processes, the findings of this survey are not generalizable to all physiotherapists and physiotherapy students. Further, it is unclear how representative the views expressed by these respondents translate across countries. Lastly, this survey may have attracted respondents with special interest in EF and other cognitive abilities. In that case this survey may not have reached physiotherapists who are unfamiliar with EF.

2.5 Conclusion

This is the first survey that investigated subjective and objective understanding and knowledge of EF among physiotherapists and physiotherapy students, their views on EF assessment, and their experiences assessing EF. The establishment of a diagnosis and prognosis requires the ability to conduct relevant assessments and interpret findings. It is essential that physiotherapists have the resources and skills to work with patients experiencing impairments in EF, particularly during the demographic shift to an aging population in Canada. The results have the potential to improve physiotherapy practice by highlighting the importance given to EF assessment by physiotherapists. Additionally, as part of our collaboration domain of the Competency Profile for Physiotherapists in Canada (2017), physiotherapists need to be able to identify practice situations that require interprofessional collaboration to advocate for the assessment of EF in their patients.

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Chapter 3

3 A systematic review of normative data for the interpretation of executive functioning in older adults: Clock drawing, verbal fluency, and trail-making tests[2]

3.1 Introduction

When assessing the executive functioning (EF) of older adults, it is important to understand the implications of an individual score through comparison with normative data to maximize descriptive accuracy (Busch, & Chapin, 2008). When applying normative data to assist in the interpretation of assessment measure scores in clinical practice, clinicians must determine the similarity between their patient and the characteristics of the individuals in the normative group, including relevant demographic characteristics such as age, sex (Mitrushina, Boone, Razani, & D'Elia, 2005; Strauss, Sherman, & Spreen, 2006; Steinberg & Bieliauskas, 2005) and contextual factors (e.g., sample sizes; Busch, Chelune, & Suchy, 2005; Mitrushina et al., 2005). In this systematic review, EF refers to those functions involved in decision-making and self-

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[2] A version of this paper has been submitted for publication: Guitar, N. A., Connelly, D. M., Murray, L. & Hunter, S. W. (2021). A systematic review of normative data for the interpretation of executive functioning in older adults: Clock Drawing Tests, Verbal Fluency Tests and Trail-Making Tests. Submitted to *Aging Research Reviews*.

regulation (i.e., control one's behaviour in pursuit of long-term goals; Lezak, Howieson & Loring, 2004; Barkley, 2012). It includes the ability to self-regulate, plan, judge, reason, solve problems and organize (Hankee et al., 2013; Wang et al., 2014).

EF is impaired in many patients referred for assessment and treatment in clinical physiotherapy practice, including those who have been diagnosed with dementia (Hollamby, Davelaar & Cadar, 2017; Pérès et al., 2008), acquired brain injuries (Montenigro et al., 2017; Chung et al., 2013; Riepe et al., 2003), Parkinson's disease (Petkus et al., 2020; Muslimović et al., 2005), and those living with chronic pain (Bunk et al., 2019; Berryman et al., 2014) or who are at risk for falls (Caetano et al., 2018; Muir, Gopaul & Montero-Odasso, 2012; Kearney et al., 2013; Buracchio et al., 2011). EF declines with increasing age, and currently the number of older adults living in Canada is rising along with the health care demands related to aging (Hedden and Gabrieli, 2004; Fuster, 1989; Albert & Kaplan, 1980). Johnson, Lui and Yaffe (2007) demonstrated that poor EF scores can predict functional decline and mortality in older adults, and Herman et al. (2010) demonstrated that older adults' EF scores can predict future falls. Therefore, EF is relevant to physiotherapists as a significant and independent correlate of functional status. EF scores also correlate with Instrumental Activities of Daily Living scores

(IADLs; e.g., preparing meals, managing money, grocery shopping, and/or using a telephone; Wattmo et al., 2016). Low IADL scores are associated with lower quality of life secondary to the detrimental effects of chronic illness among older adults. Low IADL scores result in lower functional independence and increased requirements for help from health services (Cahn-Weiner et al., 2002).

Clock drawing (CDTs), verbal fluency, and trail-making Tests (TMTs) have been selected for review in this paper because they each measure different constructs of EF (Chan et al., 2008). It is important to have normative data across multiple constructs to provide a holistic summary of ability. In addition, these three assessment measures were the top three EF outcome measures reported to be used by a sample of Canadian physiotherapists in *a survey of physiotherapists and physiotherapy students' knowledge and use of executive functioning assessments in clinical practice* (Guitar et al., 2021 in press). Therefore, these measures may be familiar to, and used by, physiotherapists more often than other measures of EF.

A previous systematic review of CDTs' psychometric properties determined that these tests tap into visual constructive abilities, are quick and easy to administer and have excellent acceptability by subjects (Shulman, 2000). A CDT is unique because its scoring can include both a quantitative component in conjunction with a qualitative assessment of clock-drawing. It differs from the other EF measures in this review because it is considered part of ‘complex’ EF (Berryman et al., 2014; Miyake et al., 2000; 2012). A CDT relies on mental set shifting, information updating and monitoring, and inhibition of prepotent responses (Miyake et al., 2000.) Further, telling time by a clock face is familiar across all “major cultures and civilizations” (Borson et al., 1999, p. 538), as opposed to other visual assessments such as abstract figure copying which are more familiar to those educated in high income countries. Multiple sets of normative data exist for CDTs but the information has not been synthesized for ease of use in clinical physiotherapy practice; therefore, a comprehensive review of CDT scores for older adults is needed to simplify clinical interpretation of scores (Von Gunten et al., 2008; Kim & Chey, 2010; Caffarra et al., 2011; Santana et al., 2013; Ricci et al., 2016).

TMTs primarily assess motor speed and visual attention (Gaudino, Geisler & Squires, 1995). A TMT, therefore, measures the mental set shifting component of EF (Miyake et al., 2000). Part A of these tests provides useful information concerning attention, visual scanning, and speed of eye-hand coordination and information processing. Part B assesses, with more precision, the ability to alternate between two cognitive sets of stimuli (Mitrushina, Boone, & D'Elia, 1999). TMTs have been referred to as one of the most frequently used and most thoroughly studied measures in neuropsychological assessment (Lezak, 1995; Barncord, & Wanlass 2001). Multiple sets of normative data exist for TMTs but have not been synthesized for use in clinical physiotherapy practice; therefore, a systematic narrative synthesis of TMT scores for older adults is needed (Tombaugh et al., 2004; Lucas et al., 2005; Steinburg et al., 2005; Fernandez et al., 2008, Peña-Casanova et al., 2009; Senior et al., 2018).

Verbal fluency tests are thought to assess both language and EF (Whiteside et al., 2016). They assess the information updating and monitoring component of EF (Miyake et al., 2000). Verbal fluency performance is largely determined by the generation and utilization of effective retrieval strategies (Baddeley & Wilson, 1988; Parker & Crawford, 1992). Some studies suggest that fluency measures' reliance on language may provide unique information that is not traditionally assessed by other EF tasks (Piatt et al., 1999). Chertkow and Bub (1990) concluded that effective verbal fluency performance requires: (1) an intact semantic store for supplying a knowledge base of related words; and (2) an effective search process to access and retrieve this information. Poor performance on fluency tests can result from deterioration of a stored knowledge base or from "an inefficient search" (i.e., not generating strategies or not shifting to new searches when previous ones are exhausted; Troyer et al., 1997). Multiple sets of normative data exist for both letter and category verbal fluency tests, but a systematic review consolidating the information has not been performed; therefore, a comprehensive review of scores for older adults is needed (Bolla et al., 1998; Gladsjo et al., 1999; Shores et al., 2006; Peña-Casanova et al., 2009; Magnusdottir et al., 2019). This systematic review aimed to produce a comprehensive review and summary for application by physiotherapists of available normative data for CDTs, fluency tests and TMTs in older adults (i.e., people ≥ 65 years of age).

3.2 Method

3.2.1 Data Sources

The following databases were searched: PubMed (MEDLINE), CINAHL, PsycINFO, EMBASE, and SCOPUS (ProQuest Nursing and Allied Health). These databases were selected based on the recommendation of two research and instructional university librarians as databases that would ensure literature saturation. A manual search of bibliographies from review and original articles was performed to ensure literature saturation. The International Prospective Register of Systematic Reviews (PROSPERO) was searched for completed systematic reviews on this topic. The current systematic review protocol was registered with PROSPERO on August 25th, 2020 (registration number: CRD42020201002). The protocol was written in accordance with the PRISMA-P and PRISMA E&E transparent reporting of systematic reviews recommendations.

The words used in the search of computerized databases included *normative data*, *normal range(s)*, *normal value(s)*, *reference range(s)*, *reference value(s)*, *normal data*, *normal*, and *normative*, with *older adult(s)*, *elderly*, *geriatric(s)*, *senior(s)*, *aged*, and variations of *trail making test, clock drawing test* and *fluency test* including *CDT*, *CLOX* and *TMT*. All search terms were searched as keywords in addition to each database-specific subject headings, which varied among databases (e.g., PubMed's use of subject headings). The search was first conducted on September 4, 2020, and repeated on June 3, 2021, with no additional or new relevant articles found.

3.2.2 Inclusion/Exclusion Criteria and Selection Process

Articles were included that met the following criteria: (1) had a stated purpose to present normative data, or presented normative data within a study with another stated purpose; (2) presented normative data for any scoring system used for any TMT, CDT and/or verbal fluency test (i.e., the three eligible outcome measures); (3) provided normative data for at least a subsample of participants who were ≥ 65 years of age; (4) administered the outcome measures in English; and (5) were written and published in English. Studies were selected for inclusion based on any study duration and there were no restrictions regarding type of setting. Studies were excluded from the systematic review if they were: (1) theoretical articles, descriptions of treatment approaches, or methodological protocols; (2) review articles; (3) non-human studies; and/or (4) non-English language articles. Grey literature was excluded from this systematic review, as published studies tend to show less bias (Hopewell et al., 2007). No limit was applied to the year of publication.

3.2.3 Data Extraction

The first author (NG) independently examined the titles and abstracts yielded by the search against the inclusion and exclusion criteria. Two reviewers (NG & DC) then both screened all full text reports and confirmed that the reports met the inclusion criteria. The two reviewers sought additional information from the remaining study authors where necessary to resolve questions about eligibility. Disagreements between the reviewers were resolved through discussion to achieve consensus. Reasons for excluding papers from the review were recorded. Neither of the reviewers were blind to the journal titles, study authors, or institutions. The following information was extracted the two review authors (NG & DC) from the papers included in the systematic review: study setting, sample characteristics, design, duration, inclusion and exclusion criteria, EF outcomes used, type of normative data generated, and the raw normative data.

3.2.4 Data Presentation

Raw normative data from each of the included studies were summarized in separate tables, one for each EF assessment measure. These are presented for TMT parts A and B, animal category fluency and the FAS-test. To illustrate data in a summary table, we identified the minimum and maximum scores on these assessments across age groups. For the TMT, these data were stratified by age and education level for ease of interpretation. We combined data from all studies that included Reitan's (1958) TMT, any 60-sec animal fluency test, and all FAS-tests.

3.2.5 Quality Assessment

The methodological quality of each included study was assessed independently by two reviewers (NG & DC) using an Adapted Study Quality Rating Tool (see Table 4). This rating tool was adapted from Murray et al. (2018) and is based on information from the Guidance for Undertaking Reviews in Healthcare (Akers &Baba-Akbari, 2009; Khan et

Table 4. *Adapted Study Quality Rating Tool*

	Rating		
Quality Categories	High	Moderate	Low
Design	Large number of participants (e.g., >10 within each cell)	Small number of participants (e.g., some cells <10 participants)	Small number of participants (e.g., all cells <10 participants) or number per cell not reported
Control for confounding factors	Adjustment for at least 3 confounding factors (e.g., ethnocultural background, gender) including age and education	Adjustment for at least age and education	Adjustment for ≤1 confounding factor
Assessment variables	Specification of assessor qualifications and assessment conditions (e.g., same assessor for participants in different groups; all participants tested in same location)	Specification of assessor qualifications or assessment conditions	No specification of assessment variables
Interpretation	Comparison to all other included participant groups or an appropriate control group or reference standard (e.g., healthy adults, MCI)	Comparison to at least one participant group(s) or an appropriate control group or reference standard (e.g., healthy adults, MCI)	No specification of any comparison or reference standard

Complete reporting of EF variables	Specification of normative values for all stratification variables collected (e.g., age, gender)	Specification of some normative values, but not all, for some stratification variables collected	Specification of only one set of normative values for one stratification variable

Note. EF = executive functioning; MCI = mild cognitive impairment. This Study Quality Rating Tool is adapted from Murray et al., (2018) and is based on information in NIHR York University Guidelines and Criteria for Appraising Diagnostic Test Studies; Khan et al. (2003), STARD and COSMIN checklists. A study must score high in 4 out of 5 categories for an overall High rating (with no low rating); an overall moderate rating for a study cannot include any low rating.

al., 2003), Standards for the Reporting of Diagnostic Accuracy Studies (STARD; Bossuyt et al., 2003) and Consensus-Based Standards for the Selection of Health Status Measurement Instruments (COSMIN; Mokkink et al, 2009; 2010) checklists. As highlighted in previous reviews of clinical assessments and measures (Murray et al., 2018; Salis, Murray & Vonk, 2021), an adapted rating tool is necessary given that existing quality appraisal scales are not suitable for the assessment of the study designs aiming to produce normative data. The adapted tool appraised study quality in terms of five categories: study design, control for confounding factors, assessment variables, normative data interpretation, and complete reporting of EF variables. Ratings of high, moderate, or low were assigned for each quality category as well as an overall study quality assessment. For a study to receive an overall high quality rating, four of the five categories had to achieve a high rating with no category receiving a low rating; a study with an overall moderate rating could also not have any category receiving a low rating. Inter-rater agreement was examined for all 35 papers and Cohen's kappa (κ) was calculated using SPSS version 25 (IBM Corp., 2017), with the level of significance set at $p < 0.05$ for each quality category to determine the agreement of reviewers' ratings over and above chance. Guidelines from McHugh (2012) informed by Altman (1999) and Landis and Koch (1977) were used to determine poor, fair, moderate, good, or very good classifications of Cohen's κ. Cohen's κ values ≤ 0 – 0.009 indicate no agreement between reviewers, 0.01 – 0.20 indicate poor agreement, 0.21 – 0.40 indicate fair agreement, 0.41 – 0.60 indicate moderate agreement, 0.61 – 0.80 indicate good agreement, and 0.81 – 1.00 indicate very good or almost perfect agreement (McHugh, 2012; Altman, 1999; Landis and Koch, 1977). All discrepant ratings were resolved via discussion between NG and DC.

3.3 Results

3.3.1 Study Selection and Characteristics

A summary of the selection process is illustrated in Figure 1. The original search yielded 11323 articles. There was, however, duplication of 3467 articles among the databases. After review of the titles and abstracts of 7856 articles, 53 full text articles were assessed

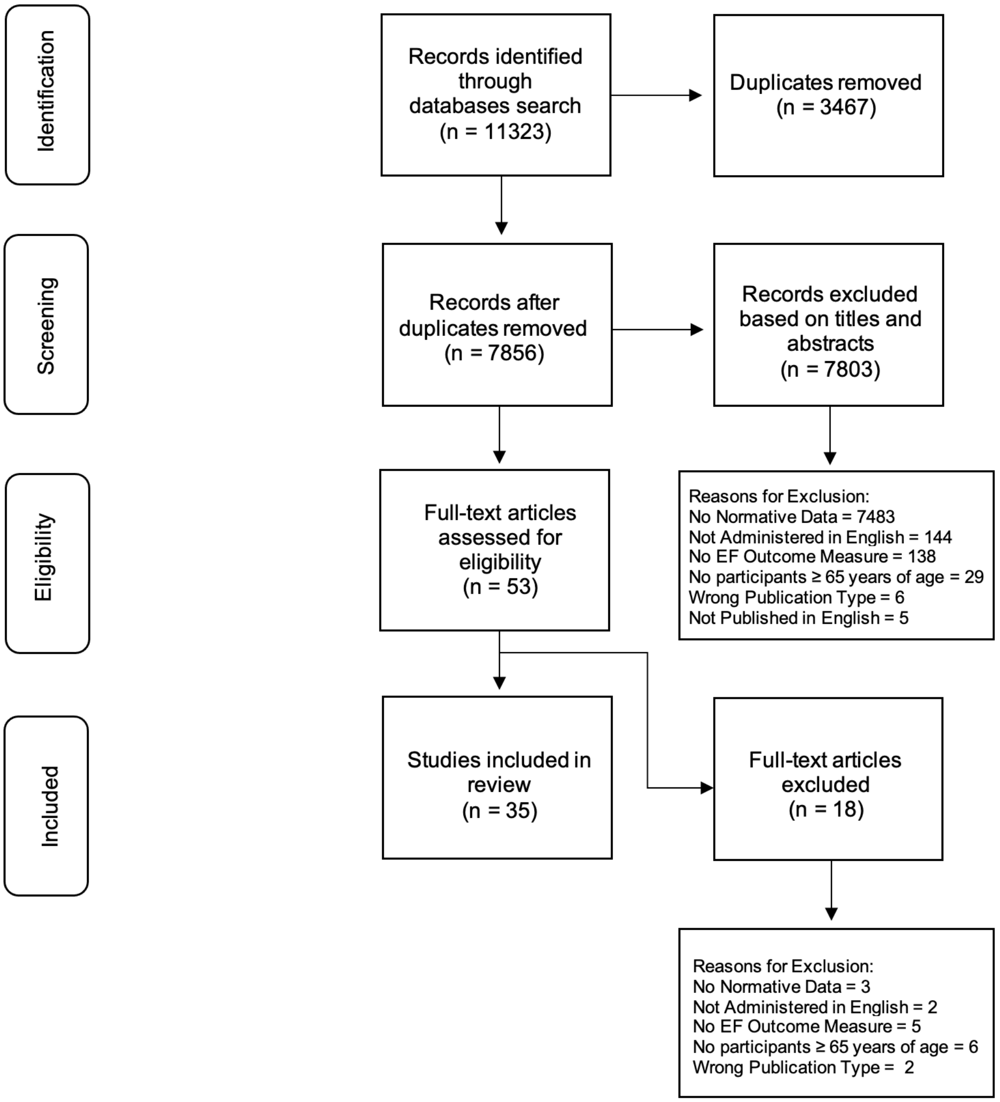

Figure 3. *Flow-chart of the process of the systematic review identification, screening, and eligibility.*

based on the inclusion criteria established for this systematic review. Thirty-five articles published between 1978 and 2020 were included in the review.

3.3.2 Participants and Settings

The studies included in this review contained a total of 20102 participants ranging from 30 (Picciotto & Friedland., 2001) to 2005 (Holtzen et al., 2008) participants. The duration of study recruitment included in this review ranged from 6 months (Ruff et al., 1996) to 42 years (Nyborn et al., 2013). The mean age of the participants in each study ranged from 40.0 ± 21.2 (Woods et al., 2016) to 79.9 ± 8.3 (Lucas et al., 1998) years at study inception. Mean age was not reported in seven studies included in this review; however, authors of each of these studies were explicit that they had included a subsample of people ≥ 65 years of age were included in their study. Twenty-one studies were conducted in the United States of America, four in Canada, three in Australia, two in Italy, and one in each of Korea, South Africa, Sweden, Switzerland, and the United Kingdom.

3.3.3 Study Details

Appendix D presents the details of the 35 included studies. Twenty-six of the 35 studies included a single eligible measure of EF. Eight studies included two measures and two studies included all three of the eligible measures of EF (O’Bryant et al., 2018; Stewart et al., 2001). Normative data were found for in 19 studies for a TMT, 34 studies for a fluency test and five studies for a CDT.

3.3.4 Normative Data

3.3.4.1 Clock Drawing Tests

Normative data for CDTs from five studies are available in Appendix E. Each study used a different method of CDT administration and scoring (e.g., CLOX 1 & 2 [Royall, Cordes & Polk, 1998], Goodglass & Kaplan's [1983] scoring system, and the command and copy variation of CDT scoring [Goodglass & Kaplan, 1972]). Although this prevents the development of a normative data summary, we were able to present the normative data available in each study for a range of ages from 55 - 80+ years. Some studies stratified the data by age and education (Marcopulos et al., 1997; Nybron et al., 2013) while one study stratified the data with the Wide Range Achievement Test (WRAT-3) scores (Crowe et al., 2010). Only one study did not provide stratified data (Stewart et al., 2001).

3.3.4.2 Verbal Fluency Tests

Normative data for verbal fluency tests from the twenty-four studies are available in Appendix F. The method of test administration and scoring was consistent (e.g., the number of eligible words generated in one minute for a letter or category), but the categories and letters used across the studies varied greatly. In category fluency tests, animals, fruits, and vegetables were the most used categories either in isolation or combination (Acevedo et al., 2000; Devora et al., 2020; Elkadi et al., 2006; Gladsjo et al., 1999; Hankee et al., 2013; Baker et al., 2001; Stewart et al., 2001; Tombaugh et al., 1999; Troyer et al., 2000; Schneider et al., 2020). Birds and articles of furniture (i.e., the BAF-test) were used as a category in one study (Quaranta et al., 2016). In terms of letter fluency tests, the FAS-test, also known as the Controlled Oral Word Association Test (COWAT; Benton, 1967) was commonly used (Gladsjo et al., 1999; Hankeet et al., 2013; Holtzer et al., 2008; Tombaugh et al., 1999; Troyer et al., 2000; Ruff et al., 1996; Schneider et al., 2020). Letter fluency data for S, G, U, N, F, T, J, P (Cauthen et al, 1978), L (Devora et al., 2020), C, A and T (Holtzer et al., 2008), and T and P (Baker et al., 2001) were also reported. Although this heterogeneity prevents the development of a comprehensive normative data summary, we were able to present the normative data available in each study for a range of ages from 50 - 95+ years. One study stratified the data with intelligence quotient (IQ) scores (Cauthen et al., 1978) and only one study did not provide stratified data (Stewart et al., 2001). All other studies stratified their data with either age and/or education. Table 5 presents the summary data for the three studies that stratified their animal category fluency data with both age and education (Elkadi et al., 2006; Gladsjo et al., 1999; Schneider et al., 2020). Table 6 presents the summary data for the three studies that stratified their FAS-test data with both age and education (Gladsjo et al., 1999; Holtzer et al., 2008; Schneider et al., 2020).

Table 5. *Summarized normative data for animal category fluency, mean number of words (SD).*

		Approximate Age 65-74	75-79	80-84
Study	Education (years)			
Elkadi et al., (2006) Australia N=257	<12	18.90 (0.57)	-	-
	≥12	20.90 (0.82)	-	-
Gladsjo et al., (1999) USA N=768	0-11	15.28 (3.80)	-	-
	12-15	18.05 (4.81)	-	-
	16+	19.35 (4.42)	-	-
Schneider et al., (2020) USA N=712	<12	14.28 (8.01)	13.49 (7.22)	12.69 (6.42)
	12	14.52 (8.25)	13.72 (7.45)	12.92 (6.65)
	>12	17.33 (11.06)	16.53 (10.26)	15.74 (9.47)

Note. – indicates data is not available. Mean number of words generated in 60 seconds. Approximate age indicates that some studies reported different but overlapping age categories. NR = not reported.

Table 6. *Summarized normative data for FAS-test letter fluency, mean number of words (SD).*

		Approximate Age		
		65-74	75-79	80-84
Study	Education (years)			
Gladsjo et al., *(1999)* *USA* *N=768*	0-11	31.47 (13.21)	-	-
	12-15	38.63 (11.98)	-	-
	16+	41.81 (12.75)	-	-
Schneider et al., *(2020)* *USA* *N=712*	<12	22.32 (6.48)	21.16 (5.32)	20.01 (4.17)
	12	28.07 (12.23)	26.92 (11.08)	25.76 (9.92)
	>12	37.78 (21.93)	36.62 (20.78)	35.46 (19.62)
Holtzer et al., *(2008)* *USA* *N=2005*	<10	-	22.6 (14.37)	32.5 (13.75)
	10-12	-	31.7 (11.77)	32.1 (11.28)
	>12	-	41.0 (11.49)	39.5 (12.52)
	13-15	-	37.9 (11.11)	34.9 (12.52)
	>16	-	43.9 (11.18)	42.4 (9.25)

Note. – indicates data is not available. Mean number of words generated in 60 seconds. . Approximate age indicates that some studies reported different but overlapping age categories. NR = not reported.

3.3.4.3 Trail-Making Tests

Normative data for TMTs from nineteen studies are available in Appendix G. The method of test administration and scoring was consistent for most studies and the time, reported in seconds, it took to complete the TMT was provided. Most studies reported the scores (i.e., time to completion) for trails A and B (Reitan, 1958). One study (Lavrencic et al., 2019) provided scores for the oral version of the TMT (i.e., “Oral TMT”; Ricker, Axelrod & Houtler, 1996). Some studies also reported trails B error scores (Clark et al., 2004; Hankee et al., 2013; Holtzer et al., 2008), trails B:A ratio scores (Kim et al., 2019), trails B-A difference scores (Drane et al., 2002), and pen lifts during testing (Hankee et al., 2013). Two studies did not report trails B scores (Stewart et al., 2001; Kim et al., 2019), and two did not report trails A scores (Hankee et al., 2013; Clark et al., 2004). We were able to present the normative data available in each study for a range of ages from 55-80+ years. Table 7 presents the normative data summary for the seven studies that stratified their data with age and education of ≥ 12 years (Amodio et al., 2002; Ashendorf et al., 2008; Clark et al., 2004; Holtzer et al., 2008; Moggi et al., 2020; Tombaugh et al., 2004; Schneider et al., 2020). Table 8 presents the normative data summary for the six studies that stratified their data with age and education of < 12 years (Amodio et al., 2002; Ashendorf et al., 2008; Holtzer et al., 2008; Moggi et al., 2020; Tombaugh et al., 2004; Schneider et al., 2020).

Table 7. *Summarized normative data for TMT across studies reporting education ≥12 years, mean (SD) in sec.*

		Approximate Age		
Study	Assessment	65-74	75-79	80-84
Amodio et al., (2002) *Italy* *N=300*	A	-	-	-
	B	154-227(NR)	172-239(NR)	248-276(NR)
Ashendorf et al., (2008) *USA* *N=526*	A	29.7(7.8)	40.3(13.2)	-
	B	62.7(20.6)	90.5(37.1)	-
Clark et al., (2004) *Australia* *N=257*	B errors	0.36(0.80)	-	-
	B	80.3(NR)	-	-
Holtzer et al., (2008) *USA* *N=2005*	A	-	49.2(16.13)-52.4(15.98)	66.0(29.53)-69.1(27.60)
	B	-	111.1(35.90)-126.2(62.99)	116.6(52.11)-(132.60(62.72)
	B errors	-	1.1 (1.74)- 1.4(2.0)	1.6(3.59)-1.8(3.35)
Moggi et al., (2020) *Switzerland* *N=494*	A	39.46(17.56)	-	-
	B	113.46(50.57)	-	-
Tombaugh et al., (2004) *Canada* *N=911*	A	33.84(6.69)-40.13(14.48)	41.74(15.32)	55.32(21.28)
	B	67.12(9.31)-86.27(24.07)	100.68(44.16)	132.15(42.95)
Schneider et al., (2020) *USA* *N=712*	A	45.80(76.43)-55.99(93.42)	50.41(84.12)-61.62(102.82)	55.49(92.59)-67.82(113.17)
	B	120.41(208.84)-153.72(240)	133.84(232.14)-170.86(240)	148.77(240)-189.92(240)

Note. – indicates data is not available. All scores are reported in seconds. Approximate age indicates that some studies reported different but overlapping age categories. NR = not reported.

Table 8. *Summarized normative data for TMT across studies reporting education <12 years, mean (SD) in sec.*

		Approximate Age		
		65-74	75-79	80-84
Study	Assessment			
Amodio et al. (2002) *Italy* *N=300*	A	72-92 (NR)	79-95 (NR)	81-95 (NR)
	B	199-291 (NR)	227-318 (NR)	238-343 (NR)
Ashendorf et al., (2008) *USA* *N=526*	A	33.2 (13.1)	44.8 (13.4)	-
	B	80.8 (30.4)	109.7 (42.5)	-
Holtzer et al., (2008) *USA* *N=2005*	A	-	57.3(23.16)- 76.7 (37.85)	58.4(20.01)-58.8(12.73)
	B	-	125.5(55.56)-165.9(95.83)	151.0(57.50)-156.6(50.74)
	B errors	-	1.6(2.56)-3.3(4.3)	0.7(0.95)-1.2(1.76)
Moggi et al., (2020) *Switzerland* *N=494*	A	55.05(19.14)	-	-
	B	140.50(67.96)	-	-
Tombaugh et al., (2004) *Canada* *N=911*	A	39.14(11.84)-42.47(15.15)	50.81(23.31)	58.19(23.31)
	B	91.32(28.89)-109.95(35.15)	130.61(45.74)	152.74(65.68)
Schneider et al., (2020) *USA* *N=712*	A	72.06(120.24)	79.31(132.34)	87.29(145.65)
	B	184.36(240)	204.93(240)	227.78(240)

Note. – indicates data is not available. All scores are reported in seconds. Approximate age indicates that some studies reported different but overlapping age categories. NR = not reported.

3.3.5 Methodological Quality of the Included Studies

Figure 4 presents the percentage of studies with low, moderate or high quality ratings for six categories: study design, control for confounding factors, assessment variables, normative data interpretation, complete reporting of EF variables, and overall study quality rating. The individual category quality ratings are available in Table 9. Inter-rater agreement was examined for all 35 papers and yielded 80.96% agreement across all items, with 97.14% agreement for each paper's overall quality rating. Cohen's κ was computed to determine if there was agreement between the two reviewers' judgement on whether the studies' quality ratings were high, moderate, or low. There was very good agreement between the two reviewers' judgements for overall rating, κ = 0.877 (95% CI, 0.635, 1.119), $p < 0.001$, and the design category, κ = 0.880 (95% CI, 0.716, 1.044), $p <$

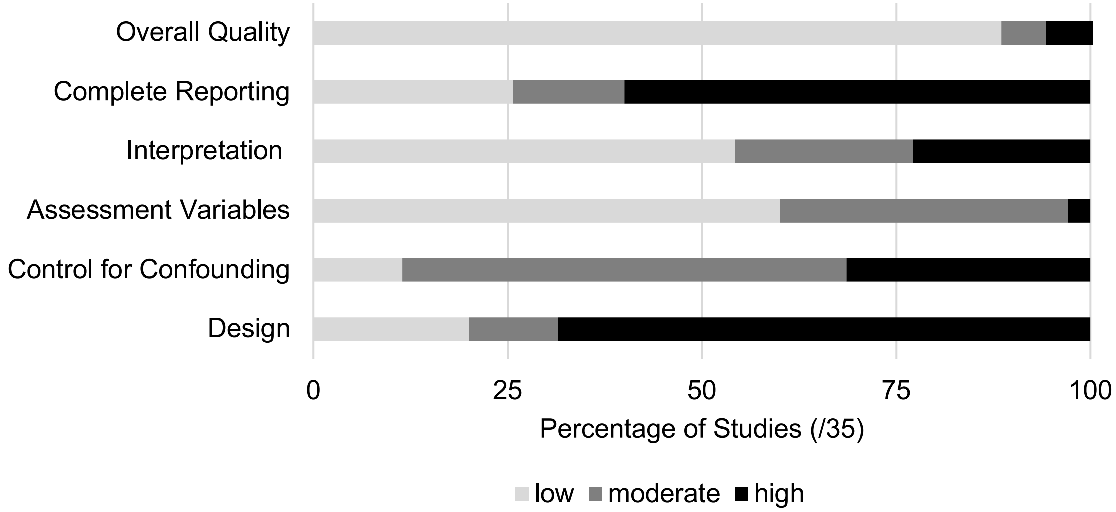

Figure 4. *Percentage of studies with low, moderate or high quality ratings for six categories: study design, control for confounding factors, assessment variables, normative data interpretation, complete reporting of EF variables, and overall study quality rating.*

0.001. Moderate agreement was achieved for the control for confounding category, κ = 0.539 (95% CI, 0.295, 0.783), *p* < 0.001, assessment variables category, κ = 0.471 (95% CI, 0.191, 0.751), *p* < 0.001, as well as the interpretation category, κ = 0.514 (95% CI, 0.288, 0.740), *p* < 0.001. Lastly, the complete reporting of EF variables had good agreement, κ = 0.654 (95% CI, 0.423, 0.876), *p* < 0.001.

The majority of studies received an overall low quality rating. It is important to recall that a low quality rating in any of the five categories resulted in a low overall study quality rating. Control for confounding factors was rated as moderate quality across most of the included studies. Only two studies received a moderate overall study quality rating (Crowe et al., 2010; Elkadi et al., 2006) or an overall high study quality rating (Moggi et al., 2020; Steinberg et al., 2005). The majority of studies received a high quality rating in the areas of design and complete reporting. Of concern were the majority of low quality ratings for interpretation, assessment variables and overall quality.

Table 9. *Study quality ratings by category.*

Study	Design	Control for confounds	Assessment variables	Interpretation	Complete reporting	Overall rating
Acevedo et al. (2000)	high	high	low	low	high	low
Amodio et al. (2002)	moderate	high	low	low	high	low
Ashendorf et al. (2008)	high	moderate	low	high	high	low
Baker et al. (2001)	low	moderate	moderate	moderate	high	low
Cauthen (1978)	high	moderate	moderate	low	low	low

Clark et al. (2004)	high	moderate	low	low	high	low
Crowe et al. (2010)	high	moderate	moderate	high	high	moderate
Devora et al. (2020)	high	moderate	low	low	high	low
Drane et al. (2002)	high	low	low	low	low	low
Elkadi et al. (2006)	high	moderate	moderate	moderate	high	moderate
Gladsjo et al. (1999)	low	moderate	moderate	moderate	high	low
Hankee et al. (2013)	high	moderate	low	moderate	high	low
Holtzer et al. (2008)	high	moderate	low	high	moderate	low
Invnik et al. (1996)	high	high	moderate	low	low	low
Kim et al. (2019)	moderate	moderate	low	low	high	low
Lavrenic et al. (2019)	high	high	low	high	high	low
Lucas et al. (1998)	high	high	low	low	high	low
Lucas et al. (2005a)	high	moderate	moderate	low	low	low
Lucas et al. (2005b)	high	high	moderate	low	moderate	low
Marcopulos et al. (1997)	low	moderate	moderate	low	moderate	low
Moggi et al. (2020)	high	moderate	moderate	high	high	high
Nyborn et al. (2013)	high	moderate	low	low	high	low
O'Bryant et al. (2018)	low	high	moderate	high	moderate	low
Piatt et al. (2004)	high	moderate	low	low	low	low
Picciotto et al. (2001)	low	low	low	high	low	low
Quaranta et al. (2016)	low	moderate	low	moderate	high	low

Ruff et al. (1996)	high	high	moderate	low	moderate	low
Schneider et al. (2020)	high	high	high	low	high	low
Selander et al. (2020)	high	low	low	low	low	low
Steinberg et al. (2005)	high	high	moderate	moderate	high	high
Stewart et al. (2001)	moderate	high	low	high	high	low
Tombaugh et al. (1999)	moderate	moderate	low	low	high	low
Tombaugh et al. (2004)	high	moderate	low	moderate	high	low
Woods et al. (2016)	high	low	low	moderate	low	low
Troyer et al. (2020)	low	moderate	low	low	low	low

Note. See Table 1 for descriptions of these categories.

3.4 Discussion

This systematic review presented an overview of peer-reviewed studies exploring normative data in older adults for three tests of EF. To our knowledge, this is the first systematic review to synthesize normative data for these three tests for older adults. Our assessment of the methodological quality of evidence of these studies demonstrated that most studies had low overall quality ratings; therefore, the values presented in this review cannot be used with certainty. Most studies in this systematic review presented normative values stratified by age, gender, or education. The accurate interpretation of EF tests is largely dependent on these factors for interpreting test results (Heaton et al., 1996; Reitan & Wolfson, 1995; Hamdan & Hamdan, 2009).

The results of the thirty-five studies included in the review demonstrated that multiple sets of normative data exist for these EF assessment measures. Across studies, there was considerable variation in the normal values. For example, two studies, both published in the USA, reported conflicting normal ranges for a TMT in older adults approximately 65-74 years of age. The TMT Part B ranged from 62.7 ± 20.6 sec (Ahendorf et al., 2008) to a spread from 120.41 ± 208.84 to 153.74 ± 240.00 sec (Schneider et al., 2020). Ashendorf et al., (2008) reported the sex of their participants, while Schneider et al. (2020) did not. To maximize descriptive accuracy (Busch, & Chapin, 2008), clinicians must determine the similarity between their patient and the characteristics of the individuals in the normative group. In an older adult population, there may be even more potential confounding variables to consider, such as age-related comorbidities.

This systematic review identified only four studies with high or moderate overall study quality ratings (Crowe et al., 2010; Elkadi et al., 2006; Moggi et al., 2020; Steinberg et al., 2005). This causes several concerns regarding the description and use of most of these sets of normative data with older adults. Study design and complete reporting of EF variables were rated as high in most papers, but issues were apparent in the categories of assessment variables and interpretation. In assessment variables, there was rarely specification of assessor qualifications and/or assessment conditions, which makes the application of these studies' normative data questionable. Only one study described both the assessor's qualifications and the assessment conditions (Schneider et al., 2020), and 13 studies described either the assessor's qualifications or the assessment conditions. Additionally, in interpretation, few authors provided comparison(s) to other participant groups included in their study and did not use any comparison or reference standard.

A limitation of the studies included in this review was the wide heterogeneity in administration procedures and scoring systems used, which prevented the generation of comprehensive normative data summaries for all included studies. Because of the methodology of the included studies that used CDTs for example, we were unable to make comparisons between normative data sets. With the TMTs and fluency tests that we could compare and collate, normative data ranges varied greatly. Previous research shows that normative data from different countries and cultures are not equivalent, which can lead to serious errors in interpretation of scores (Fernandez & Marcopulos, 2008). In a comparison of normative data for TMTs from different countries (e.g., Sweden and North American countries), the differences in “normal” were so dramatic that peoples’ scores on the TMT could be classified as either normal or pathological, depending upon the set of normative data used (Fernandez & Marcopulos, 2008). Different compositions of education, occupation, and intelligence within sex- and age-based groups will also impact EF test scores (Ostrosky-Solis et al., 1998). A thirteen-year-old review comparing normative data for TMTs from different countries found that method bias (i.e., incomparability of samples and administration differences) may be the main reason norms are not comparable and do not reflect real differences in the underlying constructs (Fernandez & Marcopulos, 2008).

3.4.1 Future Research

Future studies need to focus on understanding how clinicians select and apply normative data to their patients, and how to translate knowledge about the factors (e.g., age, sex, education) that impact EF scores. To bridge the gap between research and applied clinical needs, there should be dialogue between researchers and clinicians to ensure that research findings make an impact on clinical practice (Murray et al., 2018). This includes documentation of study design, how confounding factors were controlled or included in data analyses, the assessors' qualifications, assessment conditions, how the data were interpreted and compared to other groups or standards of reference, and completely reporting normative values for all stratification variables. This is especially important when we consider clinicians' limited time to derive diagnoses and create treatment plans with patients. When establishing normative data, it is highly recommended that all future studies minimally include information about age and education, and the different normal values associated with various categories of these constructs (Heaton et al., 1996; Reitan & Wolfson, 1995). This might require the development of a quality reporting tool or checklist for physiotherapists to use when choosing a set of normative data to compare to their patient.

3.4.2 Strengths and Limitations

In this systematic review, the rigorous protocols outlined by PROSPERO we followed, and the search was conducted without any limitation to year of publication. The result of this review is a comprehensive summary of available normative data for the included assessment measures in older adults. The fact that EF tests may not be measuring the same construct when applied in different countries or cultures is a limitation of this review. Further, it is well known that a test does not always measure the same construct when it is administered in a different context than where it was developed (Ardila & Morena, 2001; Greenfield, 1997; Rogoff & Chavajay, 1995). For example, Chinese students take longer to complete TMT Part B than American students. This difference is eliminated, however, when Chinese students complete a modified TMT B with Chinese characters (Lee et al., 2000), demonstrating a possible sampling bias. Studies were included that were conducted and published in English from countries where the official language is not English (e.g., Italy, Korea, Switzerland, and Sweden), and the impact of this is unknown since study authors did not indicate if their participants were monolingual or bi/multilingual.

3.5 Additionally, this review had some methodological limitations. We limited this review to papers published in English, and as a result, we excluded five studies that were not published in English that could have been possibly relevant. Despite having English abstracts available, we are unable to determine if these studies would have met our inclusion criteria (Alobaidy et al., 2017; Schmand et al., 2008; Diesfeldt et al., 2009; van Toutert, 2016; Burin et al., 2000). Inclusion of these studies if they did meet the inclusion criteria would have added an additional 1564 participants. Many studies not administered in English were also excluded from this review (N = 146). Some of these studies did contain English abstracts, and some did not. This limits the scope of this review and the application of our findings to people speaking any language other than English.Conclusions

With the proportion of older adults growing rapidly worldwide, normative data are needed for assessment measures used to evaluate the EF of older adults. This systematic review exposed various sets of normative data for three assessment measures of EF. Data from all included studies were summarized. However, summarizing data from different studies for the purposes of comparison was not always possible due to constraints surrounding the method of administration, stratification, and scoring systems used. It is recommended that clinicians carefully consider the set of normative data they use to interpret EF scores individually for every patient they screen. To maximize descriptive accuracy, normative data should match the characteristics of the patient as closely as possible. A clinician cannot simply use a single set of normative data interchangeably for all patients, even in the same country or cultural setting. Characteristics of the individuals in the normative group that need to be considered include age, gender, years of education, style of education, occupation, location, language, and cultural factors. Additionally, examining the quality of the normative data collected will be a helpful strategy for clinicians to weight the risks and benefits associated with applying a set of normative data to their patients. This review identified methodological issues that can be addressed in future studies aimed at providing normative data, such as adequate reporting of assessment variables. Based on the quality of studies included in this review, the development of a quality reporting tool for physiotherapists might be essential. This review provides the necessary information for clinicians to compare their patients' EF to various sets of currently available normative data.

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Chapter 4

4 Assessing executive functioning in females living with Chronic Pelvic Pain: A pilot study

4.1 Introduction

Meta-analyses suggest that people living with chronic pain have impaired executive functioning (EF: Berryman et al., 2014). EF refers to a family of cognitive abilities involved in decision-making and self-regulation (Lezak, Howieson & Loring, 2004; Barkley, 2012). As a result, EF allows us to think before we act, meet unanticipated challenges, and stay focused (Diamond, 2013). These cognitive abilities are impaired in people who are living with chronic pain (Berryman et al., 2014; Murata et al., 2017). The International Association for the Study of Pain (IASP) defines chronic pain as "… pain that persists beyond normal healing time…" for which three months is the conventionally used duration assigned to "normal healing time" (IASP, 1986, p. S5). Estimates suggest that 10-20% of the globe's population reports living with chronic pain (Sturgeon, 2010). The mechanism by which EF becomes impaired is thought to be due to nervous system changes associated with brain regions involved in both EF and chronic pain (Elliot, 2003; Seminowicz & Davis, 2007; Wiech et al., 2005). Alterations of brain structures involved in EF suggest there may be structural changes in regions of the brain responsible for EF because of chronic pain (Huang et al., 2020).

The results of a meta-analysis that included twenty-two studies suggests mild to moderate impairment in EF among adults living with chronic pain, as measured by significant effect estimates (Berryman et al., 2014). These authors noted impairment on EF assessments that measure response inhibition (e.g., Stroop Test, Go/Nogo Test), complex EF (e.g., Clock Drawing Test, Wisconsin Card Sorting Test), and set shifting (e.g., Trail-Making Test, Digit Symbol Substitution Test). The diagnoses of participants in the metanalysis included “chronic pain, chronic low back pain, fibromyalgia, rheumatoid arthritis, chronic non-malignant pain, osteoarthritis, [and] temporomandibular disorder” (Berryman et al., 2014, p. 568). Another cross-sectional study of 234 community-dwelling older adults, defined as being greater than or equal to 65 years of age, indicated that chronic musculoskeletal (MSK) pain interferes with EF, including processing speed as measured by semantic fluency tests (Murata et al., 2017). In this research, chronic MSK pain was defined as having moderate or severe pain (i.e., a score of ≥ 4 on the 11-point Numerical Pain Rating Scale [NPRS]) lasting > 3 months in at least one of the following locations: neck, low back, shoulder, elbow, wrist, finger, hip, knee, ankle and/or feet. Moreover, evidence also suggests that people (n = 20) living with chronic pain because of hip osteoarthritis have less volume in their prefrontal cortex, the brain region primarily associated with EF control processes (Buckner, 2004), when compared to people without pain (Rodriguez-Raecke et al., 2013).

A group of people that have not been studied in previous research about the relationship between impaired EF and chronic pain are those living with a diagnosis of Chronic Pelvic Pain (CPP), a MSK condition treated by Pelvic Health Physiotherapists (Baker et al., 1993). Pelvic Health Physiotherapists are physiotherapists with additional training who are rostered to perform the controlled act of "inserting a hand, finger, or instrument beyond the labia majora or anal verge for the purposes of assessing or rehabilitating pelvic musculature relating to incontinence or pain" (College of Physiotherapists of Ontario, 2021). CPP is defined by the International Continence Society as constant or intermittent pain in the pelvic region of at least six months in duration that features abdominal or pelvic pain, hypersensitivity or discomfort often associated with elimination changes of the bowel or bladder, and sexual dysfunction that often exists in the absence of organic etiology (Doggweiler et al., 2017). This condition affects approximately 26% of females according to the 2021 clinical practice recommendations update on CPP in females from the American College of Obstetricians and Gynecologists (ACOG; Arnold et al., 2021). The prevalence of CPP is higher (20.5%) in females of reproductive age when compared to older adult females (i.e., ≥ 65 years of age; 9.6%; Avorinde et al., 2017). The cause of CPP is unclear; however, associations with conditions like interstitial cystitis, endometriosis, depression, anxiety, and fibromyalgia are well established (Steege & Siedhoff, 2014). CPP is associated with significant central nervous system changes when compared to healthy pain-free females (Brawn et al., 2014). As a result of chronic pain, the nervous system goes through a process called 'central sensitization' that creates a state of high reactivity that triggers a prolonged increase in the excitability and synaptic efficacy of neurons in central nociceptive pathways (Woolf, 2011; Apkarian, Baliki, & Geha, 2009; Farmer, Baliki, & Apkarian, 2012; Farmer et al., 2011; Moseley & Flor, 2012; Tracey & Bushnell, 2009; Wand et al., 2011). These changes contribute to increased symptoms and predispose people to the development of additional chronic health conditions. In females living with CPP, alterations of brain structures involved in EF, such as the frontal-parietal control network, suggest there may be structural changes in regions of the brain responsible for EF because of chronic pain (Huang et al., 2020). These changes have been documented with

Magnetic Resonance Imaging (MRI) and Diffusion Tensor Imaging (DTI; Huang et al., 2020).

Physiotherapists working with people who are living with MSK conditions, such as CPP, focus on restoring function to the MSK system, including joints, tendons, muscles, ligaments, and bones. According to The Conference Board of Canada's publication on the Role of Physiotherapy in Canada, MSK physiotherapy is the predominant area of practice. MSK physiotherapists comprise approximately 40% of all practicing physiotherapists in Canada. Physiotherapists whose primary area of practice is MSK physiotherapy in Canada reported being the least knowledgeable about EF impairments, when compared to physiotherapists who reported their primary area of practice was neurological, cardiorespiratory, or multi-systems physiotherapy (Guitar et al., 2021 in press). In this previous survey research, some MSK physiotherapists even noted that they do not see patients living with EF impairments in their practice (Guitar et al., 2021 in press). However, we know that many patients seeking physiotherapy treatment do so for MSK pain (McRae & Hancock, 2017) and that people living with chronic pain may have impairments on measures of EF (Berryman et al., 2014; Murata et al., 2017). People living with chronic pain comprise a large patient population seen by MSK physiotherapists, and survey research suggests that approximately 89% of patients present to outpatient physiotherapists seeking pain relief (McRae & Hancock, 2017).

The CPP population has not been included in previous research examining the relationship between chronic MSK pain and EF (Berryman et al., 2014; Murata et al., 2017). Therefore, the purpose of this study was to evaluate the feasibility of recruitment, retention of potential participants, assessment procedures and data collection for research examining EF in females living with CPP. Additionally, we sought to understand: (1) if EF assessment measures suggested the presence of EF impairments in this sample; and (2) how self-reported scores on pain catastrophizing, central sensitization, depression, anxiety, and stress compare to age- and sex-matched normative data. These objectives were addressed by conducting virtual interviews with females living with CPP.

4.2 Method

4.2.1 Study Design

This cross-sectional pilot study was descriptive in nature and, as a pilot study, no sample size calculation was appropriate, and no inferential statistical tests were proposed *a priori* (Leon, Davis & Kramer, 2012). Guidelines on the role and interpretation of pilot studies in clinical research from Leon et al. (2012) were used in this study. The proposed study duration, based on the length of time deemed pragmatic by the researchers, was 2-months. The study was open between June 28 and August 28, 2021, during the coronavirus disease (COVID-19) pandemic in Canada. Ethics approval for the study was obtained from The University of Western Ontario’s Internal Review Board (see Appendix H). No incentives were provided to study participants. An academic institution’s licensed Zoom platform was used to conduct this study. All audio-recordings and data were securely stored on a firewall protected computer.

4.2.2 Participants

A convenience sample was recruited through a public Instagram post explaining the purpose of the study and inviting potential participants to volunteer to participate (see Appendices I & J). These advertisements for recruitment were shared through Instagram, community bulletin boards at local outpatient clinics that offer pelvic health physiotherapy, and word-of-mouth. Recruitment advertisements were shared from the first authors’ pelvic health physiotherapy themed Instagram account on June 28th, June 30th, and July 12th, 2021. The first author (NG) scheduled and conducted all interviews. Potential participants contacted NG or DC via Instagram, email or telephone and were provided the Letter of Information (LOI: see Appendix K). If potential participants met the inclusion criteria and were interested in participating, a 90-minute virtual interview was scheduled at a mutually agreeable time. Participants were included if they self-identified as a female, were living with CPP (i.e., pain in the pelvic region of at least six months in duration; as defined by Doggweiler et al., 2017), and were 18-40 years of age (i.e., adults of pre-menopausal age; Okeke, Anyaehie & Ezenyeakku, 2013). Only participants able to read, write and speak in the English language were included in this study. Study volunteers were excluded from participating if they reported being diagnosed with a cognitive impairment, terminal cancer, a stroke, neurological or demyelization disease, myopathies, or another illness likely to influence cognitive function (Lussier et al., 2013). Also, volunteers were excluded if they reported reaching premature menopause (i.e., they had not had a menstrual period in the last 12-months, were not using hormone therapy, and had not been diagnosed with another condition that would explain the absence of a menstrual cycle). In addition, potential participants who were currently receiving physiotherapy treatment where the first author was employed (NG) were not eligible for participation.

4.2.3 Procedures

All interviews began with collection of demographic characteristics and screening (see Appendix L & M), followed by the completion of six assessment measures. In the demographics screening, the NPRS (McCaffery & Beebe, 1993), bother score (rated on an 11-point scale from 0-10 where 0 = not bothered at all and 10 = bothered the most you imagine you could be), and motivation score (also rated on an 11-point scale from 0-10 where 0 = not motivated at all and 10 = motivated the most you imagine you could be) were assessed. The subsequent assessments were: the Central Sensitization Inventory (CSI; Mayer et al., 2012), the Pain Catastrophizing Scale (PCS; Sullivan, Bishop, & Pivik, 1995), the short version of the Depression, Anxiety and Stress Scale (DASS; Antony et al., 1998), the Oral Trail-Making Test (oTMT; Ricker, Axelrod & Houtler, 1996), a phonemic verbal fluency test (i.e., FAS-test; Benton et al., 1994), and the Executive Skills Questionnaire-Revised (ESQ-R; Strait et al., 2020). Each assessment measure was assigned a number 1-6, and an online random number generator was used to determine the order of assessments for each interview to reduce possible order effects that could influence responses on subsequent assessments (Perreault, 1975).

4.2.4 Assessment Measures and Scales

4.2.4.1 NPRS

The NPRS was created by McCaffery and Beebe (1993) as a subjective measure of pain intensity. It is used to evaluate changes in pain over time. It is an 11-point scale that ranges from 0-10 and takes < 1 min to administer orally. In this study, participants were asked "on a scale from 0-10, how would you rate your pain if a score of 0 indicates no pain at all, and a score of 10 indicates the worst pain you could possibly imagine?". Scores of 4-5/10 on the NPRS are commonly recommended as lower limits for classification of "moderate pain", and 7-8/10 are the most common for a classification of "severe pain" (Fejer et al., 2005; Jensen et al., 2001; Paul et al., 2005; Serlin et al., 1995; Turner et al., 2004; Zelman et al., 2005). In this study, scores ≤ 5 = mild pain, 6-7 = moderate, and ≥ 8 = severe pain interference with functioning (Boonstra et al., 2016).

The NPRS has excellent internal consistency when used with people living with chronic pain (Cronbach's alpha = 0.84-0.98; Jensen & McFarland, 1993). The NPRS has adequate test-retest stability for a single pair of assessments (1 week apart; $r = 0.63$) and excellent test-retest reliability for ratings on 2 or more days during a single week, when compared to 2 or more days during the following week ($r = 0.79$-0.92). Test-retest reliability increases with increasing numbers of ratings, with the highest reliability for 4 ratings per day taken on 7 consecutive days (*r* = 0.95; Jensen and McFarland, 1993). Previous research suggests, that for people living with chronic MSK pain, a change of 1 point, or 15.0%, is indicative of a clinically important difference (Salaffi et. al. 2004).

4.2.4.2 CSI

The CSI measures central sensitization, a condition of the nervous system that is associated with the development and maintenance of chronic pain (Mayer et al., 2012; see Appendix N). The CSI has two parts. The first part, Part A, lists 25 statements related to current health symptoms that are rated on a 5-point Likert scale ranging from *never* (i.e., 0) to *always* (i.e., 4; e.g., “My muscles feel stiff and achy”) and provides a total score out of 100 that is typically reported as a percentage. Higher percentages indicate greater central sensitization. The cut-off for the presence of central sensitization is a score > 40 (Mayer et al., 2012; Neblett et al., 2015). The second part, Part B, is a checklist of health conditions (e.g., chronic fatigue syndrome) where the positive presence of one or more of the listed medical diagnoses indicates the presence of central sensitization. Test-retest reliability of the CSI in a sample of N = 149 participants (77% female) without chronic pain (age *M* = 22.4, *SD* = 4.7) is *r* = 0.817; and Cronbach’s alpha = 0.879 (Mayer et al., 2011). The clinically relevant severity levels for the CSI published by Mayer et al. (2012) and Neblett et al., (2017) will be used in this study.

4.2.4.3 PCS

The PCS is a 13-item questionnaire that quantifies an individual's pain experience by asking a person to rate items that represent different thoughts or feelings they could have when they are experiencing pain (Sullivan, Bishop, & Pivik, 1995; see Appendix O). For example, "When I'm in pain… it's terrible and I think it's never going to get any better" is an item on the PCS. Participants are asked to rank how much each statement applies to them on a 5-point Likert scale ranging from *not at all* (i.e., 0) to *all the time* (i.e., 4). Three subscales of the PCS provide specific scores for rumination (i.e., fixation on pain), magnification (i.e., hypervigilance and tendency to think the worst) and helplessness (i.e., inability to defend oneself from pain). The PCS provides a total score generated by adding all scores (range 0-52, higher = greater pain catastrophizing) where a score > 20 represents a clinically relevant moderate risk of ongoing disability over 1 year, and a score > 30 represents a clinically relevant severe risk of ongoing disability over 1 year (Sullivan, Bishop, & Pivik, 1995). The internal consistency of the PCS (13-item) is high with a Cronbach's alpha = 0.95 in a community sample (N = 215; n = 130 women with age *M* = 34.6, *SD* = 12.2; n = 85 men with age *M* = 35.9, *SD* = 10.8). The internal consistency of the rumination, magnification and helplessness subscales are also high, Cronbach's alpha = 0.95, 0.88, and 0.91, respectively (Osman et al., 2000). In a pain outpatient sample, high internal consistency of the PCS (Cronbach's alpha = 0.92) was reported (N = 60; n = 34 women, age *M* = 33, *SD* = 10.7 years; n = 26 men, age *M* = 31.2, *SD* = 8.7 years). In the same sample, the internal consistency of the rumination, magnification and helplessness subscales were high (Cronbach's alpha = 0.85, 0.75, and 0.98, respectively; Osman et al., 2000). The test-retest reliability of the PCS is also high after 6-weeks (*r* = 0.75) and 10-weeks (*r* = 0.70; Osman et al., 2000). In the current study, participants' total scores were compared to normative data presented by Nicholas et al. (2019) and Sullivan, Bishop, & Pivik (1995). Rumination, magnification, and helplessness are subscales of the PCS that do not have established cut-off scores but can be used descriptively with participants to monitor change over time.

4.2.4.4 DASS

The DASS short form is an assessment that measures depression, anxiety, and stress, each through seven items on the 21-item scale. Each item is rated on a 4-point Likert scale ranging from *did not apply to me at all* (i.e., 0) to *applied to me very much, or most* *of the time* (i.e., 4; Antony et al., 1998; see Appendix P). The 7-item subscales of the DASS provide specific scores for depression (e.g., "I could not seem to experience any feeling at all"), anxiety (e.g., "I was aware of dryness in my mouth"), and stress (e.g., "I find it hard to wind down"). Depression scores are categorized as follows: 0-9 = normal, 10-13 = mild, 14-20 = moderate, 21-27 = severe, 28+ = extremely severe. Anxiety scores are categorized as follows: 0-7 = normal, 8-9 = mild, 10-14 = moderate, 15-19 = severe, 20+ = extremely severe. Lastly, stress scores are categorized as follows: 0-14 = normal, 15-18 = mild, 19-25 = moderate, 26-33 = severe, 34+ = extremely severe (Lovibond & Lovibond, 1995). The internal consistency of the DASS is good, with Cronbach's alpha = 0.96, 0.89 and 0.93 for the depression, anxiety, and stress subscales, respectively (N = 437; 63.6% female, age *M* = 36.10, *SD* = 10.55, min = 18, max = 65; Brown et al., 1997). In this study, participants' scores were compared to normative data presented by Nicholas et al. (2019).

4.2.4.5 oTMT

The TMT is a neuropsychological assessment that examines processing speed and EF through two tasks related to connecting objects together in long sequences or "trails." The test was originally constructed in 1938 as "Partington's Pathways" also known as the

“Divided Attention Test” (Partington & Leiter, 1949) and was part of the Army Individual Test Battery (1944). It was later adapted by Reitan (1955) and added to the Halstead Battery (Mazur-Mosiewicz & Dean, 2011). The oral version (i.e., the oTMT), used in this study (Ricker, Axelrod & Houtler, 1996), eliminates visual and motor confounds that could be caused by poor visual acuity or motor functioning, while increasing speech demands (see Appendix Q). In the oTMT-A, the participant is asked to count forward from 1 to 25, simply to introduce the individual to the format of the task. For oTMT-B, the individual is asked to alternate between numbers and letters, sequentially, until they reach the number 13 and the letter “M”. Both parts of the task take <5 minutes for completion. The participant’s score on the oTMT is the number of seconds it takes to complete the task including the time taken to offer corrections to errors, with more errors indicated by a longer time to completion (Ricker, Axelrod & Houtler, 1996).

Scoring systems have been developed and use scores derived from the ratio of Trails B:A and B-A difference scores (Lamberty et al., 1994). Lamberty (1994) reported that ratio scores > 3.0 are found more frequently in people with impaired EF, whereas ratios ≤ 2.5 are considered within normal limits. Mean oTMT-A normal scores have been reported to be 6.25 sec with *SD* = 1.32, and oTMT-B normal scores have been reported to be *M* = 22.77 (*SD* = 14.80) in a sample of 31 men and women with an age range from 20-39 years (Mrazik, Millis, & Drane, 2010). Research also suggests that on the oTMT tests, B:A ratio scores > 3.0 are indicative of impaired EF (Lamberty, 1994). The confounding effects of education and general cognitive functioning have also been studied with the oTMT. Poorer oTMT-B performance is related to fewer years of education (Ruchinskas, 2001). The oTMT-A&B times to completion, ratios, and difference scores were calculated in this study using the methods of Ricker, Axelrod & Houtler (1996). Sex-, age-, and education-matched reference values published by Mrazik, Millis and Drane (2010) were used for comparison.

4.2.4.6 FAS-test

The FAS-test is a verbal fluency test used to investigate the spontaneous production of words under restricted search conditions (Benton et al., 1994). In phonemic fluency tests the participant must produce orally as many words as possible beginning with a specified letter during a fixed period (e.g., one minute; See Appendix R). Fluency tests therefore measure timed production of individual words under restricted search conditions (i.e., a given letter in the alphabet). The letters F, A and S are the most used letters (Benton et al., 1994). The choice of letter set affects the results because of differences in letter difficulty and word frequency for each letter (Borkowski et al., 1967). The FAS version, used in this pilot study, was scored as the total number of correct words, number of clusters, number of switches, and mean cluster size as recommended by Troyer et al. (1997). Clustering involves phonemic analysis on a phonemic fluency test and is thought to be a relatively automatic process (de Mareüil, Corredor-Ardot & Adda-Decker, 1999). Switching involves cognitive flexibility in shifting from one subcategory to another and is thought to involve a relatively effortful process that has been called complex EF (Miyake et al., 2000). On phonemic fluency tests, clustering is defined as successfully generated words that begin with the same first two letters (Patterson, 2011). The size of the cluster is counted beginning with the second word in each cluster. Mean cluster size was calculated by summing the size of each cluster and dividing by the number of clusters. Switches were calculated as the number of transitions between clusters, including single words.

Normative data presented by Tombaugh, Kozak and Rees (1999) and Weiss et al. (2006) were used in this study. The internal reliability of the FAS-test computed using the total number of words generated for each letter as individual items is high ($r = 0.83$;

Tombaugh et al., 1999). Test-retest reliability is also high (*r* > 0.70) for phonemic fluency tests with short (i.e., one-week) and long (i.e., five-year) intervals (Basso et al., 1999; Levine et al., 2004).

4.2.4.7 ESQ-R

The ESQ-R is a 25-item self-report questionnaire designed to assess EF skill strengths and challenges (Strait et al., 2020; see Appendix S). The ESQ-R is based on the Executive Skills Questionnaire (ESQ; i.e., a 36-item questionnaire that provides an indirect measure of a person's self-reported EF skills in relation to each other including: response inhibition, working memory, emotional control, sustained attention, task initiation, planning/prioritization, organization, time management, goal-directed persistence, flexibility, metacognition and stress tolerance; Dawson & Guare, 2010). Unlike the ESQ, psychometric properties are available for the ESQ-R, which has excellent internal consistency (Cronbach's alpha = 0.91) and adequate test-retest reliability (Cronbach's alpha = 0.70) in a sample of N = 347 (% female = 82.9, age *M* = 26.28, *SD* = 7.61; Strait et al., 2020). The ESQ-R also has moderate correlations with psychological symptoms' scales (i.e., the DASS, Generalized Anxiety Disorder 7-item Scale, Perceived Stress Scale; Cronbach's alpha = 0.38-0.55; Strait et al., 2020). The

ESQ-R is not a norm-referenced instrument and therefore does not relate a person's performance to the performance of a population. On the ESQ-R, "I act on impulse" is an item that a person would be asked to rank on a 4-point Likert scale ranging from *never or rarely* (i.e., 0) to *very often* (i.e., 4). On the ESQ-R, individual item scores between 0-1 should be considered a relative strength or nonproblematic and scores between 2-3 should be considered a relative weakness and problematic.

Scores are calculated means for each category on the ESQ-R (i.e., the total sum for all questions in the category divided by the number of questions in the category; Strait et al., 2020). The ESQ-R takes approximately 10 minutes to administer and measures emotion regulation, behaviour regulation, plan management, time management, and materials organization (Strait et al., 2020). Emotion regulation is a skill area reported to be identical to the EF skill of emotional control and refers to the ability to manage emotions to achieve goals, complete tasks or control and direct behaviour. Behaviour regulation refers to the ability to exhibit self-control to think before acting or responding and consider the consequences of one's actions. It includes the EF skills of response inhibition and goal-directed behaviour. Plan management refers to the ability to create and manage plans for accomplishing tasks. It includes skills like planning, sustained attention, and flexibility. Time management refers to the ability to manage various aspects of time, including time estimating, time allocation, and being able to work within time constraints. It includes EF skills of time management, task initiation and working memory. Lastly, materials organization refers to the ability to create and maintain systems to keep track of information. It includes EF skills of organization and working memory.

4.2.5 Data Management and Analyses

Data were encrypted in transit to an institutional OneDrive via transport layer security (TLS) encryption, and at rest with a unique AES256 key. Data were organized within Excel software on an academic institutional OneDrive. Data analyses were completed using SPSS Version 25 (IBM Corp, 2017). Feasibility was evaluated by examining the number of potential participants who responded to an advertisement to participate, and the retention rate of those potential participants. *A priori* it was determined that only descriptive data would be used to answer our study questions; however, *a posteriori* it was decided that, because of the large number of participants recruited, it may be possible to conduct inferential statistics in the form of *t*-tests. *A posteriori* a power analysis conducted using G*Power (Faul et al., 2007) indicated that a sample size of n = 34 would be required to complete two-tailed *t*-tests with a power (1 – β) = 0.90, alpha = 0.05 and an effect size = 0.50 (i.e., a moderate effect size according to Cohen, 1988). Therefore, multiple one-sample *t*-tests were computed to determine how the sample data compared to various cut-off scores and available normative data. Cohen's *d*, the mean difference divided by the standard deviation, was used as a measured of effect size where *d* = 0.20 is small, *d* = 0.50 is medium, and *d* = 0.80 is large (Cohen, 1988). Participant scores > 1 SD below the mean were used as a criterion to classify impairment (Dalrymple-Alford et al., 2011).

4.3 Results

4.3.1 Feasibility

A total of 35 people consented to participate in the study (see Figure 5). The length of the interviews ranged from 37.25 min to 80.48 min (*M* = 51.87, *SD* = 10.04). A total of one volunteer was excluded for not meeting inclusion criteria. Additionally, during the study, inquiries were made by two potential participants who were living on a continent that was not North America and it was decided that, because of possible cultural and health systems differences, these volunteers would be excluded. In this study we retained 60.34% of potential participants (who were eligible or had unknown eligibility) who responded to a recruitment advertisement over the course of 2-months. Of those who received a follow-up email from the study investigator after being sent the LOI, 36.11% responded to participate. The remaining 23 potential participants were not contacted nor heard from again.

Based on the activity of the Instagram account with 1166 followers that shared the recruitment advertisement, the posts were shared numerous times privately and publicly (see Table 10). The number of emails received from potential participants per day during the study period is illustrated in Figure 6. Notably, an endometriosis specialist with 1717 followers shared the post to their Instagram "story" on July 15th, 2021, which was observed to be the day before our largest influx of potential participant emails. If we were not "tagged" in the sharing of the posts on the Instagram platform, we were not able to determine who shared or saved these posts. Additionally, Pelvic Health Support (https://www.pelvichealthsupport.ca), an organization with 1961 followers and a focus on pelvic health awareness, community, and advocacy, also shared the recruitment poster on their Instagram and online website.

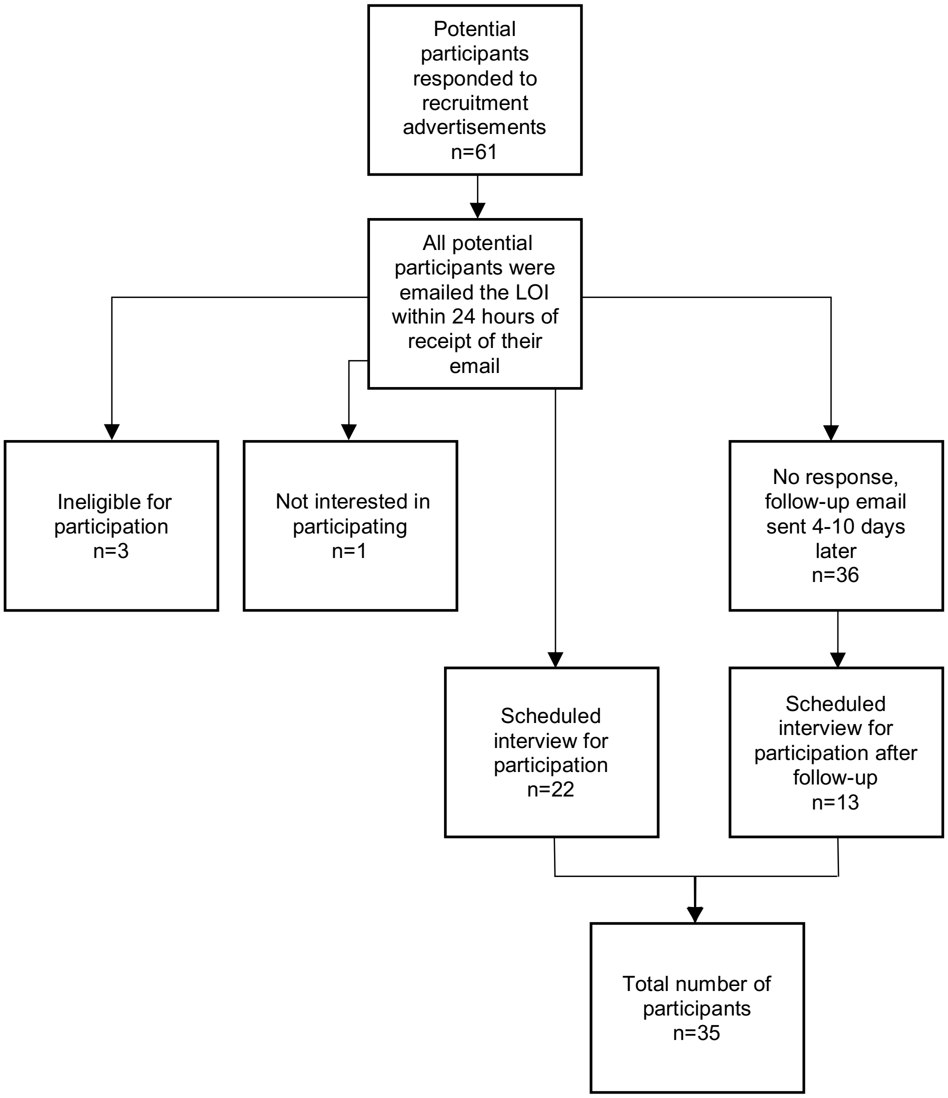

Figure 5. *Process of recruitment and retention of potential participants.*

Table 10. *Metrics for Instagram post recruitment advertisements posted by study investigator.*

Date	Likes	Comments	Shares	Saves	Impressions
June 28, 2021	69	6	82	41	945
June 30, 2021	31	3	3	1	524
July 12, 2021	59	2	43	19	605

Note. Likes = the total number of unique Instagram users who indicated they liked the post; Comments = the number of comments on a post; Shares = the total number of times an Instagram user shared the post with another account; Saves = the number of unique Instagram accounts that saved the post; Impressions: the total number of times the post was seen by any Instagram user. Data as of September 17, 2021.

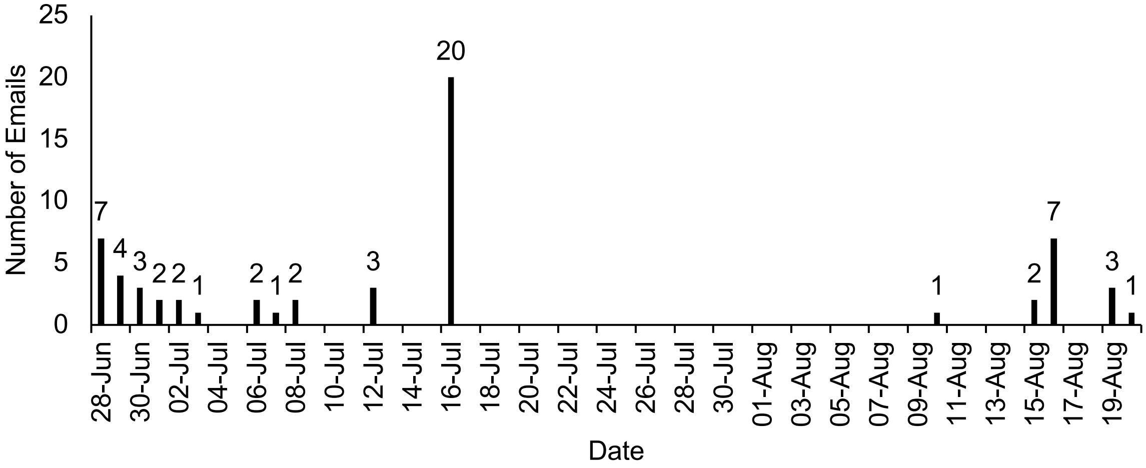

Figure 6. *Number of emails from potential participants/day.*

4.3.2 Participant Demographics and Assessment Measures

Participants (N = 35) were 27 years old on average (*M* = 27.91, *SD* = 5.01). Most participants, 65.7%, had a minimum of 4 years of post-secondary education (i.e., 4 years after high school) and 100% of the participants graduated from high school. The average number of years of education after high school was four (*M* = 4.38, *SD* = 2.53). They reported living with their pain for over a decade on average (*M* = 10.94, *SD* = 6.97) and rated their pain on average over the last 6-months as > 5 on the NPRS (*M* = 5.22, *SD* = 1.68). Patients reported severe pain on their worst day over the last 6-months (*M* = 8.60, *SD* = 1.41), and a high degree of bother regarding their pain (*M* = 8.11, *SD* = 2.11). They reported being very motivated (*M* = 9.28, *SD* = 1.48) to change their pain if they could. Participants reported sleeping for approximately seven and half hours per night (*M* = 7.57, *SD* = 1.24), and having approximately three additional diagnosed comorbid health conditions (*M* = 3.20, *SD* = 1.97). Twenty participants reported having constant pain, and 15 reported intermittent pain. Characteristics of study participants are presented in Table 11.

The top three titles participants ascribed to their pelvic pain, which were not mutually exclusive, were endometriosis (n = 25), dyspareunia (n = 14) and dysmenorrhea (n = 12;

see Appendix M). Most participants (n = 19) used the words “sharp”, “stabbing”, or “shooting” to describe their pain, followed by “cramping” (n = 10) and “heaviness” or “fullness” (n = 6). In addition to pain located in the pelvis, participants reported low back pain (n = 15), abdominal pain (n = 9), hip and leg pain (n = 5) and vulvar pain (n = 4).

Table 11. *Participant characteristics and scores on assessment measures (N=35).*

	Mean	SD	95% CI	Min-Max
Age (years)	27.91	5.01	26.19, 29.64	19.00-38.00
Education (years after high school)	4.38	2.53	15.52, 17.26	12.00-22.00
Pain Duration (years)	10.94	6.97	8.55, 13.34	1.00-25.00
Comorbidities (mean number/participant)	3.20	1.97	2.52, 3.87	0.00-9.00
Medications (mean number/participant)	0.86	1.03	0.50, 1.21	0.00-4.00
Sleep duration (mean number of hours/night)	7.57	1.24	7.14, 8.00	5.00-10.00
6-month NPRS /10				
average	5.22	1.68	4.65, 5.80	2.00-8.00
worst	8.60	1.41	8.11, 9.08	4.00-10.00
best	1.40	1.80	0.78, 2.01	0.00-6.00
Bother score /10	8.11	2.11	7.39, 8.84	1.00-10.00
Motivation score /10	9.28	1.48	8.78, 9.80	4.00-10.00
CSI Part A /100	54.40	14.24	49.51, 59.29	27.00-80.00
PCS Total /52	35.20	9.8	31.81, 38.59	7.00-51.00
PCS Rumination /16	13.29	3.19	12.19, 14.38	4.00-16.00
PCS Magnification /12	6.88	3.08	5.83, 7.95	1.00-12.00
PCS Helplessness /24	15.91	525	14.11, 17.72	2.00-23.00
DASS Depression /42	14.06	9.97	10.63, 17.48	0.00-38.00
DASS Anxiety /42	13.43	9.68	10.10, 16.76	2.00-34.00
DASS Stress /42	20.06	7.49	17.48, 22.63	6.00-42.00
oTMT A (sec)	7.67	1.69	7.09, 8.26	4.70-12.09
oTMT B (sec)	30.38	12.14	26.21, 34.55	20.17-60.28

oTMT B:A (sec)	4.23	2.32	3.43, 5.03	0.32-11.91
oTMT B-A (sec)	22.70	12.60	18.38, 27.04	-4.52-55.22
FAS (total number of words)	40.34	11.00	36.56, 44.12	26.00-70.00
FAS (mean number of words)	13.19	3.74	11.90, 14.48	7.67-23.00
F mean number of words	13.42	3.89	12.09, 14.77	7.00-24.00
A mean number of words	12.02	4.85	10.36, 13.70	4.00-24.00
S mean number of words	14.11	4.49	12.57, 15.66	5.00-26.00
FAS Clusters (mean number)	31.86	9.88	28.46, 35.25	19.00-59.00
FAS Mean Cluster Size	1.30	0.19	1.23, 1.36	1.06-1.94
FAS Switches (total number)	28.86	9.88	25.86, 32.25	16.00-56.00
ESQ-R Total /75	28.31	11.43	24.39, 32.24	9.00-56.00
Plan Management Score	1.31	1.78	0.69, 1.92	0.18-11.00
Time Management Score	1.14	0.69	0.90, 1.38	0.00-2.50
Materials Organization Score	1.18	0.86	0.88, 1.47	0.00-3.00
Emotional Regulation Score	1.26	0.66	1.04, 1.49	0.33-3.00
Behavioural Regulation Score	1.22	0.55	1.03, 1.41	0.25-2.50

Note. SD = standard deviation; 95% CI = 95% confidence interval for the mean; Min-Max = minimum value and maximum value; NPRS = numeric pain rating scale; Education: high school = 12 years; CSI Part A = Central Sensitization Inventory Questionnaire Part A; PCS: Pain Catastrophizing Scale; DASS: Depression, Anxiety & Stress Scale; oTMT: Oral Trail Making Test; FAS: FAS-test verbal fluency test; ESQ-R: Executive Skills Questionnaire Revised (scores are calculated means for each category on the ESQ-R: total sum for all questions in the category/ the number of questions; Strait et al., 2020); Note that only females were included in this study.

The most common comorbid conditions reported by participants were anxiety or panic attacks (n = 21), irritable bowel syndrome (n = 16) and depression (n = 14). Most participants (n = 30) reported that the use of heat eased their pain, in addition to Non-Steroidal Anti-Inflammatory Drugs (n = 17), rest or “not moving” (n = 8), and Cannabidiol (CBD; n = 7). Participants reported that stress (n = 9), alcohol (n = 9) and penetrative intercourse (n = 8) aggravated their pain. Additional easing and aggravating factors reported by participants are available in Appendix T. No prescribed medications were found to be common among participants. Eight of the participants were graduate level students (n = 8; i.e., they were pursing education after a four-year bachelor's degree). Other participants reported working in a form of administration assistance (n = 5), were unemployed (n = 5) or working in nursing (n = 3), or another occupation. In terms of living arrangements, participants reported living with family that did not include a married partner or their own children (n = 13), with their married partner (n = 7), with their married partner and their children (n = 5), with their unmarried partner (n = 5), with friends (n = 3), or with no other individuals (n = 2).

4.3.3 CSI

A one-sample t-test showed that participants' scores on the CSI ($M = 54.40$, $SD = 14.24$) were significantly higher than the cut-off score of 40 for the presence of central sensitization, $t(34) = 5.98$, $p < 0.001$; $d = 1.01$, 95% CI [9.51, 19.29]. This is a large effect size and indicates a difference of approximately one standard deviation between the participants' mean scores and the cut-off for the presence of central sensitization. In fact, 29/35 participants scored > 40 on the CSI and were therefore categorized as having at least a moderate severity-level of central sensitization (see Figure 7). In addition, on part B, 97.14% of participants selected one or more items. This indicated that all but one participant presented with central sensitization.

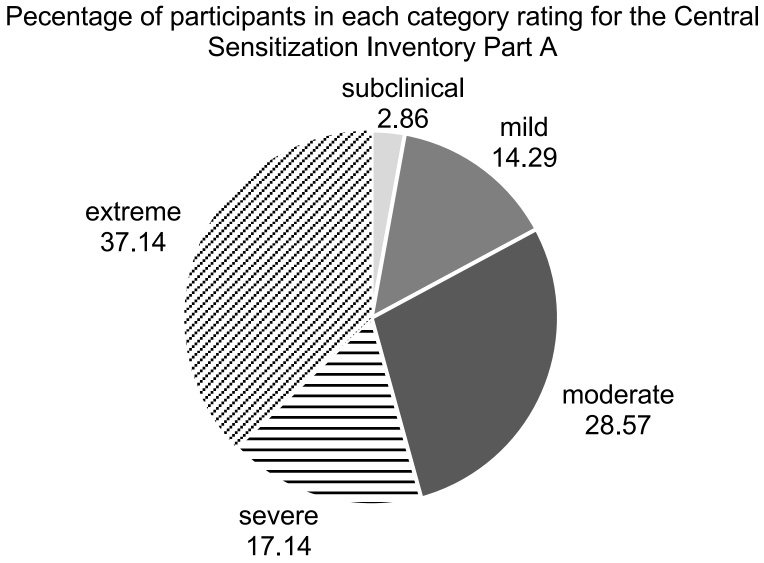

Figure 7. *Percentage of participants in each category rating for the Central Sensitization Inventory Part A; Subclinical: 0-29, mild: 30-39, moderate: 40-49, severe: 50-59, extreme: 60+ (Neblett et al., 2015).*

4.3.4 PCS

On the PCS, a one-sample *t*-test showed that participants' scores ($M = 35.20$, $SD = 9.87$) were significantly higher than the cut-off score of 30 for a clinically relevant severe risk of ongoing disability over the next year, $t(34) = 3.12$, $p < 0.01$; $d = 0.53$, 95% CI [1.81, 8.59]. This is a medium effect size and indicates a difference of approximately one half of a standard deviation between the participants' mean scores and the cut-off for ongoing severe disability. A total of 26/35 participants scored > 30 and a total of 33/35 participants scored > 20 on the PCS, which represents a clinically relevant moderate risk of ongoing disability over the next year.

4.3.5 DASS

For the DASS, a one-sample *t*-test showed that participants' scores on the depression subscale ($M = 14.06$, $SD = 9.97$) were significantly higher than the cut-off score of 9 for "normal" levels of depression, $t(34) = 3.00$, $p < 0.01$; $d = 0.51$, 95% CI [1.63, 8.48]. This is a medium effect size and indicates a difference of approximately one half of a standard deviation between the participants' mean scores and the cut-off for "normal" depression. On the anxiety subscale, scores ($M = 13.43$, $SD = 9.68$) were also significantly higher than the cut-off score of 7 for "normal" levels of anxiety, $t(34) = 3.93$, $p < 0.001$; $d = 0.66$, 95% CI [3.10, 9.76]. This also indicates a medium effect size and a difference of more than one half of a standard deviation between the participants' mean scores and the cut-off for "normal" anxiety. Lastly, on the stress subscale, scores ($M = 20.06$, $SD = 7.49$) were significantly higher than the cut-off score of 14 for "normal" levels of stress, $t(34) =$

4.78, $p < 0.001$; $d = 0.81$, 95% CI [3.48, 8.63]. This is a large effect size and indicates a difference of nearly one standard deviation between the participants' mean scores and the cut-off for "normal" stress. Five participants scored in "extremely severe" categories of a subscale on the DASS and were informed and provided three local options for counselling services (see Figure 8 for a breakdown of scores for each category for each subscale on the DASS).

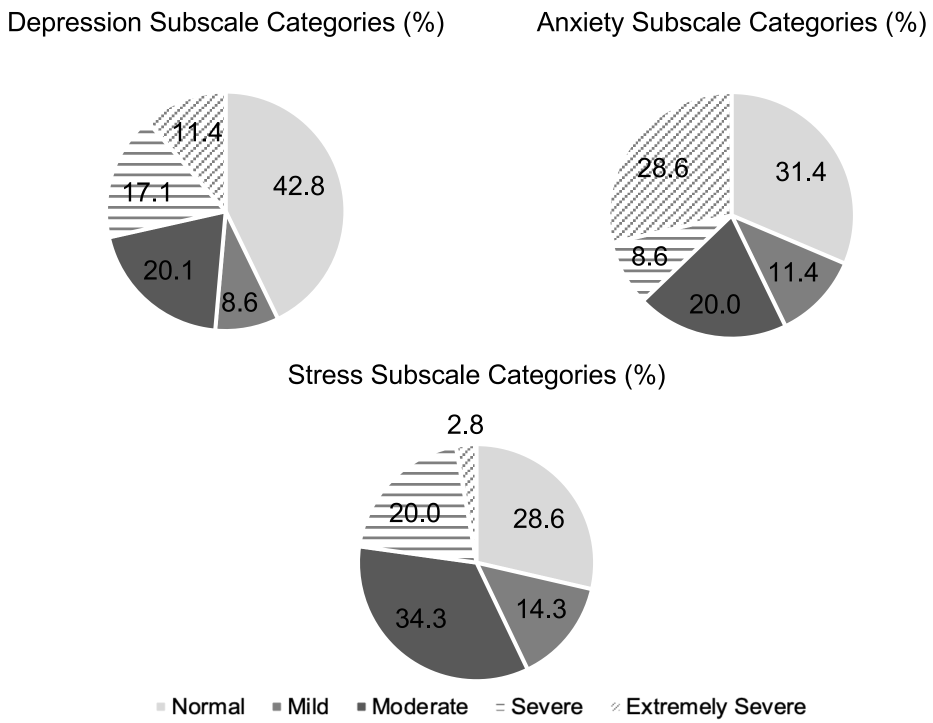

Figure 8. *Percentage of responses for each category on each subscale of the Depression, Anxiety and Stress Scale.*

4.3.6 oTMT

On the oTMT participants scored between the 9th and 25th percentiles for part A and B (Mrazik, Millis, & Drane, 2010). The 9th percentile is recommended by Mrazik, Millis, & Drane (2010) as the cut-off point for impairment in EF with the oTMT-A cut-off of > 8.0 sec and the oTMT-B cut-off of > 44.0 sec. A total of 22.85% of participants scored greater than the cut-off of > 8.0 sec on the oTMT-A, and 14.28% of participants scored greater than the cut-off of > 44.0 sec on the oTMT-B. A one-sample *t*-test shows that participants' ratio scores on the oTMT-B:A ($M = 4.23$, $SD = 2.32$) were significantly higher than the established cut-off score of 3.0, $t(34) = 3.14$, $p < 0.01$; $d = 0.53$, 95% CI [0.43, 2.03]. This constitutes a medium effect size and indicates a difference of nearly one half of a standard deviation between the participants' mean scores and the previously reported normal value for B:A ratios. A total of 62.85% of participants scored greater than the cut-off of > 3.0 for the B:A ratio score.

Further, a one-sample *t*-test showed that participants' scores on the oTMT-A ($M = 7.67$, $SD = 1.69$) were significantly higher, or worse, than the normal score of 6.25 sec (N=31, 20-39 year olds; Mrazik, Millis, & Drane, 2010), $t(34) = 4.97$, $p < 0.001$; $d = 0.84$, 95% CI [0.84, 2.01]. This is a large effect size and indicates a difference of nearly one standard deviation between the participants' mean scores and previously reported normal values of oTMT-A; however, when compared to suggested norms for the presence of impairment (i.e., the 9th percentile score from normal Mrazik, Millis, & Drane [2010] of 8.0 sec), a one-sample *t*-test showed that participants' scores on the oTMT-A (*M*=7.67, *SD*=1.69) were not significantly different, *t*(34) = -1.14, *p* = ns (0.264); *d* = -0.19, 95% CI [-0.91, 0.26].

For the oTMT-B, a one-sample *t*-test showed that participants' scores (*M* = 30.38, *SD* = 12.14) were significantly higher than the normal score of 22.77 sec (N=31, 20-39 year olds; Mrazik, Millis, & Drane, 2010), *t*(34) = 3.71, $p < 0.01$; *d* = 0.63, 95% CI [3.44, 11.78]. This is a moderate effect size and indicates a difference of more than one half of a standard deviation between the participants' mean scores and previously reported normal values of oTMT-B. When compared to normal values presented by Mrazik, Millis, & Drane (2010), a one-sample *t*-test shows that participants' scores on the oTMT-B (*M* = 30.38, *SD* = 12.14) were significantly better than the 9th percentile score of 44.0 sec, *t*(34) = -6.63, $p < 0.001$; *d* = -1.12, 95% CI [-17.79, -9.45]. This is a large effect size and indicates a difference of nearly one standard deviation between the participants' mean scores and Mrazik, Millis, & Drane's (2010) reported cut-off for EF impairment.

4.3.7 FAS-test

A one-sample *t*-test showed that participants' total scores on the FAS-test ($M = 40.34$, $SD = 11.00$) were significantly lower, or worse, than the normal score of 44.7 words generated in 60 sec on average (N = 242 between 16-59 years of age and education >13 years; Tombaugh, Kozak & Rees, 1999), $t(34) = -2.34$, $p < 0\ .05$; $d = -0.40$, 95% CI [-8.12, -0.58]. This is almost indicative of a moderate effect size and a difference of approximately one half of a standard deviation between the participants' mean scores and previously reported normal values for the FAS-test. However, when different normative data was applied for comparison (Troyer, 2000; N=411 between 18-91 and education between 5-21 years), this difference is eliminated and our sample performed significantly better, $t(34) = 6.32$, $p < 0.001$; $d = 1.07$, 95% CI [7.96, 15.52]. A final comparison based on a third set of normative data presented by Weiss et al., (2006; N = 40, with age $M = 24.96$, $SD = 3.59$), showed that our sample did perform significantly lower, or worse, than the normal score of 45.38 ($SD = 8.83$) words generated, $t(34) = -2.71$, $p < 0.05$; $d = 1.34$, 95% CI [-8.82, -1.26]. A total of 45.71% of our participants scored > 1 SD below the mean presented by Weiss et al. (2006), indicating impairment on the FAS-test. Using data presented by Weiss et al. (2006), our sample ($M = 28.86$, $SD = 9.88$) also produced a significantly lower number of switches, $t(34) = -2.11$, $p < 0.05$; $d = -0.36$, 95% CI [-6.92,

-0.13], when compared to the normal value presented of 32.38 ($SD = 7.11$). A total of 45.71% of participants scored > 1 SD below the mean for number of switches. Our sample also produced significantly larger ($M = 1.30$, $SD = 0.19$) mean cluster sizes, $t(34) = 28.94$, $p < 0.001$; $d = 50.37$, 95% CI [0.84, 0.97], when compared to the normal value presented of 0.39 ($SD = 0.20$) for mean cluster size. All participants scored > 1 SD below the mean for mean cluster size when compared to data from Weiss et al. (2006).

4.3.8 ESQ-R

On the ESQ-R scale, a one-sample *t*-test showed that participants' scores on emotion regulation ($M = 1.26$, $SD = 0.66$) were significantly higher, or worse, than the normal score of 1, $t(34) = 2.35$, $p < 0.05$; $d = 0.40$, 95% CI [0.04, 0.50]. This is a small effect size and indicates a difference of almost one half of a standard deviation between the participants' mean scores and "normal" on the scale. For behavioral regulation, scores ($M = 1.22$, $SD = 0.55$) were significantly higher, or worse, than the normal score of 1 on the ESQ-R, $t(34) = 2.32$, $p < 0.05$; $d = 0.39$, 95% CI [0.03, 0.41]. This is a small effect size and indicates a difference of almost one half of a standard deviation between the participants' mean scores and "normal" on the scale. For planning management, scores ($M = 1.31$, $SD = 1.78$) were not significantly different from the normal score of 1, $t(34) =$

1.02, *p* = ns; *d* = 0.17, 95% CI [-0.31, 0.92]. For time management (*M* = 1.14, *SD* = 0.69) scores were not significantly different from the normal score of 1, *t*(34) = 1.22, *p* = ns; *d* = 0.21, 95% CI [-0.10, 0.38], and lastly, materials organization scores, (*M* = 1.18, *SD* = 0.86), were also not significantly different from the normal score of 1, *t*(34) = 1.23, *p* = ns; *d* = 0.21, 95% CI [-0.12, 0.47].

4.4 Discussion

The purpose of this pilot study was to examine the feasibility of recruitment, retention, assessment procedures and data collection in a study examining EF in females living with CPP. Additionally, we sought to understand: (1) if EF assessment measures (i.e., the oTMT, FAS-test & ESQ-R) suggest the presence of EF impairments in this sample and (2) how self-reported scores on the CSI, PCS, and DASS compared to normative age- and sex-matched data. These objectives were addressed by conducting virtual data collection sessions using an interview style of assessment with females living with CPP.

In this study we retained 60.34% of potential participants who responded to a recruitment advertisement over the course of 2-months. Of those who received a follow-up email from the study investigator after being sent the LOI, 36.11% responded to participate. As previously mentioned, the remaining 23 potential participants were not contacted nor heard from again. It is unknown if these potential participants were ineligible, chose not to participate or if there were other life events that occupied their time and prevented them from committing to participate. Recall that this study was conducted during the COVID-19 pandemic in Canada, which may have played a factor in potential participants availability. Our data indicated that it was feasible to conduct a study of this nature using Instagram and word of mouth for recruitment. The total number of times our recruitment posts were seen by Instagram users was 2074 (i.e., total impressions as shown in Table 1). Social media allowed for sharing of the advertisements by other health care providers, resulting in an influx of potential participants. In future studies, retention could be improved by contacting potential participants with more than one follow-up email, perhaps a week or two apart and requesting if they would provide the reason that they are not responding so that we could understand the effect of eligibility criteria on recruitment. Of those who scheduled an interview, retention was perfect. This was likely due to experimenter flexibility in scheduling (including evenings) and a single reminder email provided 48-hours in advance of the scheduled interview. The virtual assessment procedures were successful. There were no issues in assessment administration or data collection, using the Zoom platform, aside from one power outage that prevented a participant from attending their scheduled interview. This interview was rescheduled, and the assessment was completed.

Since our recruitment advertisement was shared on Instagram by an endometriosis specialist, we had a high number of participants with a confirmed or suspected endometriosis diagnosis at 71.42%. Endometriosis is often diagnosed by specialists as "suspected" because it can only be truly confirmed through laparoscopic surgery. Participants used pain descriptors that align with central nociplastic changes, or central sensitization, like "shooting" and "sharp" (Walton & Elliot, 2018). These descriptions indicate pain that can be traced to the central nervous system, as opposed to pain as a response to nociceptive or neuropathic inputs where descriptions like "ache" and "dull" are more often used (Walton & Elliot, 2018). It is unsurprising that participants also reported a high incidence of low back pain at 42.85%. Previous research suggests that there is a high proportion of pelvic floor muscle dysfunction present in women with lumbopelvic pain (Dufour et al., 2018). Further, the high proportion of women reporting irritable bowel syndrome (IBS) is unsurprising given the large number of participants living with endometriosis. IBS has been referred to as a diagnosis of exclusion (Begtrup et al., 2013). It has many common signs and symptoms of endometriosis and there are reports that many patients of specialized care providers will receive a diagnosis of IBS prior to a diagnosis of endometriosis (Seckin, 2016).

Participants scored low when compared to normative data on some measures of EF in this study. This was dependent on the set of normative data used as comparison. We attempted to match the characteristics of the normative data as closely as possible to the characteristics of our sample. The oTMT ratio scores from the participants in this study were significantly larger than the cut-off recommended by Lamberty (1994), indicating impairment. On the oTMT-A, scores were also significantly larger than the normal score suggested in previous research that comes from a relatively small sample of 31 people between the ages of 20-39 (Mrazik, Millis, & Drane, 2010). When our study results were compared to 9th percentile cut-offs for EF impairment from the same authors, we did not find any impairment in EF; however, on the oTMT-B, our participants' scores were significantly higher than comparable normative data and significantly better than recommended 9th percentile cut-offs. This suggests that scores on the oTMT did not indicate EF impairment in this sample. oTMT-B provides useful information concerning attention, information processing, and the ability to alternate between two cognitive sets of stimuli (i.e., cognitive flexibility; Mitrushina, Boone & D'Elia, 1999). In this sample, on this assessment measure, participants did not show impairment in cognitive flexibility on this assessment.

Results on the FAS-test paint a different picture of EF impairment in this sample. Participants' scores were significantly worse than comparable normative values presented by Tombaugh, Kozak, and Rees (1999). These normative values were derived from a sample of 242 people between 16-59 years of age with a total education length >13 years. These normative data were comparable to the high education level of our sample, but the age range was much broader. A different set of normative data from Troyer (2000) presents an even broader age range, from 18-91 years old (*M* = 59.8, *SD* = 20.7), with an education level ranging from 5-21 years (*M* = 13.9, *SD* = 2.9). Finally, we compared our data to the normative data presented by Weiss et al. (2006) for 40 women with a mean age of 29.98 (*SD* = 3.59). Weiss et al. (2006) did not report the education level of their participants, but the age is very close to the mean of our sample and the sample was entirely female. Therefore, our sample matches more closely with the Tombaugh et al. (1999) and Weiss et al. (2006) sets of normative data, and we can be confident that our sample performed significantly worse on the FAS-test compared to these sets of normative data. Verbal fluency performance is largely determined by the generation and utilization of effective retrieval strategies (Baddeley & Wilson, 1988; Parker & Crawford, 1992). In our sample it appears as though our participants were unable to generate efficient searches. The participants in this study switched less frequently than reported in published normative data, but produced larger clusters, which lead to a smaller total number of words generated. Bolla et al. (1990) have argued that strategic thinking and good organizational skills play the most crucial role in phonemic fluency performance.

Results on the ESQ-R suggest that our participants have greater impairment in emotion and behaviour regulation, as opposed to planning management, time management, and materials organization, which might be related to the high education level of our sample. Recall that on the ESQ-R, scores between 0-1 should be considered a relative strength or nonproblematic and scores between 2-3 should be considered a relative weakness and problematic. Participants in our sample demonstrated impaired emotional control, response inhibition and goal-directed behaviour. Participants in our sample also did not show any impairments in planning management, time management or materials organization.

Descriptive patterns on the FAS-test and ESQ-R suggest the presence of EF impairments in this sample; however, results of the oTMT do not. This may be a distinction based on the components of EF each of these assessments measure. TMTs primarily assess attention (Gaudino, Geisler & Squires, 1995) and the mental set shifting component of EF (Miyake et al., 2000). On the written TMT-B and oTMT-B, evidence suggests that cognitive set-shifting is an important aspect of performance on part B of this measure regardless of administration modality (Kaemmerer & Riordan, 2016). Moreover, verbal fluency tests are thought to assess both language and EF (Whiteside et al., 2016). Verbal fluency tests assess the information updating and monitoring component of EF (Miyake et al., 2000). Some studies suggest that fluency measures' reliance on language may provide unique information that is not traditionally assessed by other EF tasks (Piatt et al., 1999). In the current study, small to moderate impairments were observed on the FAS-test and the emotion and behavioral regulation components on the ESQ-R.

In previous research examining EF in people living with chronic MSK pain (Berryman et al., 2014; Murata et al., 2017) small to moderate impairments in EF performance were found in people living with chronic pain across response inhibition, complex EF, set shifting and updating; however, all studies had a high risk of bias (Berryman et al., 2014).

The diagnoses of participants included chronic pain, chronic low back pain, fibromyalgia, rheumatoid arthritis, chronic non-malignant pain, osteoarthritis, and temporomandibular disorder. The interpretation of effect estimates was based on Cohen (1998): small (0.20), moderate (0.5) or large (≥0.8). Results from Murata et al.'s (2017) previous cross-sectional research also suggested that chronic MSK pain interferes with processing speed and semantic fluency as measured by a digit symbol substitution task and a category verbal fluency test. Significantly lower scores were observed by authors in the MSK group (n = 44) than the control group (n = 190, $p < 0.05$; Murata et al., 2017). These authors also did not find any impairments on their written TMT, which may indicate that a large sample size is required to identify EF impairments in set shifting ability in people living with chronic MSK pain.

On the CSI, participants' scores indicated a high presence of central sensitization. Note that central sensitization is an indication that the nervous system is in a state of high reactivity that triggers a prolonged increase in the excitability and synaptic efficacy of neurons in central nociceptive pathways (Woolf, 2011; Apkarian, Baliki, & Geha, 2009; Farmer, Baliki, & Apkarian, 2012; Farmer et al., 2011; Moseley & Flor, 2012; Tracey & Bushnell, 2009; Wand et al., 2011). The changes caused by central sensitization on the central nervous system have been observed in neural networks common to both pain and cognitive performance, including those networks in the prefrontal cortex involved in EF (Elliot, 2003; Seminowicz & Davis, 2007; Wiech et al., 2005). This aligns with our results from some of the EF assessments in this study. Participants in this study also scored high on the PCS. Not only were their scores indicative of a clinically relevant severe risk of ongoing disability for most participants in our sample, but their scores were significantly worse than the cut-off score for severe risk of ongoing disability. On the DASS, a quarter of participants scored as severe or extremely severe in each subscale, which is significantly higher than normal levels for depression, anxiety, and stress. Anxiety, for example, has been found to contribute to pain intensity and pain-related disability (Edwards, Auguston & Fillingim, 2003; Meredith, Strong & Feeney, 2006). These results indicate that people living with CPP should be included in research investigating chronic pain and EF. The results of the present study also suggest that, compared to age- and sex-matched normative data, the participants in our sample presented with central sensitization, high pain catastrophizing and high depression, anxiety, and stress scores.

4.5 Strengths, Limitations and Future Research

The purpose of this pilot study was to examine the feasibility of an approach that is intended to be used in a larger scale future study (e.g., recruitment, retention, and assessment procedures). A limitation of this study is that, as a pilot study, the results do not generalize beyond the inclusion and exclusion criteria of this study. A pilot study's sample size should be based on the pragmatics of recruitment and necessities for examining feasibility (Leon et al., 2012); however, due to high levels of participation, *a posteriori* we were able to achieve large enough power to conduct inferential statistics in the form of *t*-tests.

Results of this pilot study cannot be used to determine a larger scale study's sample size because of the inherent imprecision between group effect size estimates from this small sample (Leon et al., 2012). According to Leon et al. (2012), "if a pilot study effect size is unduly large (i.e., a false positive result), subsequent trials will be designed with an inadequate number of participants to provide the statistical power needed to detect clinically meaningful effects and that would lead to negative trials" (p. 4). This is another limitation of conducting a pilot study.

Further, an additional limitation that must be discussed is the possible introduction of selection bias into this study. Selection bias is introduced by the selection of individuals, groups, or data for analysis in such a way that proper randomization is not achieved, thereby ensuring that the sample obtained is not representative of the population intended to be analyzed (Nunan, Bankhead & Aronson, 2017). The recruitment methods used in this pilot study were convenience-based and therefore there is a high risk of selection bias present. Additionally, it is possible that we observed the Hawthorne effect such that a participants' behaviour during the study was altered by their awareness of the study topic and objectives (Roethlisberger & Dickson, 2003). Participants might have been inclined to attempt to alter their own scores to indicate impairments to appease the researcher because they were aware of the objectives of the study from the LOI. Our consecutive convenience sampling method of participant recruitment likely introduced a self-selection bias (i.e., it is not possible to know what attributes are present in those who offer themselves as participants, as compared with those who do not, and it is unclear how these attributes may affect the ability to generalize experimental outcomes; Portney & Watkins, 2009). For example, the volunteers in this study may have been atypical of the target population in terms of characteristics such as age, motivation, activity level, or other correlates of health consciousness (Emery et al., 2005; Hennekens & Buring, 1987).

Further, by using an online social media platform (i.e., Instagram) for participant recruitment, our recruitment advertisement was exposed to audiences interested in pelvic health worldwide. Potential participants responded to recruitment advertisements internationally; therefore, a study of this nature could inform institutions and resources that deliver health care services worldwide.

By excluding any potential participants over the age of 40 we aimed to reduce any influence on the data associated with cognitive change during menopause; however, we excluded many potential participants for which this research would be beneficial. The cognitive changes associated with menopause are believed to be the result of declining estrogen on the brain (Henderson, 2009). It will be an asset in future research to include people over the age of 40, or who are peri- or post-menopausal to be able to better represent the associations of chronic pelvic pain with EF.

Lastly, there are limitations in this pilot study regarding which assessment measures were used to measure EF. In future research, a larger variety of assessments would be able to provide more comprehensive data that may have greater sensitivity to other components of EF. Chan et al. (2008) published a review of instruments used for assessment of EF, that highlights 24 tests and the components of EF they measure (e.g., the Cambridge

Neuropsychological Inventory assesses motor initiation, sequencing, and inhibition [Chen et al., 1995]; the Wisconsin Card Sorting Task assesses switching and perseveration [Heaton et al., 1981; 1993]; the Sustained Attention to Response Task assesses attention [Robertson et al., 1997], the N-back test assesses updating [Callicott et al., 1998], and the Naturalistic Action Test assesses planning [Schwartz et al., 2002]).

A strength of this study is the experience of developing consistent practices to enhance data integrity in future large-scale studies. These practices include refinement of documentation, informed consent procedures, data collection tools, and reporting procedures. These results will allow us to develop monitoring and oversight procedures, which is especially useful for integrating multiple sites and investigators into future research. Impairments in EF have negative implications for physiotherapy rehabilitation due to impairments in balance, mobility and the coordination of other motor functions involved in exercise (Hayes, Donnellan & Stokes, 2011; Donovan et al., 2008).

The findings of this study in a sample of women living with CPP suggest that the current physiotherapy curriculum should think broadly about cognitive impairment and executive dysfunction. Physiotherapy clinicians are encouraged to consider the variety of patient populations, in addition to older adults, that would benefit from EF assessment such as people living with chronic musculoskeletal pain. Current physiotherapy curriculum should include cognitive screening measures in addition to global cognition, which is more commonly used to identify mild cognitive impairment and/or dementia in older adults. These novel findings expand physiotherapy practice in the care of people living with chronic pelvic pain to include psychological assessment of their pain experience. The implications of these findings suggest that care planning, communication and education may need to be adjusted to promote patient engagement in self-management for following physiotherapy recommendations (e.g., providing repetition, written and audio-visual education options).

4.6 Conclusions

This virtual pilot study aimed to examine the feasibility of recruitment, retention, assessment procedures and data collection in a study examining EF in females living with CPP. We also asked: (1) if EF assessment measures (i.e., the oTMT, FAS-test & ESQ-R) suggested the presence of EF impairments in this sample and (2) how self-reported scores on the CSI, PCS, and DASS compared to normative age- and sex-matched data. A total of 35 females participated in virtual interviews that lasted 51.87 minutes on average. Results suggest that a virtual interview study format is feasible for larger scale studies on this topic, that scores on some EF assessment measures are indicative of impaired EF in this sample of females, and that central sensitization, pain catastrophizing, depression, anxiety, and stress are high in this sample.

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Chapter 5

5 General Discussion

The aim of the present program of research was to determine what physiotherapists understood about executive functioning (EF), to contextualize normative data for application by physiotherapists, and to provide an evaluation of the feasibility for studying EF impairments in people living with chronic pain. Many patient populations seen by physiotherapists have impairments in EF (Petkus et al., 2020; Bunk et al., 2019; Caetano et al., 2018; Hollamby, Davelaar, & Cadar, 2017; Montenigro et al., 2017; Berryman et al., 2014; Kearney et al., 2013; Chung et al., 2013; Muir, Gopaul, & Montero-Odasso, 2012; Buracchio et al., 2011; Pérès et al., 2008; Muslimović et al., 2005; Riepe et al., 2003); however, EF is not a focus of current Canadian physiotherapy curricula (CCPUP, 2019). Further, little research exists within the physiotherapy discipline discussing how to assess and screen for EF impairments in patients. In previous research examining EF impairment in people who had experienced a stroke, physiotherapists reported that they believed EF impairments had negative implications for their patients' physiotherapy rehabilitation outcomes (ADLs; Hayes, Donnellan & Stokes, 2015). Observational comparisons between participants' (N = 20) EF scores and age- and/or education-matched normative data demonstrated that poorer performance on measures of EF (i.e., Trail Making Test, Stroop Word-Colour Test, Zoo Map test, Frontal Assessment Battery & Digit Span backward test) were more frequently associated with poorer performance in complex gait tests compared with basic gait tests on the Motor Assessment Scale (Hayes, Donnellan & Stokes, 2015). These researchers concluded that impairments in EF may negatively affect physical performance and that physiotherapists should consider impairments in EF when developing physiotherapy rehabilitation strategies to improve physical function.

To achieve the aim of this program of research, a series of three studies were completed. The first study examined physiotherapists and physiotherapy students' understanding and knowledge of EF assessments in physiotherapy practice. The second study systematically and critically evaluated normative data in a systematic review of three EF assessment measures. Finally, the third study in this dissertation presented the results of a pilot study examining EF in a patient population living with Chronic Pelvic Pain (CPP). The aim was to raise awareness of the importance of EF impairment in physiotherapy clinical practice and to summarize data as a resource for use by physiotherapists in patient care. This dissertation addressed a gap in current research where it was previously unknown what physiotherapists understood about EF as a concept and what normative data were appropriate to apply to patients seen in clinical physiotherapy practice.

The first study, which has been accepted for publication in *Physiotherapy Canada* (see Guitar et al., 2021 in press), was designed to investigate physiotherapists' and physiotherapy students' understanding about EF as a concept and its utility in clinical practice. The second objective was to discover which EF measures are used in physiotherapy practice and why. The final objective was to explore whether a physiotherapist's primary area of practice (i.e., in musculoskeletal, neurological, cardiorespiratory, or multi-systems physiotherapy) influenced EF assessment. An open online survey was distributed by the Canadian Physiotherapy Association (CPA), its various Divisions, and Colleges of Physiotherapy within Canada to registered members. There was a statistically significant moderate positive correlation between subjective and objective EF understanding and knowledge and significant differences between survey responses related to a physiotherapist's primary area of practice. Respondents subjectively reported that they understood what EF was, but this only moderately correlated with their objective understanding. A physiotherapist's primary area of practice also impacted their experience with assessment of EF. Physiotherapists practicing in musculoskeletal (MSK) primary areas of practice reported less knowledge and understanding of EF, and less experience with EF assessment, when compared to physiotherapists who identified practicing in another primary area of practice.

The results of study 1 indicated that physiotherapists understand what EF is, believe it is relevant to their work, treatment plans and patient prognoses, but lack confidence in administering and interpreting EF assessments. Respondents also reported that assessing EF can be valuable for documenting progress, creating treatment plans, and informing prognostic decisions in physiotherapy. The novel contribution of Study 1 is the evidence suggesting Canadian physiotherapists and physiotherapy students believe they have sufficient knowledge about what EF is, which is corroborated by a moderate positive correlation between their subjective and objective EF understanding and knowledge. There does, however, appear to be a gap in which physiotherapists believe that tests of global cognition can measure EF, which may explain why the correlation between subjective and objective EF knowledge was only moderate. In this study, 22% of respondents confused measures of global cognition (e.g., knowledge, language, memory) with EF tests and indicated that they believed that assessments like the Montreal Cognitive Assessment (MOCA) and Mini-Mental State Examination (MMSE) were measures of EF. Although some of these assessments have individual items that assess EF, their summary scores do not provide insight into EF. A person can score quite well on these assessments and still have impairments in EF (Zhao et al., 2014; Mungas, Reed, & Kramer, 2003).

The results of this study have direct implications for informing future physiotherapy curricula. Recall that according to the most recent 'Description of Physiotherapy in Canada' published by the CPA (2012), the scope of physiotherapy assessment in Canada includes, but is not limited to, examination of joint integrity and mobility, gait and balance, muscle performance, motor function, cardiorespiratory function, neuromotor and sensorimotor development, cardiovascular capacity, pain, cognition, and mental status across all body systems (ACCPAP, Alliance, CPA, CCPUP, 2009). The biopsychosocial model, in which physiotherapists practice, allows for the co-existence of the biological, psychological, and social branches of ill-health, and the interplay between these (Engel, 1979; 2012). This person-centered approach to health enables a physiotherapist to step into the world of the individual, embrace the person's lived experience and begin to understand their unique lifeworld (i.e., all that makes up the world of the individual; Dahlberg, Todres, & Galvin, 2009; Jones, Edwards, & Gifford, 2002; Langendoen, 2004;

Solvang & Fougner, 2016). Therefore, Canadian physiotherapy curricula would benefit from the addition of education about EF, including examination of how it differs from global cognition, education on EF assessment measures and interpretation of EF scores, and education about which patient populations to monitor for EF impairment (e.g., older adults, people living with stroke, dementia, or chronic MSK pain). To truly practice in a biopsychosocial model of care, we cannot ignore the influence EF impairment could have on physiotherapy rehabilitation and patient outcomes.

To begin implementing the assessment of EF and aiding the interpretation of scores on these assessments for screening purposes in physiotherapy practice, a gap was identified such that multiple sets of normative data exist for interpreting scores on assessments of EF. The establishment of a prognosis requires the ability to conduct relevant assessments and interpret their findings. To accurately interpret patients' scores, we need to have normative data available for comparison that has been systematically and critically evaluated. It would be valuable for physiotherapists to have the resources and skills to identify patients experiencing impairments in EF, particularly during the demographic shift to an aging population in Canada (Statistics Canada, 2014). There are multiple sets of normative data for older adults available for the three EF assessment measures reported to be used the most by respondents from study 1 (i.e., clock drawing, verbal fluency, and trail-making tests). Since there are many sets of normative data for these assessment measures, a systematic review was needed to serve as a reference tool for interpreting scores on these EF measures.

The second study in this thesis was designed to provide a review of normative data that physiotherapists could apply to their patients in clinical practice. The objective was to produce a comprehensive review, assess the quality of available normative data, and summarize values for application by clinicians. An electronic search of databases retrieved studies presenting normative data for people ≥ 65 years of age for any scoring system on a clock-drawing, verbal fluency, or trail-making test. Methodological quality of 35 studies meeting the inclusion and exclusion criteria that were published between 1978-2020 were scored independently by two raters using an Adapted Study Quality Rating Tool (Murray et al., 2018). The adapted tool appraised study quality in terms of five categories: study design, control for confounding factors, assessment variables, normative data interpretation, and complete reporting of EF variables. Normative data were found for a trail-making test in 19 studies, 34 studies for a fluency test and five studies for a clock drawing test. Across studies, there was considerable variation in the age range, education levels and proportion of males and females assessed, resulting in variation of reported “normal” scores between sets of normative data. This suggested that the accurate interpretation of EF scores in older adults requires matching the set of normative data to the characteristics of each individual patient. In addition, normative data summaries were presented in study 2 for verbal fluency and trail-making tests by age and education. Due to the use of multiple different scoring systems, we were not able to sum available normative data for clock drawing tests. To our knowledge, this was the first systematic review to synthesize normative data for these tests in older adults.

Our assessment of the methodological quality of studies included in the review demonstrated that most studies had low overall quality ratings; therefore, the values presented in study 2 cannot be used with certainty. Most studies in the systematic review presented normative values stratified by age, gender, or education, and it is well established that the accurate interpretation of EF tests is largely dependent on these factors (Heaton et al., 1996; Reitan & Wolfson, 1995; Hamdan & Hamdan, 2009). To maximize descriptive accuracy (Busch & Chapin, 2008), clinicians must determine the similarity between their patient and the characteristics of the individuals in the normative group. Physiotherapists should, at minimum, use the set of normative data that matches their patients age, sex, and education level. In an older adult population, there may be even more potential confounding variables to consider, such as age-related comorbidities. Study 2 presents normative data that will assist physiotherapists to compare their patients scores to established norms and provide an indication of study quality that will moderate the physiotherapist's confidence in the accuracy of the data.

The results of the first study suggested that physiotherapists practicing primarily in MSK physiotherapy had the least knowledge and understanding of EF, and experience assessing EF, when compared to people who identified as practicing in another primary area of physiotherapy practice (Guitar et al., 2021 in press). Despite this finding, MSK physiotherapists are likely exposed to large numbers of patients living with impairments in EF, such as people living with chronic pain (McRae & Hancock, 2017). In fact, people living with chronic pain comprise one of the largest patient populations seen by MSK physiotherapists, and survey research suggests that approximately 89% of patients present to outpatient physiotherapists seeking pain relief (McRae & Hancock, 2017).

In previous metanalyses examining EF in people living with chronic MSK pain (Berryman et al., 2014; Murata et al., 2017), small to moderate impairments in EF performance were found. These findings were consistent across assessment measures that included multiple components of EF, such as response inhibition, complex EF, set shifting and updating, on the Stroop and-Trail Making Tests. However, in this research all studies had a high risk of bias (Berryman et al., 2014). The diagnoses of participants included chronic pain, chronic low back pain, fibromyalgia, rheumatoid arthritis, chronic non-malignant pain, osteoarthritis, and temporomandibular disorder. Previous metanalyses examining EF in people living with chronic MSK pain did not include people living with CPP (Berryman et al., 2014; Murata et al., 2017), which is a condition affecting approximately 26% of females according to the 2021 clinical practice recommendations update on CPP in females from the American College of Obstetricians and Gynecologists (ACOG; Arnold et al., 2021). CPP is a MSK condition that results in alterations of the frontal-parietal control network as seen on Magnetic Resonance Imaging (MRI) and Diffusor Tensor Imaging (DTI). These alterations are suggestive of connectivity changes in EF processing that may accompany pelvic pain (Huang et al., 2020). Therefore, the final study of this thesis focused on the assessment of EF in a sample of females living with CPP. The primary objective of study 3 was to determine the feasibility of recruitment of, and data collection from, females living with CPP. We also aimed to determine if EF assessment measures suggested the presence of EF impairments in this sample and finally, if scores for pain catastrophizing, central sensitization, depression, anxiety, and stress were indicative of impairments in this sample.

In the third study, 35 females were recruited to participate in a cross-sectional pilot study and completed six assessment measures: the Central Sensitization Inventory (CSI; Mayer et al., 2012), the Pain Catastrophizing Scale (PCS; Sullivan, Bishop, & Pivik, 1995), the short version of the Depression, Anxiety and Stress Scale (DASS; Antony et al., 1998), the Oral Trail-Making Test (oTMT; Ricker, Axelrod & Houtler, 1996), a phonemic verbal fluency test (i.e., FAS-test; Benton et al., 1994), and the Executive Skills Questionnaire-Revised (ESQ-R; Strait et al., 2020). A total of 60.34% of potential participants who responded to a recruitment advertisement over the course of 2-months were retained and completed the study. Feasibility results demonstrated that it is feasible to conduct a study of this nature, including administration of certain types of EF assessments, virtually. This is especially important given the current coronavirus disease pandemic and the difficulties with in-person data collection for non-essential research. Participants scored as impaired when compared to normative data on some measures of EF in this study (i.e., the FAS-test and ESQ-R). We attempted to match the characteristics of the normative data as closely as possible to the characteristics of our sample. Participants' scores on the oTMT did not indicate EF impairment in this sample. TMTs primarily assess the mental set shifting component of EF (Miyake et al., 2000). Small to moderate impairments were previously found in updating and set shifting components of EF in other MSK chronic pain conditions (Berryman et al., 2014). Murata et al.'s (2017) previous cross-sectional research with other MSK chronic pain conditions also did not indicate impairments on the written TMT, which may suggest that a large sample size is required to identify EF impairments on the TMT in people living with chronic MSK pain.

In contrast, scores on the ESQ-R and FAS-test painted a different picture in this sample. Participants' total scores on the FAS-test were significantly worse than comparable normal values: even when using multiple data sets for comparison (Tombaugh, Kozak, & Rees, 1999; Weiss et al., 2006). This was also true of the participants' number of switches and mean cluster size on the FAS-test. Our data indicated that participants switched significantly less frequently when compared to published normal values, but produced significantly larger clusters, which lead to a smaller total number of words generated. Similarly on the ESQ-R, participants demonstrated significant impairment on the emotion and behaviour regulation subscales. Overall, small to moderate impairments were observed on the FAS-test and the emotion and behavioral regulation components of the ESQ-R.

Impairments were also observed on other assessment measures in this study. On the CSI, participants' scores indicated the presence of central sensitization. Central sensitization is an indication that the nervous system is in a state of high reactivity that has triggered a prolonged increase in the excitability and synaptic efficacy of neurons in central nociceptive pathways (Woolf, 2011; Apkarian, Baliki, & Geha, 2009; Farmer, Baliki, & Apkarian, 2012; Farmer et al., 2011; Moseley & Flor, 2012; Tracey & Bushnell, 2009; Wand et al., 2011). The changes caused by central sensitization on the central nervous system have been observed in neural networks common to both pain and cognitive performance, including those networks in the prefrontal cortex involved in EF (Elliot, 2003; Seminowicz & Davis, 2007; Wiech et al., 2005). This aligns with our results from the FAS-test and ESQ-R in this study. Participants also scored high on the PCS. Not only were scores indicative of a clinically relevant severe risk of ongoing disability for most participants in our sample, but their scores were significantly worse than the cut-off score for severe risk of ongoing disability. On the DASS, a quarter of the participants scored as severe or extremely severe in each subscale, which is significantly higher than normal levels for depression, anxiety, and stress. Anxiety, for example, has been found to contribute to pain intensity and pain-related disability (Edwards, Auguston & Fillingim, 2003; Meredith, Strong & Feeney, 2006). These results indicate that, compared to age- and sex-matched normative data, the participants in our sample presented with central sensitization, high pain catastrophizing and high depression, anxiety, and stress scores.

The findings of study 3 suggest that a virtual interview study format is feasible for larger scale studies on this topic. Scores on some EF assessment measures were indicative of impaired EF in this sample, and central sensitization, pain catastrophizing, depression, anxiety, and stress were high. Physiotherapists need to be aware of which patient populations are likely to have impairments in EF, so that they can appropriately screen EF. Based on the results of study 3, it is recommended that physiotherapists screen for EF impairments in patients living with chronic MSK pain because previous research shows that physiotherapists believe EF impairment has negative implications for physiotherapy rehabilitation (Hayes, Donnellan & Stokes, 2011; Donovan et al., 2008).

5.1 Implications for Physiotherapy Practice and Future Directions

The focus of future research should be on helping patients minimize impairments in EF by altering the way physiotherapists provide care so that a patient's ability to achieve their goals and improve their functional abilities is maximized (Studer, 2007). When treating a person living with impairments in EF, the focus for the physiotherapist should be on understanding how the impairment is manifested clinically, and how examination and treatment could be adjusted to maximize a patient's ability while minimizing their limitations. Awareness of the possibility and nature of these types of cognitive deficits should signal the therapist to redirect the methods of assessment and treatment (O'Sullivan, Schmitz & Fulk, 2019). Failure to do so may result in denying access to opportunities for rehabilitation to patients with impairments in EF and contribute to the increased risk of care home admission and poor quality of life (Goodwin & Allan, 2018). Having a structure for assessment practices that includes the completion of cognitive assessments prior to physiotherapy interventions would be beneficial as it would alert the physiotherapist of the need for alternate treatment strategies. Moreover, as part of the collaboration domain of the Competency Profile for Physiotherapists in Canada, physiotherapists must be able to identify practice situations that require interprofessional collaboration and recognize where their scope of practice ends and another professional, like a clinical neuropsychologist or occupational therapist, could play a role in the healthcare team. An example of an intervention approach that could be used by various health professionals is Goal Management Training (GMT). GMT is a cognitive rehabilitation program that improves EF, attention and goal attainment through education, awareness and narrative exercises, mindfulness practices, and complex task practices (Stamenova & Levine, 2018). In a systematic review of the effectiveness of GMT for rehabilitating EF in people living with acquired brain injuries, twelve studies demonstrated that GMT was an effective intervention when combined with other rehabilitation interventions such as Problem-Solving Therapy, personal goal setting and daily life training activities (Krasny-Pacini, Chevignard, & Evans, 2014). In people living with major depressive disorder (N = 35), nine sessions of GMT (two hours weekly) resulted in improvements in EF as measured by The Behaviour Rating Inventory of EF – Adult Version (Hagen et al., 2020). Similar findings have been demonstrated in people living with spina bifida (Stubberud et al., 2013) and schizophrenia (Levaux et al., 2012). Recent research also suggests that GMT may improve prospective memory in community-dwelling older adults (Fine et al., 2021).

Future research should consider what interventions can improve, or prevent, EF impairment in older adults and people living with chronic MSK pain. Previous research suggests that impairments in EF can be improved. For example, physical exercise, including but not limited to resistance and aerobic exercises, can improve scores on measures of EF. Nagamatsu et al. (2012) reported that resistance training twice per week for 12 months significantly improved EF in people living with mild cognitive impairments as measured by reaction times on the Stroop test. In their study, community-dwelling women (N =86) 70 - 80 years old were randomly allocated to twice-weekly resistance training exercise (n = 28), twice-weekly aerobic training exercise (n = 30), or twice-weekly balance and tone training (i.e., the control group, n = 28). In the resistance training group, 60-minute classes were led by certified fitness instructors. Participants performed 2 sets of 6 to 8 repetitions of resistance exercise, and loading was increased when sets were completed with proper form. The aerobic program was an outdoor walking program,where participants began walking at 40% of their age-specific target heart rate (i.e., heart rate reserve [HRR]) and progressed to 70% to 80% of their HRR. The BAT program consisted of stretching, range of motion, balance exercises, and relaxation techniques. The resistance training group showed significant improvements in EF, and these results were also documented by changes in frontal brain regions seen on functional MRI (Nagamatsu et al., 2012). These findings align with other research showing that a 12-month long resistance training exercise program improved EF in older sedentary women (Liu-Ambrose et al., 2010). In this study, authors compared the effect of once weekly and twice-weekly resistance training with that of twice-weekly balance and tone exercise training on the performance of EF in older adult women (N = 155) aged 65 – 75. A progressive, high-intensity exercise protocol was used that included free weights and exercise machines. Exercises included, but were not limited to, biceps curls, triceps extensions, seated rowing, latissimus dorsi pull-down exercises, leg presses, hamstring curls, and calf raises. The intensity of the training stimulus was set to a range of 6 to 8 repetitions (2 sets). The training stimulus was subsequently increased when 2 sets of 6 to 8 repetitions were completed with proper form and without discomfort. The authors found that both (i.e., once or twice weekly) resistance training exercise groups showed significant improvements on the Stroop test and trail-making test. Further, in a pilot study of community-dwelling older adult females (N = 24), previous research has also suggested that a 12-week long multicomponent intervention of 30 minutes of pelvic floor muscle training and 20 minutes of videogame step-dancing once per week, in conjunction with 20 minutes of static pelvic floor muscle exercises five days per week, can significantly improve EF (measured by the Stroop, trail-making, and n-back tests;

Fraser et al., 2014). These authors were interested in the relationship between pelvic floor muscle dysfunction, urinary incontinence, and walking. They concluded that a multicomponent intervention could improve EFs and the dual-task gait of older women (Fraser et al., 2014).

Moreover, a meta-analysis of 18 studies concluded that physical exercise improved EF in older adults and was moderated by: the length of the physical exercise intervention, the type of intervention, the duration of the sessions, and the gender of the participants (Kramer & Colombe, 2003). Smith and colleagues (2010) stated, based on another meta-analysis of 29 randomized controlled trials, that aerobic exercise was associated with improvements in EF. Collectively, these positive findings for improved EF were found using a variety of EF outcome measures, such as fluency and trail-making tests. A systematic review of the effects of physical exercise on EF in community-dwelling older adults living with Alzheimer's type dementia (Guitar et al., 2018) also suggested that significant improvements on assessments of EF were observed in this population because of physical exercise. This was measured by clock drawing test, trail-making tests, Stroop tests, and sematic verbal fluency tests with exercise interventions ranging from 18

(Holthoff et al., 2015) to 104 hrs (Öhman et al., 2016) across 12 to 52 weeks, respectively.

The results of this program of research demonstrate that there is a need for change within National Physiotherapy Entry-to-Practice Curriculum Guidelines (2019) from the Canadian Council of Physiotherapy University Programs (CCPUP). The scope of physiotherapy assessment in Canada includes, but is not limited to, cognition and mental status across all body systems (ACCPAP, Alliance, CPA, CCPUP, 2009). In the current curriculum guideline, cognition, including attention, orientation, emotion, processing, memory, communication, language, perception, and decision making, is listed as "foundational entry-to-practice knowledge" (p. 7). It is clear from the survey results of Study 1 that physiotherapists do not possess this foundational knowledge about EF. Further, in the Academic Content Foundational Entry-to-Practice Knowledge section of the curriculum guideline, cognition is also listed as a "basic core knowledge skill" of "human physiology and movement science" for understanding the effects of practice, feedback, and cognition (p. 12). Being able to ask questions about cognition changes is also an essential entry-to-practice requirement for subjective interviewing skills and objective assessment of cognition (e.g., arousal, attention, orientation, perceptions, processing, retention, recall and language; p. 25). In this guideline, the Mini-Mental State Examination (MMSE) is listed as an entry-to-practice outcome measure for physiotherapists. It is the only cognitive outcome measure listed in this guideline and is a measure of global cognition, not EF. Previous research has shown that scores on measures of EF are significant and independent correlates of functional status, and neither a normal baseline global cognition score, nor a stable global cognition score over time preclude functionally significant changes in EF (Royall et a., 2004). Given the significant relationship between functional ability and EF (Marshall et al., 2011), physiotherapists should be aware of EF, the patient populations they treat that might have impairments in EF, and the negative implications of these impairments on physiotherapy. Therefore, the results of this dissertation support change to current physiotherapy entry-to-practice curricula to incorporate knowledge of EF identification, screening, and assessment.

Future studies should also aim to examine the psychometric properties of assessments of EF in people living with chronic pain. Many patients seek physiotherapy because of pain and survey research has suggested that approximately 89% of patients present to outpatient physiotherapists seeking pain relief (McRae & Hancock, 2017). Further, estimates suggest that 10-20% of the globe's population reports living with chronic pain (Sturgeon, 2010). When it comes to chronic pain, we need to gain a better understanding of EF performance and the processes that underpin it to better understand its effect on physiotherapy rehabilitation (Berryman et al., 2014; Solberg Nes, Roach, & Segerstrom, 2009). This information, in turn, may assist physiotherapists in choosing the right type of approach to physiotherapy rehabilitation for a patient living with EF impairments and chronic pain (Eccleston, Morley, & Williams, 2013).

When it comes to impairments in EF and physiotherapy rehabilitation, we must also consider neuroplasticity, the capacity of the central nervous system to change and adapt (Ylvisaker et al., 1987), and the four critical elements that must be present to stimulate neuroplasticity in the context of motor control (Studer, 2007). These are: task specificity, complexity, intensity, and difficulty (Sullivan, 2007). As physiotherapists, we must challenge the patient with the right amount of task difficulty at the correct times. Studer (2007) provided three recommendations for the physiotherapists' role in rehabilitation for patients living with impairments in EF. They suggested that physiotherapists: (1) ask patients to predict their performance before they begin a task to increase their awareness and opportunity to learn; (2) to ask patients to provide post-task feedback about their performance, including what they would do differently next time; and (3) to use systematic cueing (i.e., encourage patients recognize their own errors before providing corrections; Wesolowski & Zencius, 1994) to maximize patients' recognition of error and to improve their ability to independently generate solutions. This structure could be applied to future research analyzing the impact of these recommendations on physiotherapist-patient interactions in a variety of clinical contexts.

5.2 Conclusion

To our knowledge, this is the first doctoral dissertation to focus on physiotherapists' potential need to recognize impairments in EF so that rehabilitation can be adjusted to maximize a patient's ability while minimizing their limitations. Further, this is the first research on this topic outside of stroke rehabilitation (Hayes, Donnellan & Stokes, 2011; Hayes, Donnellan & Stokes, 2013; Hayes, Donnellan & Stokes, 2015). This dissertation aimed to determine what physiotherapists understood about EF, to contextualize normative data for application by physiotherapists, and to provide an evaluation of the feasibility for virtually studying EF impairments in people living with chronic pain. Given the rapidly aging population in Canada and worldwide, and the number of patients seeking physiotherapy assessment and treatment for pain, this is a critical step in addressing this gap in Canadian physiotherapy practice. The first study, an online survey, examined what physiotherapists understood about EF as a concept, what EF assessments they used clinically, and if this was influenced by their primary area of practice (i.e., musculoskeletal, neurological, cardiorespiratory, or multi-systems). Respondents subjectively reported that they understood what EF was, but this only moderately correlated with objective understanding. A physiotherapist's primary area of practice also impacted their knowledge of EF and their experience assessing EF. The second study presented the results of a systematic review of normative data for three assessments of EF in older adults (i.e., clock-drawing, verbal fluency, and trail-making tests). Methodological quality of 35 studies meeting the inclusion criteria were assessed. Normative data were found for a trail-making test in 19 studies, 34 studies for a fluency test, and five studies for a clock drawing test. Data were summarized by age, education, and gender. Finally, the third study described the feasibility of virtual recruitment and data collection in females living with CPP, a MSK chronic pain condition not examined in previous research. Results from 35 females suggested that study format used is feasible for larger scale studies on this topic and could be used in research aiming to identify impairment on EF assessments. Scores in this sample were indicative of impaired EF, and high central sensitization, pain catastrophizing, depression, anxiety, and stress. Helping patients overcome impairments in EF could maximize a patient's ability to achieve their physiotherapy goals and improve functional abilities.

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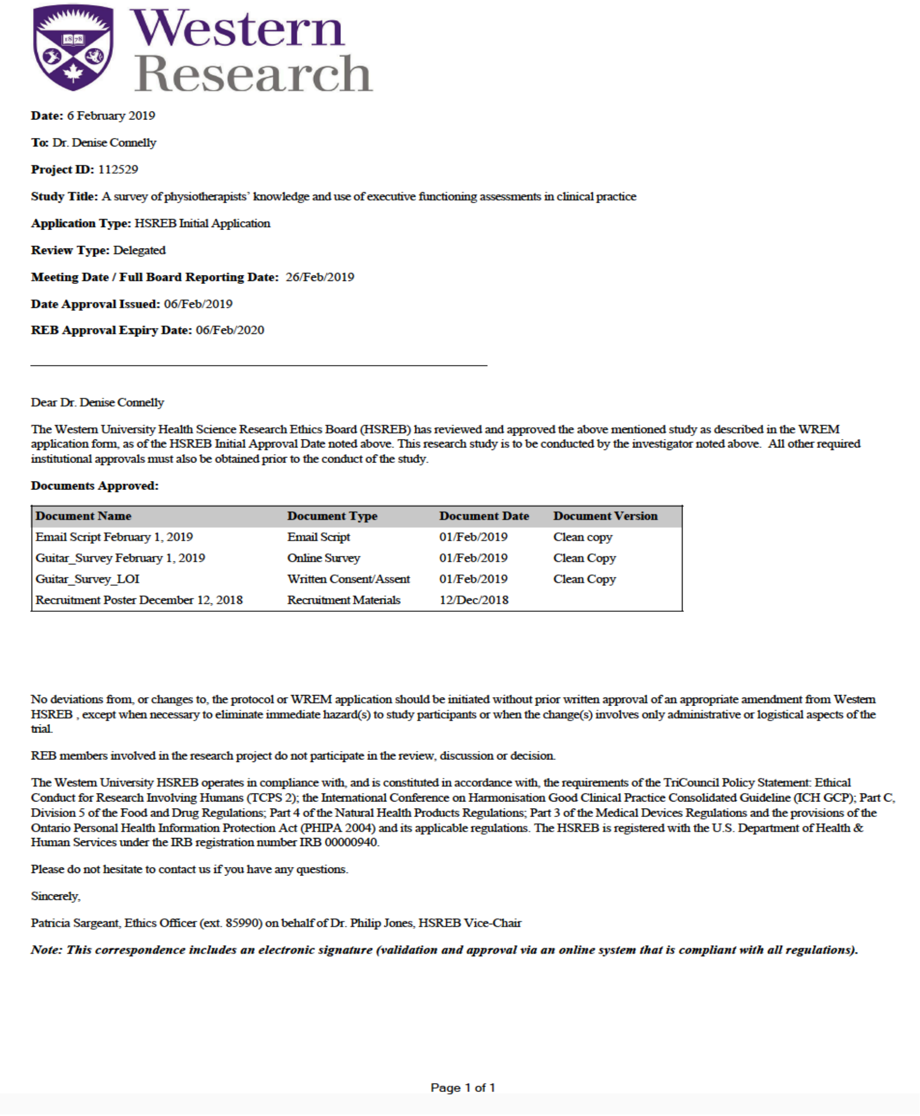
Appendices

Appendix A: Ethics Approval for Study 1



Western Research

Date: 6 February 2019

To: Dr. Denise Connelly

Project ID: 112529

Study Title: A survey of physiotherapists' knowledge and use of executive functioning assessments in clinical practice

Application Type: HSREB Initial Application

Review Type: Delegated

Meeting Date / Full Board Reporting Date: 26/Feb/2019

Date Approval Issued: 06/Feb/2019

REB Approval Expiry Date: 06/Feb/2020

Dear Dr. Denise Connelly

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
Email Script February 1, 2019	Email Script	01/Feb/2019	Clean copy
Guitar_Survey February 1, 2019	Online Survey	01/Feb/2019	Clean Copy
Guitar_Survey_LOI	Written Consent/Assent	01/Feb/2019	Clean Copy
Recruitment Poster December 12, 2018	Recruitment Materials	12/Dec/2018	

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Patricia Sargeant, Ethics Officer (ext. 85990) on behalf of Dr. Philip Jones, HSREB Vice-Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix B: Survey Content

Block 1: Letter of Information and Survey Instruction

1. I have read the above Letter of Information (Yes; No)

Block 2: Consent

2. I consent to participate in this study (Yes; No)

Block 3: Designation

3. Are you a licensed physiotherapist or a student currently studying physiotherapy in Canada? (Physiotherapist; Student; I am neither)
   Selection here dictates if the participant receives section 8a or 8b

Block 4: Understanding & Knowledge

4. Have you ever received specific training/ education related to executive functioning or working with people living with impairments in executive functions? (Yes; No)
5. I understand what the term "executive functioning" means (Strongly agree; Agree; Somewhat agree; Neither agree nor disagree; Somewhat disagree; Disagree; Strongly disagree)
6. I am confident that I could assess a person's executive functioning (Strongly agree; Agree; Somewhat agree; Neither agree nor disagree; Somewhat disagree; Disagree; Strongly disagree)
7. I assess executive functioning in patients when indicators to do so are present (Strongly agree; Agree; Somewhat agree; Neither agree nor disagree; Somewhat disagree; Disagree; Strongly disagree)
8. If Strongly agree; Agree; or Somewhat agree were selected in Q7, please list the executive functioning assessments you use when indicators to do so are present (List up to three assessments, in order of frequency of use)
   Questions 9-17 ask if the participant agrees or disagrees that the following cognitive skills/components are involved in executive functioning.
9. Cognitive shifting: the mental process of consciously redirecting one's attention from one fixation to another (Agree; Unsure; Disagree)

10. Problem-solving: the process of finding solutions to problems (Agree; Unsure; Disagree)
11. Language: human communication consisting of the use of words in a structured way (either written or spoken) (Agree; Unsure; Disagree)
12. Mental Switching: tasks that involve conflict and demand switching between subtasks or categories (Agree; Unsure; Disagree)
13. Reference Memory: memory concerned with the stable features of an experience (Agree; Unsure; Disagree)
14. Inhibition: conscious or unconscious constraint of a process or behavior (such as impulses or desires) (Agree; Unsure; Disagree)
15. Planning: the process of thinking about the activities required to achieve a desired goal (Agree; Unsure; Disagree)
16. Knowledge: facts, information, and skills acquired by a person through experience or education (Agree; Unsure; Disagree)
17. Working Memory: memory concerned with immediate conscious perceptual and linguistic processing (Agree; Unsure; Disagree)

Block 5: Assessment Practices

18. Do you have experience assessing Executive Functioning (Definitely yes; Probably yes; Might or might not; Probably not; Definitely Not)
19. Do you have experience assessing Global Cognition (Definitely yes; Probably yes; Might or might not; Probably not; Definitely Not)
20. Are you a member of a health care team? (Yes; No)
    If yes go to Q21
21. Is another member of your health care team typically responsible for administering cognitive assessments (including assessments of executive functioning)? (Yes; No)
    If yes go to Q22
22. Who is typically responsible for administering cognitive assessments (including assessments of executive functioning)? (Select all that apply: Speech-Language Pathologist; Psychologist; Nurse; Occupational Therapist; Medical Doctor; Social Worker; Other Health Care Professional (please specify); My health care team does not administer cognitive assessments)

Block 6: Beliefs about Executive Functioning

23. I believe that problems with a patient's executive functioning are not relevant to my work as a physiotherapist (e.g., how I deliver treatment and/or prognosticate) (True; False)
24. I expect that problems with a patient's executive functioning would have an impact on functional recovery during rehabilitation (True; False)
25. My expectation for a positive rehabilitation outcome for a patient with problems with executive functioning are less than they are for patients without (True; False) *If True for Q23, go to Q26*
26. Please select the reasons why you believe that problems with a person's executive functioning are not relevant to your work as a physiotherapist (lack of time available for administering these assessments; lack of access to assessments; lack of training on how to administer these assessments; lack of utility of the results of these assessments; other (please specify))
27. I believe that assessing executive functioning can be valuable to physiotherapists for documenting progress during rehabilitation (Strongly agree; Agree; Somewhat agree; Neither agree nor disagree; Somewhat disagree; Disagree; Strongly disagree)
28. I believe that assessing executive function can be valuable to physiotherapists while creating treatment plans (Strongly agree; Agree; Somewhat agree; Neither agree nor disagree; Somewhat disagree; Disagree; Strongly disagree)
29. I believe that assessing executive function can be valuable to physiotherapists when making prognostic decisions (Strongly agree; Agree; Somewhat agree; Neither agree nor disagree; Somewhat disagree; Disagree; Strongly disagree)

Block 7: Assessment Experience

30. Which of the following assessments/ types of assessments have you ever administered? (Cambridge Neuropsychological Inventory [CAMCOG]; Trail Making Test [TMT]; Clock Drawing Tests [CDT]; Stroop Test, Wisconsin Card Sorting Task [WCST]; Fluency Tests [e.g., Verbal and/or Categorical]; Hayling Sentence Completion Test; Tower Test [e.g., of London and/or of Hanoi]; Sustained Attention to Response Task; N-back Test; Letter-Number Span Test; Six Elements Test; Hotel Test; Gambling Task; Assessment of Motor and Process Skills; Naturalistic Action Test; Cognitive Failures Questionnaire; Dysexecutive

Questionnaire; Frontal Systems Behavior Scale; Other (please specify); None of the above)

For each assessment indicated above go to Q31

31. Please describe the circumstances under which you administered the test(s) (Reason for administration: please specify; Patient Population: please specify; Method of administration: please specify)
32. Where have you ever heard about executive functioning? (Course work during your schooling; Webinar; Presentation; Journal article; Heath care team members; Clinical placement; I have not learned about executive function)

Block 8a: Demographics presented to Physiotherapy Students only

33. How many months of physiotherapy training have you completed? (Enter number)
34. At this stage in your physiotherapy education, how many weeks of clinical placement have you experienced? (Enter number)
35. In which clinical practice setting(s) have you had a clinical placement? (Acute inpatient; Inpatient rehabilitation; Outpatient (e.g., hospital or school-based); Outpatient community (e.g., family heath team); Home care/ Long-term care; I have not had a clinical placement)

    If "I have not had a clinical placement" is not selected proceed to Q36-39
36. Which patient population(s) have you worked with during a clinical placement experience? (Pediatric [birth-18 years of age]; Adults [19-64 years of age]; Older Adult [65-84 years of age]; Oldest Old [85+ years of age])
37. In which clinical practice setting was your current/ most recent clinical placement? (Acute inpatient; Inpatient rehabilitation; Outpatient (e.g., hospital or school-based); Outpatient community (e.g., family heath team); Home care/ Long-term care)
38. In your clinical placement experience which patient population(s) have you currently/ most recently worked with? (Pediatric [birth-18 years of age]; Adults [19-64 years of age]; Older Adult [65-84 years of age]; Oldest Old [85+ years of age])
39. In your current/ most recent clinical placement experience have you worked with people living with any of the following conditions/ diseases? (Stroke; Dementia [e.g., Alzheimer's disease]; Traumatic Brain Injury [e.g., concussion];

Huntington’s Disease; Parkinson’s Disease; Epilepsy; Multiple Sclerosis; Attention Deficit Disorder; Cerebral Palsy; I have not worked with people living with any of the above conditions/ diseases)

40. What is your gender identity? (Male; Female; Other)
41. What is your current age in year? (Enter age)

Block 8b: Demographics presented to Physiotherapists only

42. Select your highest clinical degree in physiotherapy (Bachelor’s; Master’s; Doctoral; Other [please specify])
43. How many years have you practiced physiotherapy? Please include all years of practice since graduation [full or part-time] (Enter number of years)
44. What would you describe yourself as? (Clinician [e.g., practicing physiotherapist]; Academic [e.g. teaching and research]; Clinician & Academic [e.g., teaching and/or research and practicing physiotherapist])
45. In which clinical practice settings have you worked as a registered physiotherapist? (Acute inpatient; Inpatient rehabilitation; Outpatient (e.g., hospital or school-based); Outpatient community (e.g., family heath team); Home care/ Long-term care)
46. In which areas of care have you worked as a registered physiotherapist? (Musculoskeletal; Neurological; Cardiorespiratory; Multi-Systems)
47. Indicate which groups have ever been on your caseload (Stroke; Dementia [e.g., Alzheimer’s disease]; Traumatic Brain Injury [e.g., concussion]; Huntington’s Disease; Parkinson’s Disease; Epilepsy; Multiple Sclerosis; Attention Deficit Disorder; Cerebral Palsy; I have not worked with people living with any of the above conditions/ diseases in my caseload)
48. In which clinical practice setting(s) do you currently work? (Acute inpatient; Inpatient rehabilitation; Outpatient (e.g., hospital or school-based); Outpatient community (e.g., family heath team); Home care/ Long-term care)
49. What is currently your primary area of physiotherapy practice? (Musculoskeletal; Neurological; Cardiorespiratory; Multi-Systems)
50. Do you currently have people in your caseload living with any of the following conditions/diseases? (Stroke; Dementia [e.g., Alzheimer’s disease]; Traumatic Brain Injury [e.g., concussion]; Huntington’s Disease; Parkinson’s Disease; Epilepsy; Multiple Sclerosis; Attention Deficit Disorder; Cerebral Palsy; I have

not worked with people living with any of the above conditions/ diseases in my caseload)

51. What is your gender identity? (Male; Female; Other)
52. What is your current age in years? (Enter age)

Appendix C: Study 1 Letter of Information

A survey of physiotherapists' knowledge and use of executive functioning assessments in clinical practice

Principal Investigator:
Denise M. Connelly, PT, PhD
Associate Professor School of Physical Therapy

Co-Investigator:
Nicole A. Guitar, PhD Candidate

Introduction

The literature tells us that executive functioning is impaired in many patient populations that would benefit from physiotherapy treatment. Approximately 75% of people living with acquired brain injury, including stroke (Riepe et al., 2003; Chung et al., 2013), and a third of people living with early Parkinson's disease experience deficits in executive functioning (Muslimović et al., 2005). In college football players, concussive and sub-concussive impacts predict later-life executive dysfunction (Montenigro et al., 2017).

Moreover, scores on measures of executive functioning are significant and independent correlates of functional status, and neither a normal baseline global cognition score, or a stable global cognition score over time preclude functionally significant changes in executive functioning (Royall et a., 2004). Impairments in executive functioning are key contributors to impairments in Instrumental Activities of Daily Living (IADLs) (Marshall et al., 2011), reflective of functional status and often used in physiotherapy assessments (Graf, 2008). In fact, in people living with dementia, deficits in executive functioning can be detected up to a decade before a clinical diagnosis of the disease (Pérès et al., 2008) and are highly related to IADLs in older adults. The results of this survey have the potential to improve Canadian physiotherapy practice by contributing to knowledge that informs maintaining independence and functional ability in older adults while aging in place.

Executive dysfunction is prevalent in many patient populations treated by physiotherapists. However, current knowledge and understanding of assessments of executive functioning is unknown among physiotherapists and physiotherapy students.

Background/ Purpose

This online survey will ask questions to understand your current knowledge of executive functioning, as well as their utility in clinical practice. The primary objective of this survey is to understand the current state of physiotherapy students', and licensed physiotherapists', knowledge of executive functioning and understanding of the utility of assessments of executive functioning in clinical practice. This is important because assessments of executive functioning are predictors for functional deterioration in older adults (Pérès et al., 2008), are highly related to functional abilities (Marshall et al., 2011), and therefore could be used as indicators of how patients will respond to physiotherapy treatment.

Study Design

You are receiving this survey as a member of the Canadian Physiotherapy Association who has agreed to receive third-party communication. The survey is comprised of questions formatted as Likert scales, yes/no, true/false, multiple choice, slider, matrix table and open-ended response questions about your understanding of executive functioning. You will be asked about your education and/or work experience (e.g. caseload or practice setting).

Completing the survey is estimated to take 10-15 minutes during a single sitting using a computer or mobile phone with an internet connection. All questions should be completed independently without working with other people. Navigating backward in the survey is not possible and the survey will be automatically submitted upon completion. You will know that the survey has been submitted when a confirmation screen appears.

There are ~15,000 members of the Canadian Physiotherapy Association and National Student Assembly. We hope to achieve a response rate of at least 10%, or 150 responses.

Voluntary Participation

Your participation in this survey is completely voluntary. You are eligible to participate in this survey if you are currently licensed as a Canadian physiotherapist (physical therapist) or a student training in an accredited physiotherapy (physical therapy) program in Canada.

Confidentiality

Responses to this survey are anonymous. Results will be presented as grouped data. Only the Principal Investigator and the Graduate Student will have access to this information. Data from the survey will be exported from Qualtrics into Excel as .csv files, stored on a USB key in a locked cabinet in the Principal Investigators office, and destroyed after seven years. The Western University Health Sciences Research Ethics Board may require access to the study data to monitor the conduct of the study.

Withdrawal from Study

You have the right to exit from this survey at any time without explanation by closing your internet browser prior to completing all questions. Because this is an anonymous online survey

without personal identifying data, once the survey is submitted it cannot be withdrawn.

Risks

There are no known risks to participating in this survey.

Benefits

To you: As a physiotherapist or physiotherapy student, you may contribute to understanding of gaps in physiotherapy practice.

To society: This research has the potential to improve Canadian physiotherapy practice by contributing to knowledge that informs maintaining independence and functional ability while aging in place.

Participants may also not experience any benefit from participating in this study

Costs

There is no cost associated with your participation in this survey.

Compensation

There is no compensation associated with your participation in this survey.

Questions about the Study

If you have any questions regarding participating in this survey please contact Nicole Guitar at ________ or Dr. Connelly at ___________.

Contact for Concerns about the Rights of Research Participants:

If you have any questions about your rights as a research participant or the conduct of this survey, you may contact The Office of Research Ethics (519) 661-3036,
email: ethics@uwo.ca.

Appendix D: Study 2 Summary of Study Details for Papers Included in the Systematic Review

Study	**Study Subjects, Recruitment & Setting**	**Sample Characteristics (μ & SD)**	**Study Design**	**Inclusion Criteria**	**Exclusion Criteria***	**Executive Function Outcome(s)**	**Stratification of Normative Data**	**Overall Study Quality**
Acevedo et al. (2000) The United States of America	CD people at the Wien Center for Alzheimer's disease & Memory Disorders in Florida	N = 316 Age μ = 69.1±6.9; % female = 74.0; Years of Education μ = 14.4±2.5	Cross-sectional	≥50 years of age; English born speakers born in the United States of America/ Spanish born speakers born in a country where Spanish is the primary language	MMSE total score ≤26 & a score of <10 on the four delayed recall trials of the three words used on the MMSE	Category Fluency (animals, vegetables & fruits)	Age, education & gender	Low
Amodio et al. (2002) Italy	CD people selected randomly from electoral registers & a convenience sample from rural towns	N = 300; Age μ = NR, min-max: 20-80; % female = 52% in random sample, 51% in convenience sample;	Cross-sectional	20-80 years of age; "fair knowledge of the numerical and Italian alphabet sequence" (p. 118)	Subjects unavailable by phone after 5 attempts; refusal to participate; less than 5 years of education; alcohol consumption	TMT A&B	Age & education	Low

		University Education = 22.9% of random sample, 8.6% in convenience sample			>70g/day for males & >40g/day for females; severe hypertension (lasting >5 years & requiring ≥2 drugs); hx of CAD or cerebrovascular disease; insulin-treated diabetes; severe renal, liver or pulmonary drugs; hx of any cerebral disease			
Ashendorf et al. (2008) The United States of America	CD people at Boston University Alzheimer's disease Core Center (BU-ADCC)	N = 526; Age μ = 72.4±8.5; % female = 66.9; Years of Education μ = 16.1±2.8	Cross-sectional	CD; English speaking; adequate hearing & visual acuity; study partner available to provide collateral information about functioning;	Hx of major psychiatric illness; significant central nervous system disorder	TMT A&B	Age & education	Low

				cognitive test performance within normal range >1.5; CDR score = 0				
Cauthen (1978) Canada	CD volunteers & people ≥60 years of age living in institutional settings	N = 64; Age μ = mean NR; % female = 56.2; Years of Education μ = NR	Cross-sectional	NR	NR	Letter fluency (various letters: S, G, U, N, F, T, J & P)	IQ & age	Low
Clark et al. (2004) Australia	CD people from the Melbourne Women's Midlife Health Project (MWMHP) longitudinal study of the menopause transition	N = 257; Age μ = 60±NR, min-max = 56-67; % female = 100; Years of Education μ = 11.5±2.2	Cross-sectional	Centre for Epidemiological Studies Depression Scale score = 0	Neurological & major medical conditions; inability to travel to location	TMT A&B	Age & education	Low

Crowe et al. (2010) The United States of America	CD older adults from the University of Birmingham Study of Aging	N = 375; Age μ = 72.8±5.3, min-max:65-89; % female = 57.6; Years of Education years = ≥13: 38.9%, 12: 31.2%, 7-11: 23.7%, 0-6: 6.1%	Cross-sectional	CD older adults able to schedule their own appointments	≤23 on the MMSE	CDT: CLOX 1 & 2	Reading ability & age	Moderate
Devora et al. (2020) The United States of America	CD adults from the National Alzheimer's Coordinating Centre (NACC)	N = 1803; Age μ = NR, <60: 15.3%, 60-69: 38.3%, 70-79: 36.2%, ≥80: 10.3%; % female = 65; Years of Education μ = NR; <12: 9.6%, 13-15: 18.1%, 16 = 26.8%, ≥17:	Retrospective cross-sectional	English speaking; cognitively normal; CDR = 0	NR	TMT A&B; Category fluency (animals & vegetables); & Letter fluency (F & L)	Not	Low

		44.5, missing: 1%						
Drane et al. (2002) The United States of America	CD people via a variety of civic organizations, setting NR	N = 285; Age μ = 48±19.68; % female: 28.0%; Years of Education μ = 12.98±2.65	Cross-sectional	Independently living	Hx of substance abuse; psychiatric disorder; neurologic disorder; currently on psychotropic medication	TMT A&B, B-A, B:A	Age	Low
Elkadi et al. (2006) Australia	Women from the Melbourne Women's Midlife Longitudinal Health Project	N = 257; Age μ = 60±NR, min-max:56-67; % female = 100; Years of Education μ = NR, ≥12: 45%, <12: 52%	Cross-sectional	Menstruated within the last 3 months; have a uterus & at least 1 ovary; not taking menopausal hormone therapy or hormonal contraceptive medications; agreed to participate in a longitudinal study; willingness to	Neurological diagnoses; major medical illness	Category fluency (animals)	Age & education	Moderate

				provide a blood sample				
Gladsjo et al. (1999) The United States of America	Adult volunteers at the University of California Geriatric Psychiatry Clinical Research Center, Alzheimer's disease Research Centre, HIV Neurobehavioral Research Centre	N = 768; Age μ = 50.4±19.4; % female = 48; Years of Education μ = 13.6±3.1	Cross-sectional	English as the persons primary language	Conditions associated with cognitive deficits; past psychiatric disorders on axis 1 of DSM-3R; significant head trauma (i.e., loss of consciousness for > 20 minutes or persisting neurological sequalae; neurological illness or conditions expected to affect test performance; any psychotic disorder or other psychiatric	Category fluency (animal); Letter fluency (FAS-test)	Age & education	Low

					illness; current substance dependence or abuse (in last 6 months)			
Hankee et al. (2013) The United States of America	CD adults in the Framingham Heart Study	N = 1907; Age μ = NR, <55: 7.1%, 55-64: 35%, 65-74: 34%, ≥75: 23.9%; % female: 54% Years of Education μ = NR, <HS diploma: 3.4%, HS diploma: 56.6%, College degree: 21.2%, Graduate degree(s): 18.9%	Cross-sectional	NR	Prevalent clinical stroke; dementia; neurological diseases (e.g., head trauma)	TMT B; Letter fluency (FAS-test); Category fluency (animals)	Age & education	Low

Holtzer et al. (2008) The United States of America	CD people from the Einstein Aging Study	N = 2005, $n_{conventional}$ = 1251, n_{robust} = 3-7, $n_{incidence}$ = 58, $n_{prevalence}$ = 75, lost to follow up = 314; Age μ conventional = 78.8±5.16, robust 77.2±4.47, incidence 81.4±4.8, prevalence 82.6±5.49, lost to follow-up 78.4±5.14; % female: conventional 59.9%, robust 6.8%, incidence 67.2%, prevalence	Cross-sectional	Age ≥70; English speaking; born in the Bronx in New York City, New York	Institutionalization; Sensory deficits (visual & hearing loss) of “sufficient” severity to interfere with neuropsychological testing	TMT A&B, errors; Letter fluency (FAS-test); Category fluency (animals, fruits & vegetables)	Age & education	Low

		64%, lost to follow-up 63.7%; Years of Education μ = conventional 12.7±3.90, robust 13.5±3.46, incidence 12.5±3.79, prevalence 10.6±4.30, lost to follow-up 11.90±3.58						
Ivnik et al. (1996) The United States of America	CD people who participated in the Mayo's Older African Americans Normative Studies (MOAANS)	N = 746; Age μ = NR, min-max:56-95+; % female = 61.5 for COWAT, 53.4% for TMT; Years of Education μ =	Cross-sectional	Independently functioning; CD; had a recent exam by their physician & have no active neurologic o psychiatric disorders with the potential to effect cognition	Prior exposure to any of the tests used in the study	TMT A&B; Letter fluency (COWAT)	Age, education, sex, race & handedness	Low

		NR, min-max:≤7 – ≥18						
Kim et al. (2019) Korea	Adults, setting NR	N = 180; Age μ = 49.37±17.42, min-max:20-79; % female = 50.6; Years of Education μ = NR	Cross-sectional	Age between 20-79	Cognitive impairment; problems in daily life; physical health issues	TMT A:B	Age	Low
Baker et al. (2001) The United States of America	Older adults from retirement communities & seniors centers	N = 280; Age μ = 70.5±NR, min-max:0-87; % female = 55.3; Years of Education μ = NR	Cross-sectional	Speaker of English; Score ≥25 on the MMSE	Having ever been enrolled in a special education class; positive hx of communication disorder; neurological impairment (e.g., head injury)	Category fluency (animals & food); Letter fluency (T & P)	Age & education	Low
Moggi et al. (2020)	People with Alcohol Use Disorder in a	N = 494; Age μ = 45.5±11.59,	Cross-sectional	Primary diagnosis of Alcohol Use Disorder;	Continued withdrawal	TMT A&B	Age & education	High

Switzerland	residential treatment program	min-max:18-75; % female = 32; Years of Education μ = 13.07±2.9		detoxified & abstinent for ≥ 3-weeks	symptoms at the time of testing			
Lucas et al. (1998) The United States of America	CD people who participated in the Mayo's Older African Americans Normative Studies (MOAANS) in Jacksonville, Florida & Rochester, Minnesota, setting NR	N = 412; Age μ = 79.9±8.3, min-max:56-95+; % female = 64.3; Years of Education μ = 13.7±3.0	Cross-sectional	Independently functioning; CD Caucasian; >55 years of age	Active medical, neurologic, or psychiatric disorder with the potential to affect cognition	Category fluency (fruits & vegetables)	Age	Low
Lucas et al. (2005a) The United	CD people who participated in the Mayo's Older African	N = 309 (from MOAANS sample: N = 412)	Cross-sectional	Independently functioning; CD; self-identified African American; >55 years of age	Active medical, neurologic, or psychiatric disorder with the	TMT A&B; Letter fluency (COWAT); Category fluency	Age, education, sex & handedness	Low

States of America	Americans Normative Studies (MOAANS)	Age μ = 79.9±8.3, min-max:56-94; % female = 64.3; Years of Education μ = 13.7±3.0			potential to affect cognition	(animals, fruits & vegetables combined, & animals alone)		
Marcopulos et al. (1997) The United States of America	CD people in rural central Virginia counties recruited from senior centers, community centers, homes for adults, and retirement communities	N = 133; Age μ = 76.48±7.87; % female = 76.9; Years of Education μ = 6.65±2.14	Cross-sectional	Non-demented; rural CD; ≥55 years of age; ≤10 years of formal education	The presence of chronic or severe psychiatric disorder; extensive psychotropic drug use; long-term substance abuse hx; hx of electroconvulsive therapy; hx of neurological disease; hx of head injury with loss of consciousness	CDT (Goodglass & Kaplan, 1983); Category fluency (names, foods, vegetables)	Age & education	Low

O’Bryant et al. (2018) The United States of America	CD older adults from TMAANS, Project FRONTIER, TARCC, & HABLE	N = 653; Age µ = 67.46±8.93; % female = 73.4; Years of Education µ = 9.9±4.6	Cross-sectional	Mexican Americans; CDR score = 0; consensus review assignment of normal cognition	People with prevalent stroke; dementia or other neurological disease (e.g., multiple sclerosis; severe head trauma)	TMT A&B; CDT (CLOX 1 & 2); Category fluency (animals); Letter fluency (FAS-test)	Education & age	Low
Piatt et al. (2004) The United States of America	CD older adult caregivers who were enrolled in studies at a major medical school	N = 145; Age µ = 72.93±7.02; % female = 63; Years of Education µ = 14.96±2.31	Cross-sectional	Caregivers of people living with Alzheimer’s disease or Parkinson’s disease who were enrolled in studies at a major medical school; or independently residing in retirement communities	NR	Action fluency	Education & age	Low
Picciotto &	CD in retirement villages	N = 30;	Cross-sectional	Living independently in retirement	Hx of diabetes, stroke, other	Category fluency (animals)	Language	Low

Friedland (2001) South Africa		Age μ = 77±NR, min-max:60-95; % female = NR; Years of Education μ = 12±NR, min-max:11-15	Duration NR	villages; ≥10 years of education	neurological conditions			
Quaranta et al. (2016) Italy	CD relatives of patients at the Neuropsychology Unity of the Policlinico Gemelli in Rome	N = 268; Age μ = 68.03±11.50, min-max:40-92; % female = 48.9; Years of Education μ = NR, <5: 30, 5-7: 86, 8-12: 84, ≥13: 68	Cross-sectional	CD; living independently	Educational level <3 years of schooling; any current or prior neurological disease affecting CNS (e.g., brain injury or stroke); current or past hx of alcohol or drug abuse; current depression or major psychiatric diseases;	Category fluency (BAF-test)	Age & education	Low

					familiarity for dementia; chronic medical conditions potentially affecting CNS (e.g., hypothyroidism, renal or hepatic failure)			
Ruff et al. (1996) The United States of America	CD adults, setting NR	N = 360; Age μ = NR, min-max: 16-70; retested sample (n_1 = 120) 40.5, not retested sample (n_2 = 240) 40.4; Years of Education μ = NR, min-max: 7-22, retested sample: 14.0, not retested sample: 14.2	Cohort prospective observational	English speaking; healthy normal	Positive hx of psychiatric hospitalization; chronic poly-drug use or neurological disorders	Letter fluency test (COWAT: CFL & PRW)	Age & education	Low

Selander et al. (2020) Sweden	CD volunteers from Swedish driving license registers, advertisements & local seniors organizations, setting NR	N = 410; Age μ = 52±16.8, min-max:20-80; % female = 63.6; Years of Education μ = NR	Cross-sectional	≥18 years of age; in possession of a drivers license	Medical conditions affecting cognition function (e.g., stroke or head injury) determined by the participants' statement & confirmed at the time of assessment	TMT A&B	Age	Low
Steinburg et al., (2005) The United States of America	Health normal volunteers community-based study at Mayo Clinic in Olmsted County	N = 1131, n_{TMT} = 354, n_{COWAT} = 777; Age μ n_{TMT} = NR, min-max:56-94, n_{COWAT} μ = NR, min-max:56-95+; % female = n_{TMT}: 53.4, n_{COWAT}: 61.9;	Cross-sectional	Functionally independent; CD seniors	NR	TMT A&B; Letter fluency test (COWAT)	Age	High

		Years of Education μ = n_{TMT} & n_{COWAT} = NR, min-max:<7 - >18+						
Stewart et al. (2001) United Kingdom	CD, registration lists of seven primary care practices in South London, setting NR	N = 285; Age μ = NR, min-max:55-75; % female = 56.8; Years of Education μ = NR, “high”: 35, “normal”: 146, “low”: 95	Cross-sectional	Between the age of 55-75 years; born (or 1 parent born in) a Caribbean nation; living in community accommodation	Difficulty hearing that interfered with test performance; visual difficulty in testing on the BNT, CDT, TMT	CDT (Goodglass & Kaplan, 1983); TMT A&B; Category fluency (animals)	Age, education & sex	Low
Tombaugh et al. (1999) Canada	CD people recruited through booths at shopping centers, social organizations, places of employment,	N = 1300; Age μ = 60.7±19.9, min-max:16-95; % female = 57; Years of Education μ = 12.1±3.2	Cohort study retrospective	Independently living; score > 23 on the MMSE & a score < 12 on the GDS	Any person with a known history of neurological disease, psychiatric illness, head injury, or stroke was excluded	Letter fluency (FAS-test); Category fluency (animals)	Age & education	Low

	psychology classes, & by word-of-mouth							
Tombaugh et al. (2004) Canada	CD volunteers, recruited through booths at shopping centers, social groups, places of employment, psychology classes, and by word-of-mouth	N = 911 Age μ = 58.5±21.7; min-max:18-89 % female = 55.2; Years of Education μ = 12.6±2.6, min-max:5-15	Cohort study retrospective	Received a consensus diagnosis of “no cognitive impairment” on two successive evaluations separated by approximately 5 years	Hx of neurological disease, psychiatric illness, head injury or stroke	Trails A&B	Age & education	Low
Troyer et al. (2000) Canada	CD health adults recruited from university-based subject	N = 411; Age μ = 59.8±20.7, min-max:18-91; % female = 70.0;	Cross-sectional	Aged 60 years and older; score >25 on the MMSE, or a score within normal range on an episodic memory	Hx of neurological disease or psychiatric illness that could affect cognitive function	Letter fluency (FAS-test); Category fluency test (animals & supermarket items)	Age & education	Low

	pools, hospital database of outpatients, seniors centers & advertisements posted in the community, setting NR	Years of Education μ = 13.9±2.9, min-max: 5-21		test (Anderson, Craik & Naveh-Bejamin, 1998)				
Woods et al. (2016) The United States of America	CD people recruited by advertisements on Craigslist	N = 180; Age μ = 40.0±21.2, min-max:18-82; % female = 39.0; Years of Education μ = 14.5±2.0	Cross-sectional	English-speaking; on a stable dosage of any required medication; auditory functioning sufficient to understand normal conversational speech, visual acuity normal or corrected to ≥ 20/40	Prior hx of psychiatric illness; current substance abuse; hx of neurological disease known to affect cognitive functioning	Letter fluency (F only); Sematic fluency (animals)	Age & education	Low

Schneider et al. (2020) The United States of America	Healthy normal volunteers 16-70 years of age	N = 712; Age μ = 71.0±NR, min-max:61-82; % female = NR; Years of Education μ = NR, education < high school = 26.6%, high school/ GED = 23.8, ≥ college = 49.7	Longitudinal	Participants in the Atherosclerosis Risk in Communities Study without clinical or subclinical/ latent neurological disease	Presence of clinical neurological disease (e.g., stroke or transient ischemic attack, MS, PD, brain tumor, history of surgery or radiation to brain or skill, diagnosis of dementia, use of cholinomimetic medication); subclinical neurologic disease or latent dementia; MMSE score <22, two APOE ε4 alleles; self-report of often misplacing or losing items	Word fluency test, Animal naming, Trails A&B	Age & education	Low

					around the house; self-report of often having trouble remembering conversations that occurred a few days earlier; ICD-9 discharge code for dementia at any hospitalization; missing education data, missing cognitive test score data			
Nyborn et al. (2013) The United States of America	CD older adults with no cognitive impairment, mild cognitive impairment, or dementia	N = 1476; Age μ = 67.46±8.93, min-max:43-91; % female = 53.9 Years of Education μ =	Longitudinal	Biological offspring from original 1971 Framingham Heart Study and their spouses; must have completed examination cycle	Participants with prevalent clinical stroke; dementia or other neurological diseases (e.g., MS, severe head trauma)	CDT: command & copy	Age, education & gender	Low

		NR, < high school = 2.9%, high school = 32.1%, some college = 25.1%, >college = 39.9%		7 and neurological testing between 1999-2005				
Lucas et al. (2005b) The United States of America	Older African American adults	N = 309; Age μ = 69.5±6.9, min-max:43-91; % female = 74.0% Years of Education μ = 12.2±3.5	Longitudinal	Normal cognitive functioning based on self-report informant report, and physician report; normal cognitive capacity to perform independent activities of daily living based on informant report; no active or uncontrolled central nervous system, systemic, or psychiatric condition that	Patients with prior histories of dementia; stroke; movement disorder; MS; brain tumour, seizures, severe head trauma, schizophrenia, bipolar mood disorder, or major depression	Category fluency (animal, fruit, vegetable); Trails A&B	Age & education	Low

				would adversely affect cognition based on physician report; no use of psychoactive medications in amounts that would be expected to compromise cognition or for reasons indicating a primary neurologic disease or psychiatric illness;				
Lavencic et al. (2019) Australia	Aboriginal Australians from the Koori Growing Old Well Study	N = 104; Controls Age μ = 64.9±4.26, min-max: 60-74; % female = 52.0% Years of Education μ =	Cross-sectional	All aboriginal and Torres Strait Islander people aged 60 years and older; living in the five study catchment areas for at least 6 months	Participants who did not meet predefined screening cut-offs (with high sensitivity) or ≤26 on the MMSE, ≤35 on the mKICA	Oral Trails A&B	Education	Low

9.71±2.43; MCI group Age μ = 67.7±6.36, min-max: 60-80; % female = 66.0% Years of Education μ = 8.76±2.93; Dementia group Age μ = 69.5±6.78, min-max: 60-88; % female = 37.0% Years of Education μ = 8.40±3.31	and/or ≤25 on the RUDAS

Notes. μ = mean; min-max = minimum to maximum; CD = Community Dwelling; MMSE = Mini Mental State Examination; NR = not reported; hx = history; CDR = Clinical Dementia Rating; IQ = Intelligence Quotient; CDT = Clock Drawing Test; DSM-3R: Diagnostics and Statistical Manual Version 3 Revised; HS = high school; COWAT: Controlled Oral Word Association Test; SD = standard deviation; *as reported by the study authors; TMAANS = The Texas Mexican American Adult Normative Study; Project FRONTIER = Facing Rural Obstacles Now Through Intervention, Education, and Research; TARCC = Texas Alzheimer's Research and Care Consortium; HABLE = Health & Aging Brain among Latino Elders; CNS = Central Nervous System; BAF-test = birds and furniture; BNT = Boston Naming Test; GDS = Geriatric Depression Scale; PD = Parkinson's disease; MS = Multiple Sclerosis; mKICA = modified Kimberley Indigenous Cognitive Assessment; RUDAS = Rowland Universal Dementia Assessment Scale

Appendix E: Normative Data from Studies that Included Clock Drawing Tests.

Study Authors	Clock Drawing Outcome	Sample Characteristics (µ & SD)	Normative Data
Crowe et al. (2010) The United States of America	CLOX 1 & 2 stratified by Age and WRAT-3 score	N = 375; Age µ = 72.8±5.3, min-max:65-89; % female = 57.6; Years of Education years = ≥13: 38.9%, 12: 31.2%, 7-11: 23.7%, 0-6: 6.1%	**CLOX scores, mean (SD)**

CLOX scores, mean (SD)

	CLOX1			**CLOX2**		
	Age					
	65-69	**70-74**	**75+**	**65-69**	**70-74**	**75+**
WRAT-3 score						
≤38	11.23 (2.33) n=31	11.06 (1.79) n=50	10.36 (2.36) n=45	13.16 (1.32) n=31	12.90 (1.44) n=50	12.47 (1.44) n=45
39-46	11.75 (2.31) n=51	11.50 (2.44) n=40	12.18 (2.34) n=33	13.76 (0.86) n=51	13.58 (0.90) n=40	13.72 (0.91) n=33
≥47	12.63 (2.05) n=38	12.51 (1.63) n=45	11.31 (2.89) n=42	13.86 (0.91) n=38	14.02 (0.83) n=45	13.54 (1.21) n=42

Note. WRAT-3 Scores: ≤38 = 6th grade level or less, 39-46 = 7th grade to highschool, ≥47 = high school +. CLOX1 = spontaneous clock drawing scored /15, CLOX2 = clock copying scored /15.

<table>
<tr>
<td>Marcopulos et al. (1997)

The United States of America</td>
<td>CDT (Goodglass & Kaplan, 1983) stratified by age and education</td>
<td>N = 133;
Age μ = 76.48±7.87;
% female = 76.9;
Years of Education μ = 6.65±2.14</td>
<td>
Clock Drawing Score, mean (SD)
<table>
<tr><th></th><th>Age</th><th></th><th></th><th></th><th></th></tr>
<tr><th>Years of Education</th><th>55-64</th><th>65-74</th><th>75-84</th><th>85+</th><th>Totals by Education</th></tr>
<tr><td>0-4</td><td>8.0(-)
n=1</td><td>6.0(3.7)
n=5</td><td>7.3(2.1)
n=12</td><td>5.8(1.3)
n=4</td><td>6.8(2.4)
n=22</td></tr>
<tr><td>5-6</td><td>8.0(0.0)
n=2</td><td>9.1(1.1)
n=8</td><td>6.5(1.5)
n=15</td><td>5.5(3.5)
n=2</td><td>7.3(1.9)
n=27</td></tr>
<tr><td>7-8</td><td>9.5(0.7)
n=2</td><td>8.3(1.3)
n=20</td><td>7.9(1.9)
n=28</td><td>6.2(2.8)
n=9</td><td>7.8(2.0)
n=59</td></tr>
<tr><td>9-10</td><td>9.0(1.4)
n=2</td><td>8.8(1.5)
n=10</td><td>7.4(1.1)
n=8</td><td>9.5(0.7)
n=2</td><td>8.4(1.4)
n=22</td></tr>
<tr><td>Totals by Age</td><td>8.7(1.0)
n=7</td><td>8.3(1.9)
n=43</td><td>7.4(1.8)
n=63</td><td>6.4(2.6)
n=17</td><td></td></tr>
</table>
<i>Note.</i> Clock Drawing was scored /10 as per Libon, Swenson, Barnoski & Sands, 1993.
</td>
</tr>
<tr>
<td>O’Bryant et al. (2018)

The United States of America</td>
<td>CLOX 1 & 2</td>
<td>N = 653;
Age μ = 67.46±8.93;
% female = 73.4;
Years of Education μ = 9.9±4.6</td>
<td>Only scaled scores were presented (i.e., no raw scores) as the studies primary objective was to determine the optimal primary stratification variable rather than application of age-adjusted normative references. Data for CLOX 1 & 2 are available as scaled scores across 22 different data tables.</td>
</tr>
</table>

Stewart et al. (2001) United Kingdom	CDT (Goodglass & Kaplan, 1983)	N = 285; Age μ = NR, min-max:55-75; % female = 56.8; Years of Education μ = NR, “high”: 35, “normal”: 146, “low”: 95

Clock Drawing, mean		
	n	**score†**
Whole sample	285	2.1
Excluding disability*	220	2.0
Age		
55-64	116	1.9
65-75	168	2.2
Sex		
Male	123	1.8
Female	162	2.3
Education‡		
High	35	1.8
Normal	146	1.9
Low	95	2.4
Occupational Class±		
1-3n	88	1.9
3m	105	1.9
4-5	91	2.5

Note. *visual difficulties. †Clock Drawing scored /6 as per Shulman et al., 1993 (lower scores = better performance); ‡Education: high = leaving school after age 16; low = leaving school below age 15; normal = leaving school between 15-16 years of age. ±Occupational Class: based on Reistrar-Generals Model of Social Class 1=professional, 2=intermediate, 3n=non-manual skilled, 3m=manual skilled, 4=semi-skilled, 5=unskilled. SD of clock drawing score not reported.

Nyborn et al. (2013) The United States of America	CDT: command & copy stratified by age and education	N = 1476; Age μ = 67.46±8.93, min-max:43-91; % female = 53.9 Years of Education μ = NR, < high school = 2.9%, high school = 32.1%, some college = 25.1%, >college = 39.9%	**Clock Drawing Command & Copy Error Scores, mean (SD) *[min-max]***

		Age			
Education		**<55**	**55-65**	**65-75**	**75+**
High School	***n***	100	179	157	37
	Com Sum	0.97(0.47)	0.98(0.47)	1.12(0.49)	1.29(0.50)
	Com Raw	1.94(1.43)	1.97(1.35)	2.46(1.83)	3.06(1.98)
		[0, 6.75]	*[0, 6.25]*	*[0, 10.00]*	*[0.25, 8.25]*
	Copy Sum	0.79(0.40)	0.82(0.37)	0.78(0.39)	1.00(0.46)
	Copy Raw	1.38(0.94)	1.43(0.84)	1.36(0.90)	1.97(1.22)
		[0, 4.24]	*[0, 4.50]*	*[0, 4.50]*	*[0, 4.75]*
Some College	***n***	108	156	86	21
	Com Sum	0.90(0.47)	0.94(0.46)	1.08(0.48)	1.17(0.56)
	Com Raw	1.75(1.37)	1.84(1.37)	2.32(1.85)	2.69(1.84)
		[0, 7.25]	*[0, 9.00]*	*[0, 11.75]*	*[0, 6.75]*
	Copy Sum	0.73(0.41)	0.74(0.40)	0.79(0.43)	0.86(0.40)
	Copy Raw	1.25(0.84)	1.27(0.93)	1.42(1.03)	1.54(0.92)
		[0, 3.75]	*[0, 4.75]*	*[0, 5.50]*	*[0, 3.00]*
College	***n***	237	208	122	23
	Com Sum	0.75(0.46)	0.85(0.48)	0.94(0.50)	1.11(0.57)
	Com Raw	1.36(1.18)	1.64(1.49)	1.94(1.75)	2.51(1.86)
		[0, 7.25]	*[0, 8.50]*	*[0, 9.25]*	*[0, 6.50]*
	Copy Sum	0.72(0.41)	0.74(0.37)	0.73(0.35)	0.83(0.40)
	Copy Raw	1.23(0.93)	1.25(0.85)	1.21(0.77)	1.48(1.12)

	[0, 5.25]	*[0, 5.0]*	*[0, 3.50]*	*[0.25, 4.25]*

Note. Com Sum = natural logarithm of command summary error score; Com Raw = raw command summary error score; Copy Sum = natural logarithm of copy summary error score; Copy Raw = raw copy summary error score. Clock Drawing scores as per the Framingham Heart Study Clock Drawing Test Scoring Protocol (FHS-CDT-SP) /20.5 (lower scores indicating better performance).

Appendix F: Normative Data from Studies that Included Verbal Fluency Tests.

Study	Verbal Fluency Test Outcome	Sample Characteristics (μ & SD)	Normative Data
Acevedo et al. (2000) The United States of America	Category Fluency (animals, vegetables & fruits) stratified by age and gender and education and gender	N = 316 Age μ = 69.1±6.9; % female = 74.0; Years of Education μ = 14.4±2.5	

Category Fluency scores by age and gender, mean (SD)

	Men: age			**Women: age**		
	50-59	**60-69**	**70-79**	**50-59**	**60-69**	**70-79**
Task						
Animals	16.4 (3.3)	16.4 (4.9)	16.0 (4.7)	18.9 (5.1)	17.3 (3.9)	15.0 (4.2)
Fruits	12.3 (2.3)	11.7 (3.5)	11.9 (3.4)	16.9 (3.9)	14.4 (3.5)	12.7 (3.0)
Vegetables	11.7 (1.7)	11.8 (2.8)	12.0 (3.0)	17.0 (3.8)	15.4 (3.8)	14.2 (3.5)
Total	40.3 (4.5)	40.0 (9.7)	39.8 (8.6)	52.7 (10.2)	47.2 (8.8)	41.9 (8.3)

Note. Fluency score: number of correct, nonreported responses for each individual category produced in 60 seconds. Total fluency score was calculated by adding the number of correct responses for the pooled categories.

Category Fluency scores by education and gender, mean (SD)

	Men: education (years)			**Women: education (years)**		
	8-12	**13-17**	**17+**	**8-12**	**13-17**	**17+**
Task						
Animals	15.6 (4.4)	16.2 (4.4)	17.4 (5.8)	14.8 (4.3)	16.4 (3.9)	19.4 (5.2)
Fruits	11.9 (3.4)	11.7 (3.3)	12.3 (3.3)	13.3 (2.9)	13.9 (4.0)	14.6 (3.6)
Vegetables	12.2 (2.3)	11.7 (3.1)	12.0 (3.0)	14.8 (3.9)	14.8 (3.6)	15.9 (3.7)

<table>
<tr><td></td><td></td><td></td><td>
<table>
<tr><td>Total</td><td>39.8 (8.3)</td><td>39.4 (8.8)</td><td>41.7 (9.3)</td><td>42.9 (8.8)</td><td>45.2 (9.3)</td><td>49.9 (10.4)</td></tr>
</table>
<i>Note.</i> Fluency score: number of correct, nonreported responses for each individual category produced in 60 seconds. Total fluency score was calculated by adding the number of correct responses for the pooled categories.
</td></tr>
<tr><td>Cauthen (1978) Canada</td><td>Letter fluency (various letters: S, G, U, N, F, T, J & P) stratified by IQ</td><td>N = 64; Age μ = mean NR; % female = 56.2; Years of Education μ = NR</td><td>
Letter Fluency scores by IQ for adults 60+ years of age, mean (SD)
<table>
<tr><th></th><th>Letter
S</th><th>G</th><th>U</th><th>N</th><th>F</th><th>T</th><th>J</th><th>P</th></tr>
<tr><th>IQ range</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td>80-106</td><td>8.8 (4.4)</td><td>6.9 (3.1)</td><td>3.1 (1.8)</td><td>5.5 (2.8)</td><td>8.0 (2.9)</td><td>7.6 (3.5)</td><td>3.7 (2.3)</td><td>7.4 (4.1)</td></tr>
<tr><td>107-118</td><td>10.9 (3.9)</td><td>8.9 (3.3)</td><td>3.9 (1.7)</td><td>6.0 (3.0)</td><td>10.1 (2.7)</td><td>9.8 (2.7)</td><td>4.7 (1.8)</td><td>10.0 (3.3)</td></tr>
<tr><td>119-140</td><td>13.9 (4.8)</td><td>10.4 (3.7)</td><td>5.5 (2.0)</td><td>8.7 (3.1)</td><td>12.9 (4.3)</td><td>13.0 (2.5)</td><td>7.1 (2.9)</td><td>13.6 (4.7)</td></tr>
</table>
<i>Note.</i>
</td></tr>
<tr><td>Devora et al. (2020) The United States of America</td><td>Category fluency (animals & vegetables); & Letter fluency (F & L)</td><td>N = 1803; Age μ = NR, <60: 15.3%, 60-69: 38.3%, 70-79: 36.2%, ≥80: 10.3%; % female = 65;</td><td>
Verbal fluency scores, mean (SD)
<table>
<tr><td>Animals, number of words</td><td>21.66 (5.65)</td></tr>
<tr><td>Vegetables, number of words</td><td>14.95 (4.07)</td></tr>
<tr><td>Phonemic fluency, F trial number of words</td><td>14.59 (4.42)</td></tr>
<tr><td>Phonemic fluency, L trial number of words</td><td>13.80 (4.25)</td></tr>
<tr><td>F words repeated</td><td>0.60 (0.97)</td></tr>
<tr><td>Non-F words & rule violations</td><td>0.36 (0.87)</td></tr>
<tr><td>L words repeated</td><td>0.63 (0.92)</td></tr>
<tr><td>Non-L words & rule violations</td><td>0.26 (0.64)</td></tr>
</table>
<i>Note.</i> N=1803 for all analyses; number of words indicates the number of correct nonreported responses for each individual category produced in 60 seconds.
</td></tr>
</table>

<table>
<tr><td></td><td></td><td>Years of Education μ = NR; <12: 9.6%, 13-15: 18.1%, 16 = 26.8%, ≥17: 44.5, missing: 1%</td><td>Summary statistics were presented for all core and derived variables. Data was not stratified by age or gender but multivariate linear regression coefficients for age, sex and education predicting derived variables are presented.</td></tr>
<tr><td>Elkadi et al. (2006) Australia</td><td>Category fluency (animals) stratified by age and education</td><td>N = 257;
Age μ = 60±NR, min-max:56-67;
% female = 100;
Years of Education μ = NR, ≥12: 45%,
<12: 52%</td><td>
Category Fluency scores by education and age, mean (SD)
<table>
<tr><th></th><th colspan="3"><12 years education</th><th colspan="3">≥12 years education</th></tr>
<tr><th>Age</th><th>55-59</th><th>60-67</th><th>55-67</th><th>55-59</th><th>60-67</th><th>55-67</th></tr>
<tr><td>Animals, number of words</td><td>19.0 (0.54)</td><td>18.90 (0.57)</td><td>19.00 (0.39)</td><td>22.30 (0.73)</td><td>20.90 (0.82)</td><td>21.70 (0.55)</td></tr>
</table>
<i>Note.</i> Number of words indicates the number of correct, nonreported responses for each individual category produced in 60 seconds.
</td></tr>
<tr><td>Gladsjo et al. (1999) The United States of America</td><td>Category fluency (animal); Letter fluency</td><td>N = 768;
Age μ = 50.4±19.4;
% female = 48;</td><td>
Letter & Category Fluency scores by education and age, mean (SD)
<table>
<tr><th></th><th colspan="3">Education (years)</th></tr>
<tr><th></th><th>0-11</th><th>12-15</th><th>16+</th></tr>
</table>
</td></tr>
</table>

<table>
<tr>
<td></td>
<td>(FAS-test) stratified by education and age</td>
<td>Years of Education μ = 13.6±3.1</td>
<td>
<table>
<tr><th>Age Group</th><th>20-34</th><th>35-49</th><th>50+</th><th>20-34</th><th>35-49</th><th>50+</th><th>20-34</th><th>35-49</th><th>50+</th></tr>
<tr><td>FAS Test</td><td>38.21 (13.43)</td><td>33.32 (11.93)</td><td>31.47 (13.21)</td><td>40.30 (9.59)</td><td>40.63 (11.43)</td><td>38.63 (11.98)</td><td>44.38 (10.54)</td><td>47.27 (13.33)</td><td>41.81 (12.75)</td></tr>
<tr><td>Animals</td><td>17.74 (5.52)</td><td>18.36 (6.63)</td><td>15.28 (3.80)</td><td>21.11 (5.90)</td><td>19.82 (6.26)</td><td>18.05 (4.81)</td><td>22.88 (4.73)</td><td>22.28 (5.57)</td><td>19.35 (4.42)</td></tr>
</table>
<i>Note.</i> Number of words indicates the number of correct, nonreported responses for each individual category produced in 60 seconds.
</td>
</tr>
<tr>
<td>Hankee et al. (2013) The United States of America</td>
<td>Letter fluency (FAS-test); Category fluency (animals) stratified by age</td>
<td>N = 1907; Age μ = NR, <55: 7.1%, 55-64: 35%, 65-74: 34%, ≥75: 23.9%; % female: 54%
Years of Education μ = NR, <HS diploma: 3.4%, HS diploma: 56.6%, College</td>
<td>
Letter & Category Fluency scores by age, mean (SD)
<table>
<tr><th></th><th></th><th>Age</th><th></th><th></th><th></th></tr>
<tr><th></th><th></th><th><55</th><th>55-64</th><th>65-74</th><th>≥75</th></tr>
<tr><td>FAS</td><td>Total</td><td>41.6 (12.6)</td><td>41.8 (12.3)</td><td>36.3 (11.9)</td><td>33.4 (11.2)</td></tr>
<tr><td></td><td>%PSV errors</td><td>2.2 (3.5)</td><td>3.6 (4.2)</td><td>3.8 (4.7)</td><td>5.0 (6.3)</td></tr>
<tr><td></td><td>%Total errors</td><td>4.3 (5.7)</td><td>5.7 (6.2)</td><td>6.3 (6.9)</td><td>8.3 (9.8)</td></tr>
<tr><td>Animals</td><td>Total</td><td>20.2 (4.8)</td><td>20.2 (4.9)</td><td>17.7 (4.7)</td><td>14.8 (4.5)</td></tr>
<tr><td></td><td>%PSV errors</td><td>2.7 (4.8)</td><td>2.7 (7.5)</td><td>3.3 (5.7)</td><td>4.1 (8.4)</td></tr>
<tr><td></td><td>%Total errors</td><td>2.7 (4.8)</td><td>2.9 (7.8)</td><td>3.6 (6.1)</td><td>4.6 (9.0)</td></tr>
</table>
<i>Note.</i> Total: the number of correct, nonreported responses for each individual category produced in 60 seconds. %PSV errors: preservations/ total responses; %Total errors: total errors/ total responses.
Letter & Category Fluency scores by education, mean (SD)
</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>degree: 21.2%, Graduate degree(s): 18.9%</td>
<td>
<table>
<tr><th></th><th></th><th colspan="4">Education</th></tr>
<tr><th></th><th></th><th><HS</th><th>HS</th><th>College</th><th>≥Graduate</th></tr>
<tr><td>FAS</td><td>Total</td><td>27.6 (13.3)</td><td>35.4 (11.5)</td><td>40.7 (12.0)</td><td>44.2 (11.8)</td></tr>
<tr><td></td><td>%PSV errors</td><td>3.8 (4.9)</td><td>4.2 (5.4)</td><td>3.3 (4.1)</td><td>3.6 (4.4)</td></tr>
<tr><td></td><td>%Total errors</td><td>9.6 (9.9)</td><td>7.1 (8.2)</td><td>5.2 (5.8)</td><td>5.4 (5.9)</td></tr>
<tr><td>Animals</td><td>Total</td><td>14.3 (5.2)</td><td>17.1 (4.7)</td><td>19.0 (5.0)</td><td>20.6 (5.2)</td></tr>
<tr><td></td><td>%PSV errors</td><td>3.6 (5.3)</td><td>3.7 (7.7)</td><td>2.4 (5.0)</td><td>2.7 (6.8)</td></tr>
<tr><td></td><td>%Total errors</td><td>3.6 (5.3)</td><td>4.0 (8.1)</td><td>2.6 (5.6)</td><td>3.0 (7.2)</td></tr>
</table>
<i>Note.</i> HS: high school; Total: the number of correct, nonreported responses for each individual category produced in 60 seconds. %PSV errors: preservations/ total responses; %Total errors: total errors/ total responses.
</td>
</tr>
<tr>
<td>Holtzer et al. (2008) The United States of America</td>
<td>Letter fluency (FAS-test); Category fluency (animals, fruits & vegetables) stratified by age and education</td>
<td>N = 2005, $n_{conventional}$ = 1251, n_{robust} = 3-7, $n_{incidence}$ = 58, $n_{prevalence}$ = 75, lost to follow up = 314; Age μ conventional = 78.8±5.16, robust</td>
<td>
Letter & Category fluency by age and education, mean (SD)
<table>
<tr><th>Age</th><th>70-79</th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><th>Edu.</th><th><10</th><th>10-12</th><th>>12</th><th>13-15</th><th>>16</th><th>Total</th></tr>
<tr><td>FAS</td><td>22.6 (14.37)</td><td>31.7 (11.77)</td><td>41.0 (11.49)</td><td>37.9 (11.11)</td><td>43.9 (11.18)</td><td>36.2 (13.16)</td></tr>
<tr><td>CAT</td><td>30.1 (5.77)</td><td>37.3 (8.05)</td><td>41.2 (8.75)</td><td>39.5 (8.27)</td><td>42.8 (8.93)</td><td>39.0 (8.87)</td></tr>
<tr><td>Age</td><td>80-89</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td>
</tr>
</table>

77.2±4.47, incidence 81.4±4.8, prevalence 82.6±5.49, lost to follow-up 78.4±5.14; % female: conventional 59.9%, robust 6.8%, incidence 67.2%, prevalence 64%, lost to follow-up 63.7%; Years of Education μ = conventional 12.7±3.90, robust 13.5±3.46, incidence

FAS	32.5 (13.75)	32.1 (11.28)	39.5 (11.07)	34.9 (12.52)	42.4 (9.25)	35.4 (11.89)
CAT	37.5 (5.32)	37.7 (7.33)	39.3 (7.30)	35.9 (5.80)	41.5 (7.47)	38.3 (7.07)

Note. Edu: education years; CAT: Category; FAS: the sum of words generated for each letter (F, A and S); Category: the sum of words generated for each category (animals, fruits and vegetables).

		12.5±3.79, prevalence 10.6±4.30, lost to follow-up 11.90±3.58	
Ivnik et al. (1996) The United States of America	Letter fluency (COWAT)	N = 746; Age μ = NR, min-max:56-95+; % female = 61.5 for COWAT, 53.4% for TMT; Years of Education μ = NR, min-max:≤7 – ≥18	Reference values given for tests' correlations (and shared variance) with age, education and sex and Mayo's Older Americans Normative Studies (MOANS) scaled scores.

<table>
<tr>
<td>Baker et al.
(2001)
The United States of America</td>
<td>Category fluency (animals & food);
Letter fluency (T & P) stratified by education</td>
<td>N = 280;
Age μ = 70.5±NR, min-max:0-87;
% female = 55.3;
Years of Education μ = NR</td>
<td>
Letter & Category Fluency scores by education for 60–87-year-olds, mean (SD)
<table>
<tr><th></th><th></th><th colspan="2">Spoken Performance (number correct)</th><th colspan="2">Written Performance (number correct)</th></tr>
<tr><th></th><th></th><th>T</th><th>Animals</th><th>P</th><th>Food</th></tr>
<tr><td>Female</td><td>No HS</td><td>7.35 (3.4)</td><td>11.38 (3.3)</td><td>7.06 (2.6)</td><td>8.94 (3.3)</td></tr>
<tr><td></td><td>HS</td><td>11.92 (3.9)</td><td>16.79 (4.3)</td><td>10.61 (3.0)</td><td>12.74 (3.3)</td></tr>
<tr><td></td><td>College</td><td>12.24 (3.4)</td><td>17.07 (4.6)</td><td>10.93 (3.0)</td><td>13.45 (3.2)</td></tr>
<tr><td>Male</td><td>No HS</td><td>8.31 (3.4)</td><td>12.00 (3.9)</td><td>7.16 (2.9)</td><td>8.03 (2.8)</td></tr>
<tr><td></td><td>HS</td><td>11.73 (5.2)</td><td>15.07 (4.5)</td><td>9.16 (3.6)</td><td>11.00 (3.3)</td></tr>
<tr><td></td><td>College</td><td>13.38 (5.1)</td><td>16.83 (5.0)</td><td>12.67 (3.9)</td><td>12.06 (4.0)</td></tr>
</table>
<i>Note.</i> HS: some high school preparation but no high school degree; HS: high school with or without college preparation; College: college degree with or without postgraduate education.
</td>
</tr>
<tr>
<td>Lucas et al.
(1998)
The United States of America</td>
<td>Category fluency (fruits & vegetables)</td>
<td>N = 412;
Age μ = 79.9±8.3, min-max:56-95+;
% female = 64.3;
Years of Education μ = 13.7±3.0</td>
<td>Only scaled scores presented, no raw scores presented for the verbal fluency test. Data presented Mayo's Older Americans Normative Studies (MOANS) age-adjusted scores.</td>
</tr>
</table>

<table>
<tr>
<td>Lucas et al. (2005a) The United States of America</td>
<td>Letter fluency (COWAT); Category fluency (animals, fruits & vegetables combined, & animals alone)</td>
<td>N = 309 (from MOAANS sample: N = 412) Age μ = 79.9±8.3, min-max:56-94; % female = 64.3; Years of Education μ = 13.7±3.0</td>
<td>Scores presented as Mayo’s Older African Americans Normative Studies (MOAANS) scaled scores for age groups 56-62, 63-65, 66-68, 69-71, 72-74, 75-77, 78+, and as correlations and shared variances of MOAANS subtest scores with age and years of education.</td>
</tr>
<tr>
<td>Marcopulos et al. (1997) The United States of America</td>
<td>Category fluency (names, foods, vegetables) stratified by age and education</td>
<td>N = 133; Age μ = 76.48±7.87; % female = 76.9; Years of Education μ = 6.65±2.14</td>
<td>
Verbal Fluency by age and education, mean (SD)
<table>
<tr><th></th><th>Age
55-64</th><th>65-74</th><th>75-84</th><th>85+</th><th>Totals by Education</th></tr>
<tr><td>Years of Education</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>0-4</td><td>17.0 (-) n=1</td><td>25.2 (5.1) n=5</td><td>24.1 (6.9) n=13</td><td>27.0 (7.0) n=3</td><td>24.4 (6.4) n=22</td></tr>
<tr><td>5-6</td><td>53.0 (12.7) n=2</td><td>31.3 (5.3) n=8</td><td>36.8 (11.4) n=15</td><td>19.5 (7.8) n=2</td><td>35.1 (11.6) n=27</td></tr>
<tr><td>7-8</td><td>39.5 (9.2) n=2</td><td>37.7 (11.4) n=20</td><td>36.9 (10.3) n=28</td><td>27.1 (5.6) n=10</td><td>35.7 (10.6) n=60</td></tr>
</table>
</td>
</tr>
</table>

9-10	36.0 (1.4) n=2	39.3 (8.7) n=10	43.8 (8.3) n=8	29.0 (1.4) n=2	39.7 (8.6) n=22
Totals by Age	39.1 (13.8) n=7	35.4 (10.2) n=43	35.2 (11.3) n=64	26.4 (5.9) n=17	

Note. Category fluency includes the sum of words generated for names, foods & vegetables.

O'Bryant et al. (2018) The United States of America	Category fluency (animals); Letter fluency (FAS-test)	N = 653; Age μ = 67.46±8.93; % female = 73.4; Years of Education μ = 9.9±4.6	Data presented as linear regression models and the Mayo method was utilized. Mid-point ranges were employed with overlapping subsamples from each stratification variable.
Piatt et al. (2004) The United States of America	Action fluency	N = 145; Age μ = 72.93±7.02; % female = 63; Years of Education μ = 14.96±2.31	**Action Fluency scores by education, mean (SD)**

	Education (years)	
	12-15	**16-20**
N	69	76
Age	73.35 (6.48)	73.46 (7.47)
Education	12.97 (1.15)	17.12 (1.22)
Action fluency (words/min)	14.35 (4.06)	17.34 (4.38)
Action fluency (preservations)	0.41 (0.72)	0.49 (0.87)
Action fluency (intrusions)	0.33 (1.36)	0.05 (0.22)

Note. An intrusion is an eligible word.

<table>
<tr>
<td>Picciotto & Friedland (2001)
South Africa</td>
<td>Category fluency (animals) stratified by education</td>
<td>N = 30;
Age μ = 77±NR, min-max:60-95;
% female = NR;
Years of Education μ = 12±NR, min-max:11-15</td>
<td>
<table>
<tr><th colspan="2">Category Fluency scores by education for 60–95-year-olds, mean (SD)</th></tr>
<tr><th>Clusters</th><th>Exemplars</th></tr>
<tr><td>3.2 (1.3)</td><td>5.1 (3.5)</td></tr>
<tr><td colspan="2"><i>Note.</i> Two or more related items were considered a cluster. Exemplars were the number of items in a cluster</td></tr>
</table>
</td>
</tr>
<tr>
<td>Quaranta et al. (2016)
Italy</td>
<td>Category fluency (BAF-test) stratified by age and education</td>
<td>N = 268;
Age μ = 68.03±11.50, min-max:40-92;
% female = 48.9;
Years of Education μ = NR, <5: 30, 5-7: 86, 8-12: 84, ≥13: 68</td>
<td>
<table>
<tr><th colspan="7">BAF Fluency scores by age and education, mean (SD)</th></tr>
<tr><th></th><th></th><th>Age
40-49</th><th>50-59</th><th>60-69</th><th>70-79</th><th>≥80</th></tr>
<tr><td>Ed (years)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td><5</td><td>BAF total</td><td>NR</td><td>NR</td><td>14.0 (2.83)</td><td>13.0 (2.48)</td><td>13.1 (2.52)</td></tr>
<tr><td></td><td>Birds</td><td>NR</td><td>NR</td><td>8.3 (3.25)</td><td>7.3 (2.29)</td><td>5.6 (2.23)</td></tr>
<tr><td></td><td>Furniture</td><td>NR</td><td>NR</td><td>5.7 (1.80)</td><td>5.8 (1.65)</td><td>7.6 (1.99)</td></tr>
<tr><td>5-7</td><td>BAF total</td><td>23.0 (NR)</td><td>18.0 (NR)</td><td>14.1 (3.40)</td><td>13.7 (3.51)</td><td>12.5 (2.98)</td></tr>
<tr><td></td><td>Birds</td><td>12.0 (NR)</td><td>8.0 (NR)</td><td>7.3 (2.68)</td><td>6.7 (2.58)</td><td>6.2 (2.24)</td></tr>
<tr><td></td><td>Furniture</td><td>11 (NR)</td><td>10 (NR)</td><td>6.8 (2.31)</td><td>7.0 (1.80)</td><td>6.3 (1.81)</td></tr>
<tr><td>8-12</td><td>BAF total</td><td>17.5 (1.96)</td><td>16.9 (3.87)</td><td>18.0 (4.26)</td><td>16.5 (4.16)</td><td>14.0 (5.85)</td></tr>
<tr><td></td><td>Birds</td><td>8.0 (1.83)</td><td>8.2 (2.57)</td><td>8.8 (3.11)</td><td>7.7 (3.53)</td><td>7.4 (3.69)</td></tr>
<tr><td></td><td>Furniture</td><td>9.5 (2.01)</td><td>8.7 (1.80)</td><td>9.2 (2.44)</td><td>8.8 (2.42)</td><td>6.6 (2.63)</td></tr>
<tr><td>≥13</td><td>BAF total</td><td>20.7 (5.15)</td><td>21.4 (3.44)</td><td>18.7 (4.37)</td><td>17.9 (3.25)</td><td>17.0 (2.16)</td></tr>
<tr><td></td><td>Birds</td><td>10.5 (2.75)</td><td>11.3 (1.92)</td><td>9.0 (2.83)</td><td>8.6 (2.47)</td><td>9.8 (2.22)</td></tr>
</table>
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</table>

<table>
<tr><td></td><td></td><td></td><td>
<table>
<tr><td>Furniture</td><td>10.2 (2.75)</td><td>10.1 (1.92)</td><td>9.7 (1.88)</td><td>9.2 (1.93)</td><td>7.3 (0.50)</td></tr>
</table>
<i>Note.</i> Ed = education. BAF = birds and furniture categories; scores are the number of correct and eligible words produced in one minute in each category.
</td></tr>
<tr><td>Ruff et al. (1996)
The United States of America</td><td>Letter fluency test (COWAT) stratified by gender and education</td><td>N = 360; Age μ = NR, min-max: 16-70; retested sample (n_1 = 120) 40.5, not retested sample (n_2 = 240) 40.4; Years of Education μ = NR, min-max: 7-22, retested sample: 14.0, not retested sample: 14.2</td><td>
COWAT Fluency scores by gender and education for 16-70-year-olds, mean (SD)
<table>
<tr><th></th><th>Gender
Men</th><th>Women</th><th>All Genders</th></tr>
<tr><td>Education (years)</td><td></td><td></td><td></td></tr>
<tr><td>≤12</td><td>36.9 (9.8)</td><td>35.9 (9.6)</td><td>36.5 (9.9)</td></tr>
<tr><td>13-15</td><td>40.5 (9.4)</td><td>39.4 (10.1)</td><td>40.0 (9.7)</td></tr>
<tr><td>≥16</td><td>41.0 (9.3)</td><td>46.5 (11.2)</td><td>43.8 (10.6)</td></tr>
<tr><td>All education</td><td>39.5 (9.8)</td><td>40.6 (11.2)</td><td>40.1 (10.5)</td></tr>
</table>
<i>Note.</i> COWAT: Controlled Oral Word Association Test; Scores are the number of correct and eligible words produced in one minute in each category.
</td></tr>
<tr><td>Steinburg et al., (2005)</td><td>Letter fluency test (COWAT)</td><td>N = 1131, n_{TMT} = 354, n_{COWAT} = 777;</td><td>Data presented as Pearson <i>r</i> correlation coefficients between demographic variables of age and education and as proportions of variance in Mayo’s Older Americans Normative Studies (MOANS) age-adjusted scores.</td></tr>
</table>

<table>
<tr><td>The United States of America</td><td></td><td>Age μ n_{TMT} = NR, min-max:56-94, n_{COWAT} μ = NR, min-max:56-95+;
% female = n_{TMT}: 53.4, n_{COWAT}: 61.9;
Years of Education μ = n_{TMT} & n_{COWAT} = NR, min-max:<7 - >18+</td><td></td><td></td></tr>
<tr><td>Stewart et al. (2001) United Kingdom</td><td>Category fluency (animals)</td><td>N = 285;
Age μ = NR, min-max:55-75;
% female = 56.8;
Years of Education μ = NR, “high”: 35, “normal”:</td><td>
<table>
<tr><th colspan="3">Category Fluency, mean (SD)</th></tr>
<tr><th></th><th>n</th><th>score†</th></tr>
<tr><td>**Whole sample**</td><td>285</td><td>13.4 (4.4)</td></tr>
<tr><td>**Excluding disability***</td><td>220</td><td>14.0 (4.2)</td></tr>
<tr><td>**Age**</td><td></td><td></td></tr>
<tr><td>**55-64**</td><td>116</td><td>14.4 (4.2)</td></tr>
<tr><td>**65-75**</td><td>168</td><td>12.9 (4.4)</td></tr>
<tr><td>**Sex**</td><td></td><td></td></tr>
<tr><td>**Male**</td><td>123</td><td>14.2 (4.4)</td></tr>
<tr><td>**Female**</td><td>162</td><td>12.9 (4.4)</td></tr>
</table>
</td><td></td></tr>
</table>

		146, “low”: 95	

Education‡		
High	35	14.9 (4.7)
Normal	146	13.7 (4.1)
Low	95	12.8 (4.5)
Occupational Class±		
1-3n	88	13.8 (4.3)
3m	105	13.6 (4.4)
4-5	91	13.0 (4.6)

Note. *visual difficulties; †The number of animal names produced in one minute; ‡Education: high = leaving school after age 16; low = leaving school below age 15; normal = leaving school between 15-16 years of age. ±Occupational Class: based on Reistrar-Generals Model of Social Class 1=professional, 2=intermediate, 3n=non-manual skilled, 3m=manual skilled, 4=semi-skilled, 5=unskilled. SD of clock drawing score not reported.

Tombaugh et al. (1999) Canada	Letter fluency (FAS-test); Category fluency (animals) stratified by age	N = 911 Age μ = 58.5±21.7; min-max:18-89 % female = 55.2; Years of Education μ = 12.6±2.6, min-max:5-15	**Verbal and Category Fluency by age, mean (SD)**

	Age (years)						
	30-39	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-95**
FAS	43.1 (11.4)	43.5 (12.2)	42.1 (11.1)	38.5 (13.7)	34.8 (12.8)	28.9 (11.7)	28.2 (11.0)
Animals	21.5 (5.5)	20.7 (4.2)	20.1 (4.9)	17.6 (4.7)	16.1 (4.0)	14.3 (3.9)	13.0 (3.8)

Note. FAS: mean number of words generated for each of the three letters; Animals: The number of animal names produced in one minute.

<table>
<tr>
<td>Troyer et al. (2000) Canada</td>
<td>Letter fluency (FAS-test or CFL); Category fluency test (animals or supermarket items)</td>
<td>N = 411;
Age μ = 59.8±20.7, min-max:18-91;
% female = 70.0;
Years of Education μ = 13.9±2.9, min-max: 5-21</td>
<td>
Verbal and Category Fluency for 18-91-year-olds, mean (SD)
<table>
<tr><th></th><th>Phonemic Score*</th><th>Semantic Score†</th><th>Animals Score</th></tr>
<tr><td>Clusters</td><td>0.24 (0.23)</td><td>0.94 (0.47)</td><td>0.75 (0.57)</td></tr>
<tr><td>Switches</td><td>23.9 (8.2)</td><td>23.4 (4.4)</td><td>9.8 (2.7)</td></tr>
<tr><td>Total</td><td>28.6 (11.1)</td><td>46.9 (7.9)</td><td>18.1 (4.6)</td></tr>
</table>
<i>Notes.</i> *Combined mean of CFL and FAS test; combined mean of animal and supermarket category fluency.
</td>
</tr>
<tr>
<td>Woods et al. (2016) The United States of America</td>
<td>Letter fluency (F only); Semantic fluency (animals)</td>
<td>N = 180;
Age μ = 40.0±21.2, min-max:18-82;
% female = 39.0;
Years of Education μ = 14.5±2.0</td>
<td>
Verbal and Category Fluency for 18-82-year-olds, mean (SD)
<table>
<tr><th>Phonemic Score*</th><th>Semantic Score†</th></tr>
<tr><td>18.8 (6.5)</td><td>26.66 (6.9)</td></tr>
</table>
<i>Note.</i> *the number of words produced beginning with the letter F in one minute;
†the number of words produced in an animal category in one minute.
</td>
</tr>
</table>

<table>
<tr><td>Schneider et al. (2020) The United States of America</td><td>Word fluency test, Animal naming stratified by age and education</td><td>N = 712;
Age μ = 71.0±NR, min-max:61-82;
% female = NR;
Years of Education μ = NR, education < high school = 26.6%, high school/ GED = 23.8, ≥ college = 49.7</td><td>
Verbal and Category Fluency by age and education, mean (-1.5 SD)
<table>
<tr><th></th><th></th><th>Age</th><th></th><th></th></tr>
<tr><th>Education (years)</th><th></th><th>65-<70</th><th>70-<75</th><th>75-<80</th></tr>
<tr><td><HS</td><td>COWA</td><td>22.32 (6.48)</td><td>21.16 (5.32)</td><td>20.01 (4.17)</td></tr>
<tr><td></td><td>Animals</td><td>14.28 (8.01)</td><td>13.49 (7.22)</td><td>12.69 (6.42)</td></tr>
<tr><td>HS/equal</td><td>COWA</td><td>28.07 (12.23)</td><td>26.92 (11.08)</td><td>25.76 (9.92)</td></tr>
<tr><td></td><td>Animals</td><td>14.52 (8.25)</td><td>13.72 (7.45)</td><td>12.92 (6.65)</td></tr>
<tr><td>>HS</td><td>COWA</td><td>37.78 (21.93)</td><td>36.62 (20.78)</td><td>35.46 (19.62)</td></tr>
<tr><td></td><td>Animals</td><td>17.33 (11.06)</td><td>16.53 (10.26)</td><td>15.74 (9.47)</td></tr>
</table>
<i>Note.</i> HS: high school, HS/equal: high school or equivalent; COWA: Controlled Oral Word Association Test using the letters F, A and S, score is the total number of acceptable words generated in one minute for the three letters; Animals: the number of animals generated in one minute.
</td></tr>
<tr><td>Lucas et al. (2005b) The United States of America</td><td>Category fluency (animal, fruit, vegetable)</td><td>N = 309;
Age μ = 69.5±6.9, min-max:43-91;
% female = 74.0%</td><td>Scores presented as Mayo’s Older African Americans Normative Studies (MOAANS) scaled scores for age groups 56-62, 63-65, 66-68, 69-71, 72-74, 75-77, 78+, and as correlations and shared variances of MOAANS subtest scores with age and years of education.</td></tr>
</table>

Years of Education μ = 12.2±3.5

Notes. μ = mean; CD = Community Dwelling; MMSE = Mini Mental State Examination; NR = not reported; hx = history; CDR = Clinical Dementia Rating; IQ = Intelligence Quotient; CDT = Clock Drawing Test; DSM-3R: Diagnostics and Statistical Manual Version 3 Revised; HS = high school; COWAT: Controlled Oral Word Association Test; SD = standard deviation; *as reported by the study authors; TMAANS = The Texas Mexican American Adult Normative Study; Project FRONTIER = Facing Rural Obstacles Now Through Intervention, Education, and Research; TARCC = Texas Alzheimer's Research and Care Consortium; HABLE = Health & Aging Brain among Latino Elders; CNS = Central Nervous System; BAF-test = birds and furniture; BNT = Boston Naming Test; GDS = Geriatric Depression Scale; PD = Parkinson's disease; MS = Multiple Sclerosis; mKICA = modified Kimberley Indigenous Cognitive Assessment; RUDAS = Rowland Universal Dementia Assessment Scale

Appendix G: Normative Data from Studies that Included Trail-Making Tests.

Study	Trail Making Test Outcome	Sample Characteristics (μ & SD)	Normative Data
Amodio et al. (2002) Italy	TMT A&B stratified by age and education	N = 300; Age μ = NR, min-max: 20-80; % female = 52% in random sample, 51% in convenience sample; University Education = 22.9% of random sample, 8.6% in convenience sample	**TMT A&B by age and education, mean**

		TMT-A (sec)		**TMT-B (sec)**			
	Ed. Years	**5**	**≥8**	**5**	**≥8**	**≥13***	**≥13†**
Age							
20		46	39	100	93	105	82
25		49	42	111	101	113	88
30		53	44	122	109	122	94
35		57	47	136	119	133	101
40		62	51	151	130	144	109
45		67	55	169	142	156	117
50		72	59	189	155	170	126
55		78	63	211	169	184	135
60		83	67	236	184	199	145
65		88	72	263	199	213	154
70		92	76	291	214	227	163

<table>
<tr><td></td><td></td><td></td><td><table>
<tr><th></th><th></th><th></th><th></th><th></th><th></th><th></th></tr>
<tr><td>75</td><td>95</td><td>79</td><td>318</td><td>227</td><td>239</td><td>172</td></tr>
<tr><td>80</td><td>95</td><td>81</td><td>343</td><td>238</td><td>248</td><td>276</td></tr>
</table>
Note. *blue collar (i.e., craftsmen, farmers, housewives, nurses and hospital technical staff), †white collar (i.e., clerks, students, technical assistants, tradesmen, secretaries, and university graduates). Ed. = education. Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.</td></tr>
<tr><td>Ashendorf et al. (2008) The United States of America</td><td>TMT A&B stratified by age and education</td><td>N = 526;
Age μ = 72.4±8.5;
% female = 66.9;
Years of Education μ = 16.1±2.</td><td>TMT A&B by age and education, mean (SD)
<table>
<tr><th></th><th>Age</th><th>55-74</th><th>75-98</th><th>55-74</th><th>75-98</th></tr>
<tr><td></td><td>Education</td><td><16</td><td><16</td><td>≥16</td><td>≥16</td></tr>
<tr><td></td><td>n</td><td>46</td><td>50</td><td>106</td><td>67</td></tr>
<tr><td>TMT-A</td><td>Mean (SD)</td><td>33.2(13.1)</td><td>44.8(13.4)</td><td>29.7(7.8)</td><td>40.3(13.2)</td></tr>
<tr><td>TMT-B</td><td>Mean (SD)</td><td>80.8(30.4)</td><td>109.7(42.5)</td><td>62.7(20.6)</td><td>90.5(37.1)</td></tr>
</table>
Note. Age and Education are measured in years. TMT-A and TMT-B are measured in seconds. Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.</td></tr>
<tr><td>Clark et al. (2004) Australia</td><td>TMT B stratified by age and education</td><td>N = 257;
Age μ = 60±NR, min-max = 56-67;
% female = 100;
Years of Education μ = 11.5±2.2</td><td>TMT-B by age and education, mean (SD)
<table>
<tr><th></th><th><12 years education</th><th></th><th></th><th>≥12 years education</th><th></th><th></th></tr>
<tr><td>Age</td><td>56-59.9</td><td>60-67</td><td>56-67</td><td>56-59.9</td><td>60-67</td><td>56-67</td></tr>
<tr><td>TMT-B (min)</td><td>1:32.6</td><td>1:36.6</td><td>1:34.3</td><td>1:16.8</td><td>1:20.3</td><td>1:18.1</td></tr>
<tr><td>TMT-B (no. errors)</td><td>0.84 (1.29)</td><td>0.80 (0.97)</td><td>0.82 (1.16)</td><td>0.38 (0.85)</td><td>0.36 (0.80)</td><td>0.36 (0.82)</td></tr>
</table>
Note. min = minutes. Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.</td></tr>
<tr><td>Devora et al. (2020)</td><td>TMT A&B</td><td>N = 1803;</td><td>Reference centile curves given for: Trail-Making Part A time (sec), Part B time (sec), Raw Difference Score, Ratio Score, Part A Commission Errors and Part B Commission Errors.</td></tr>
</table>

<table>
<tr><td>The United States of America</td><td></td><td>Age μ = NR, <60: 15.3%, 60-69: 38.3%, 70-79: 36.2%, ≥80: 10.3%;
% female = 65;
Years of Education μ = NR; <12: 9.6%, 13-15: 18.1%, 16 = 26.8%, ≥17: 44.5, missing: 1%</td><td></td></tr>
<tr><td>Drane et al. (2002)
The United States of America</td><td>TMT A&B, B-A, B:A stratified by age and education</td><td>N = 285;
Age μ = 48±19.68;
% female: 28.0%;
Years of Education μ = 12.98±2.65</td><td>
TMT scores by age, mean (SD)
<table>
<tr><th></th><th>Age
<20</th><th>20-29</th><th>30-39</th><th>40-49</th><th>50-59</th><th>60-69</th><th>70-79</th><th>>80</th></tr>
<tr><td>Trails A (sec)</td><td>23.22 (6.56)</td><td>26.12 (9.78)</td><td>28.02 (8.78)</td><td>31.00 (11.21)</td><td>36.29 (16.41)</td><td>39.60 (12.14)</td><td>45.58 (18.91)</td><td>56.37 (20.20)</td></tr>
<tr><td>Trails B (sec)</td><td>52.94 (20.10)</td><td>60.92 (33.17)</td><td>72.30 (28.55)</td><td>81.26 (23.69)</td><td>103.42 (50.26)</td><td>105.23 (41.15)</td><td>152.59 (88.42)</td><td>170.21 (84.68)</td></tr>
<tr><td>B-A score</td><td>29.72 (16.21)</td><td>35.31 (27.72)</td><td>44.13 (26.72)</td><td>50.04 (20.28)</td><td>67.24 (39.35)</td><td>65.60 (33.84)</td><td>109.14 (73.87)</td><td>113.84 (70.73)</td></tr>
<tr><td>B:A score</td><td>2.31 (0.58)</td><td>2.36 (0.78)</td><td>2.72 (1.21)</td><td>2.80 (0.93)</td><td>2.94 (0.88)</td><td>2.70 (0.77)</td><td>3.49 (1.76)</td><td>3.05 (1.05)</td></tr>
</table>
<i>Note.</i> B-A: difference score between B and A; B:A: ratio between B and A. Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.
</td></tr>
</table>

Hankee et al. (2013) The United States of America	TMT B stratified by age, and by education	N = 1907; Age μ = NR, <55: 7.1%, 55-64: 35%, 65-74: 34%, ≥75: 23.9%; % female: 54% Years of Education μ = NR, <HS diploma: 3.4%, HS diploma: 56.6%, College degree: 21.2%, Graduate degree(s): 18.9%	**TMT Part B by age, mean (SD)**; **TMT Part B by education, mean (SD)**

TMT Part B by age, mean (SD)

	Age				
	<55	**55-64**	**65-74**	**≥75**	**Total**
n	130	652	616	393	1791
Completion Time	66.7 (25.0)	74.2 (34.8)	95.0 (48.5)	124.4 (57.3)	91.8 (49.1)
Total Errors	0.4 (0.7)	0.4 (0.8)	0.7 (1.0)	0.9 (1.3)	0.6 (1.0)
Pen Lifts	0.7 (0.9)	1.0 (1.5)	1.5 (2.3)	2.3 (2.9)	1.4 (2.2)

Note. Pen lifts represents planning errors on the test when the pen was lifted from the paper. Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.

TMT Part B by education, mean (SD)

	Education				
	<HS	**HS**	**College**	**≥Graduate**	**Total**
n	47	1005	395	344	1791
Completion Time	147.8 (68.1)	98.8 (52.2)	82.7 (41.8)	74.4 (31.3)	91.8 (49.1)
Total Errors	1.5 (1.7)	0.7 (1.1)	0.5 (0.9)	0.4 (0.7)	0.6 (1.0)
Pen Lifts	2.1 (2.3)	1.6 (2.4)	1.2 (2.1)	1.0 (1.5)	1.4 (2.2)

Note. Pen lifts represents planning errors on the test when the pen was lifted from the paper. HS: high school. Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.

Holtzer et al. (2008) The United States of America	TMT A&B, errors stratified by age	N = 2005, $n_{conventional}$ = 1251, n_{robust} = 3-7, $n_{incidence}$ = 58, $n_{prevalence}$ = 75,	**TMT by age and education, mean (SD)**

TMT by age and education, mean (SD)

Age	**70-79**						**80-89**					
Education (years)	**<10**	**10-12**	**>12**	**13-15**	**>16**	**Total**	**<10**	**10-12**	**>12**	**13-15**	**>16**	**Total**

and education	lost to follow up = 314; Age μ conventional = 78.8±5.16, robust 77.2±4.47, incidence 81.4±4.8, prevalence 82.6±5.49, lost to follow-up 78.4±5.14; % female: conventional 59.9%, robust 6.8%, incidence 67.2%, prevalence 64%, lost to follow-up 63.7%; Years of Education μ = conventional 12.7±3.90, robust

TMT A: time	76.7 (37.85)	57.3 (23.16)	50.7 (16.08)	52.4 (15.98)	49.2 (16.13)	54.9 (21.95)	58.8 (12.73)	58.4 (20.01)	67.4 (28.17)	69.1 (27.60)	66.0 (29.53)	62.0 (23.26)
TMT B: time	165.9 (95.83)	125.5 (55.56)	118.1 (50.53)	126.2 (62.99)	111.1 (35.90)	123.3 (56.56)	156.6 (50.74)	151.0 (57.50)	132.60 (62.72)	151.2 (70.89)	116.6 (52.11)	144.5 (58.90)
TMT B: errors	3.3 (4.34)	1.6 (2.56)	1.1 (1.74)	1.4 (2.0)	1.0 (35.90)	1.4 (2.27)	0.7 (0.95)	1.2 (1.76)	1.8 (3.35)	2.1 (3.18)	1.6 (3.59)	1.4 (2.39)

Note. brackets represent standard deviation. Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.

<table>
<tr><td></td><td></td><td>13.5±3.46, incidence 12.5±3.79, prevalence 10.6±4.30, lost to follow-up 11.90±3.58</td><td></td></tr>
<tr><td>Ivnik et al. (1996)
The United States of America</td><td>TMT A&B</td><td>N = 746;
Age μ = NR, min-max:56-95+;
% female = 61.5 for COWAT, 53.4% for TMT;
Years of Education μ = NR, min-max:≤7 – ≥18</td><td>Reference values given for tests' correlations (and shared variance) with age, education and sex and Mayo's Older Americans Normative Studies (MOANS) scaled scores.</td></tr>
<tr><td>Kim et al. (2019)
Korea</td><td>TMT A:B stratified by age</td><td>N = 180;
Age μ = 49.37±17.42, min-max:20-79;
% female = 50.6;</td><td>TMT A:B ratio by age, mean (SD)
<table>
<tr><th>Age</th><th>20-29</th><th>30-39</th><th>40-49</th><th>50-59</th><th>60-69</th><th>70-79</th></tr>
<tr><td></td><td>0.73 (0.51)</td><td>0.73 (0.53)</td><td>0.91 (0.35)</td><td>1.02 (0.34)</td><td>1.18 (0.55)</td><td>1.44 (0.55)</td></tr>
</table>
<i>Note.</i> Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.</td></tr>
</table>

<table>
<tr><td></td><td></td><td>Years of Education μ = NR</td><td></td></tr>
<tr><td>Moggi et al. (2020)
Switzerland</td><td>TMT A&B stratified by age and education</td><td>N = 494;
Age μ = 45.5±11.59, min-max:18-75;
% female = 32;
Years of Education μ = 13.07±2.9</td><td>
TMT A and B by age and education, mean (SD)
<table>
<tr><th>Education (years)</th><th></th><th>Age
35-44</th><th>45-54</th><th>55-59</th><th>60+</th></tr>
<tr><td>0-12</td><td>Trail A (sec)</td><td>38.53 (19.75)</td><td>34.01 (14.38)</td><td>43.13 (14.67)</td><td>55.05 (19.14)</td></tr>
<tr><td></td><td>Trail B (sec)</td><td>94.98 (46.52)</td><td>92.35 (42.12)</td><td>126.13 (41.83)</td><td>140.50 (67.96)</td></tr>
<tr><td>12+</td><td>Trail A (sec)</td><td>27.58 (7.78)</td><td>32.52 (14.02)</td><td>39.00 (14.12)</td><td>39.46 (17.56)</td></tr>
<tr><td></td><td>Trail B (sec)</td><td>72.68 (29.41)</td><td>82.53 (40.91)</td><td>84.56 (29.48)</td><td>113.46 (50.57)</td></tr>
</table>
<i>Note.</i> Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.
</td></tr>
<tr><td>Lucas et al. (2005a)
The United States of America</td><td>TMT A&B</td><td>N = 412;
Age μ = 79.9±8.3, min-max:56-95+;
% female = 64.3;
Years of Education μ = 13.7±3.0</td><td>Only scaled scores presented, no raw scores presented for a TMT. Data presented as normalized raw score for Wechsler Memory Scale-Revised (WAIS-R) similarities and frequencies of Mayo’s Older African Americans Normative Studies (MOAANS) scaled scores.</td></tr>
</table>

<table>
<tr><td>O’Bryant et al. (2018)
The United States of America</td><td>TMT A&B</td><td>N = 653;
Age μ = 67.46±8.93;
% female = 73.4;
Years of Education μ = 9.9±4.6</td><td>Data is presented as linear regression models and the Mayo method was utilized. Mid-point ranges were employed with overlapping subsamples from each stratification variable.</td></tr>
<tr><td>Selander et al. (2020)
Sweden</td><td>TMT A&B stratified by age</td><td>N = 410;
Age μ = 52±16.8, min-max:20-80;
% female = 63.6;
Years of Education μ = NR</td><td>TMT A and B by age, mean (SD)
<table>
<tr><th></th><th>Age
20-39</th><th>40-59</th><th>60-69</th><th>≥70</th></tr>
<tr><td>n</td><td>107</td><td>139</td><td>89</td><td>75</td></tr>
<tr><td>TMT-A (sec)</td><td>23 (6.5)</td><td>26.4 (8.6)</td><td>32.3 (11.4)</td><td>39.6 (12.8)</td></tr>
<tr><td>TMT-B (sec)</td><td>55.2 (21.6)</td><td>57 (21.1)</td><td>75.1 (29.5)</td><td>97.9 (41.6)</td></tr>
</table>
Note. Maximum score on the TMT is 300 seconds and higher scores indicate worse performance.</td></tr>
<tr><td>Steinburg et al., (2005)
The United States of America</td><td>TMT A&B</td><td>N = 1131, n_{TMT} = 354, n_{COWAT} = 777;
Age μ n_{TMT} = NR, min-max:56-94, n_{COWAT} μ = NR, min-max:56-95+;</td><td>Data presented as Pearson r correlation coefficients between demographic variables of age and education and as proportions of variance in Mayo’s Older Americans Normative Studies (MOANS) age-adjusted scores.</td></tr>
</table>

<table>
<tr><td></td><td></td><td>% female =
n_{TMT}: 53.4,
n_{COWAT}: 61.9;
Years of Education μ =
n_{TMT} & n_{COWAT} = NR, min-max:<7 - >18+</td><td></td></tr>
<tr><td>Stewart et al. (2001)
United Kingdom</td><td>TMT A&B</td><td>N = 285;
Age μ = NR, min-max:55-75;
% female = 56.8;
Years of Education μ = NR, “high”: 35, “normal”: 146, “low”: 95</td><td>
<table>
<tr><th colspan="3">TMT-A, mean</th></tr>
<tr><th></th><th>n</th><th>score[†]</th></tr>
<tr><td>Whole sample</td><td>285</td><td>79</td></tr>
<tr><td>Excluding disability*</td><td>220</td><td>277</td></tr>
<tr><td>Age</td><td></td><td></td></tr>
<tr><td>55-64</td><td>116</td><td>68</td></tr>
<tr><td>65-75</td><td>168</td><td>88</td></tr>
<tr><td>Sex</td><td></td><td></td></tr>
<tr><td>Male</td><td>123</td><td>74</td></tr>
<tr><td>Female</td><td>162</td><td>84</td></tr>
<tr><td>Education[‡]</td><td></td><td></td></tr>
<tr><td>High</td><td>35</td><td>60</td></tr>
<tr><td>Normal</td><td>146</td><td>73</td></tr>
<tr><td>Low</td><td>95</td><td>101</td></tr>
<tr><td>Occupational Class[±]</td><td></td><td></td></tr>
<tr><td>1-3n</td><td>88</td><td>65</td></tr>
<tr><td>3m</td><td>105</td><td>80</td></tr>
<tr><td>4-5</td><td>91</td><td>98</td></tr>
</table>
</td></tr>
</table>

Note. *visual difficulties. †Clock Drawing scored /6 as per Shulman et al., 1993 (lower scores = better performance); ‡Education: high = leaving school after age 16; low = leaving school below age 15; normal = leaving school between 15-16 years of age. ±Occupational Class: based on Reistrar-Generals Model of Social Class 1=professional, 2=intermediate, 3n=non-manual skilled, 3m=manual skilled, 4=semi-skilled, 5=unskilled. SD of clock drawing score not reported.

Tombaugh et al. (2004) Canada	TMT A&B stratified by age and education	N = 1300; Age μ = 60.7±19.9, min-max:16-95; % female = 57; Years of Education μ = 12.1±3.2	**TMT A and B by age and education, mean (SD)**								
					Age						
			Education (years)		**55-59**	**60-64**	**65-69**	**70-74**	**75-79**	**80-84**	**85-89**
			0-12	**Trail A (sec)**	35.10 (10.94)	33.22 (9.10)	39.14 (11.84)	42.47 (15.15)	50.81 (17.44)	58.19 (23.31)	57.56 (21.54)
				Trail B (sec)	78.84 (19.09)	74.55 (19.55)	91.32 (28.89)	109.95 (35.15)	130.61 (45.74)	152.74 (65.68)	167.69 (78.50)
			12+	**Trail A (sec)**	31.72 (10.14)	31.32 (6.96)	33.84 (6.69)	40.13 (14.48)	41.74 (15.32)	55.32 (21.28)	63.46 (29.22)
				Trail B (sec)	68.74 (21.02)	64.58 (18.59)	67.12 (9.31)	86.27 (24.07)	100.68 (44.16)	132.15 (42.95)	140.54 (75.38)

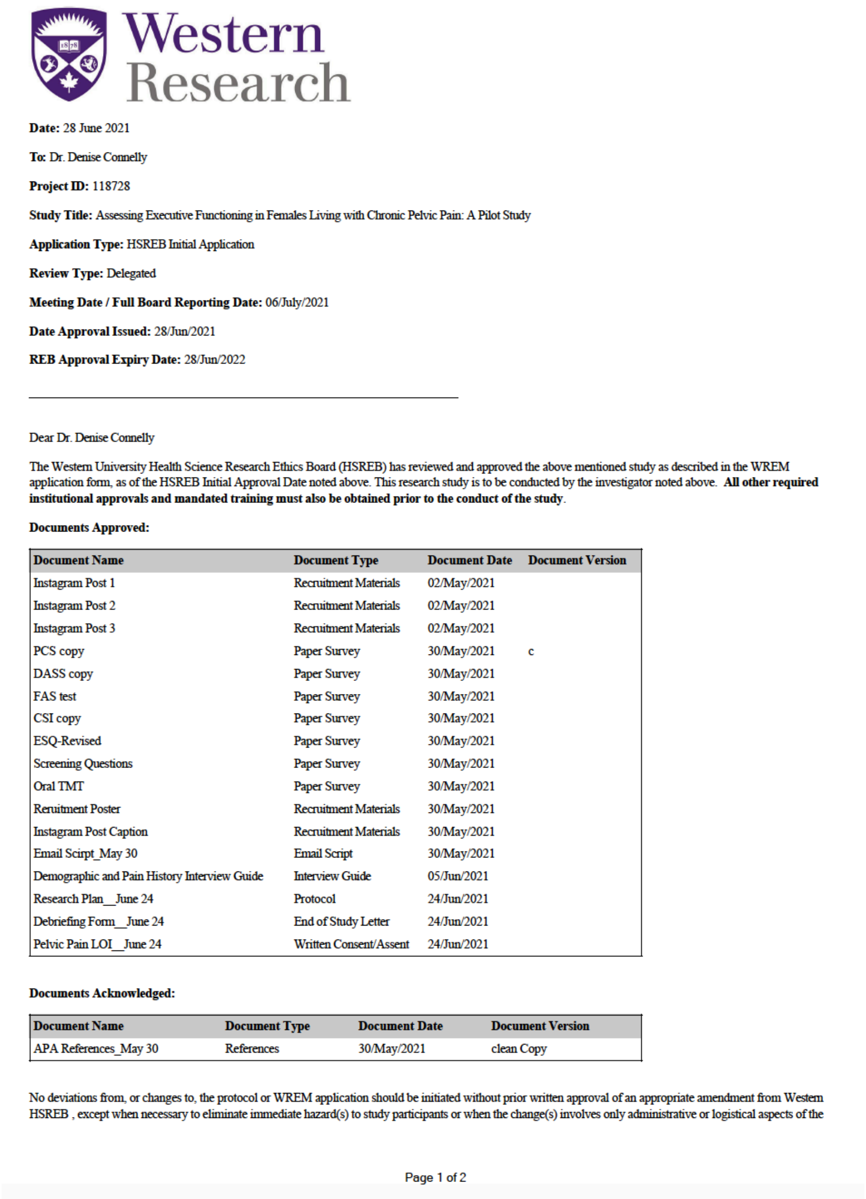
Schneider et al. (2020) The United States of America	TMT A&B stratified by age and education	N = 712; Age μ = 71.0±NR, min-max:61-82; % female = NR; Years of Education μ =	**TMT A and B by age and education, mean (-1.5 SD)**				
					Age		
			Education (years)		**65-<70**	**70-<75**	**75-<80**
			<HS	**Trail A (sec)**	72.06 (120.24)	79.31 (132.34)	87.29 (145.65)
				Trail B (sec)	184.36 (240)	204.93 (240)	227.78 (240)
			HS/equal	**Trail A (sec)**	55.99 (93.42)	61.62 (102.82)	67.82 (113.17)

<table>
<tr><td></td><td></td><td rowspan="4">NR, education < high school = 26.6%, high school/ GED = 23.8, ≥ college = 49.7</td><td></td><td>Trail B (sec)</td><td>153.72 (240)</td><td>170.86 (240)</td><td>189.92 (240)</td></tr>
<tr><td></td><td></td><td>>HS</td><td>Trail A (sec)</td><td>45.80 (76.43)</td><td>50.41 (84.12)</td><td>55.49 (92.59)</td></tr>
<tr><td></td><td></td><td></td><td>Trail B (sec)</td><td>120.41 (208.84)</td><td>133.84 (232.14)</td><td>148.77 (240)</td></tr>
<tr><td></td><td></td><td colspan="5"><i>Note.</i> HS: high school, HS/equal: high school or equivalent.</td></tr>
<tr><td>Lucas et al. (2005b)
The United States of America</td><td>TMT A&B</td><td>N = 309;
Age μ = 69.5±6.9, min-max:43-91;
% female = 74.0%
Years of Education μ = 12.2±3.5</td><td colspan="5">Scores presented as Mayo’s Older African Americans Normative Studies (MOAANS) scaled scores for age groups 56-62, 63-65, 66-68, 69-71, 72-74, 75-77, 78+, and as correlations and shared variances of MOAANS subtest scores with age and years of education.</td></tr>
<tr><td>Lavencic et al. (2019)
Australia</td><td>Oral TMT A&B</td><td>N = 104;
Controls Age μ = 64.9±4.26, min-max: 60-74;
% female = 52.0%
Years of Education μ = 9.71±2.43; MCI group Age μ =</td><td colspan="5">Reference centiles given for Trail-Making Part A time (sec) and Part B time (sec) stratified by education.</td></tr>
</table>

67.7±6.36, min-max: 60-80; % female = 66.0% Years of Education μ = 8.76±2.93; Dementia group Age μ = 69.5±6.78, min-max: 60-88; % female = 37.0% Years of Education μ = 8.40±3.31

Notes. μ = mean; CD = Community Dwelling; MMSE = Mini Mental State Examination; NR = not reported; hx = history; CDR = Clinical Dementia Rating; IQ = Intelligence Quotient; CDT = Clock Drawing Test; DSM-3R: Diagnostics and Statistical Manual Version 3 Revised; HS = high school; COWAT: Controlled Oral Word Association Test; SD = standard deviation; *as reported by the study authors; TMAANS = The Texas Mexican American Adult Normative Study; Project FRONTIER = Facing Rural Obstacles Now Through Intervention, Education, and Research; TARCC = Texas Alzheimer's Research and Care Consortium; HABLE = Health & Aging Brain among Latino Elders; CNS = Central Nervous System; BAF-test = birds and furniture; BNT = Boston Naming Test; GDS = Geriatric Depression Scale; PD = Parkinson's disease; MS = Multiple Sclerosis; mKICA = modified Kimberley Indigenous Cognitive Assessment; RUDAS = Rowland Universal Dementia Assessment Scale

Appendix H: Ethics Approval for Study 3



Western
Research

Date: 28 June 2021

To: Dr. Denise Connelly

Project ID: 118728

Study Title: Assessing Executive Functioning in Females Living with Chronic Pelvic Pain: A Pilot Study

Application Type: HSREB Initial Application

Review Type: Delegated

Meeting Date / Full Board Reporting Date: 06/July/2021

Date Approval Issued: 28/Jun/2021

REB Approval Expiry Date: 28/Jun/2022

Dear Dr. Denise Connelly

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. **All other required institutional approvals and mandated training must also be obtained prior to the conduct of the study.**

Documents Approved:

Document Name	Document Type	Document Date	Document Version
Instagram Post 1	Recruitment Materials	02/May/2021	
Instagram Post 2	Recruitment Materials	02/May/2021	
Instagram Post 3	Recruitment Materials	02/May/2021	
PCS copy	Paper Survey	30/May/2021	c
DASS copy	Paper Survey	30/May/2021	
FAS test	Paper Survey	30/May/2021	
CSI copy	Paper Survey	30/May/2021	
ESQ-Revised	Paper Survey	30/May/2021	
Screening Questions	Paper Survey	30/May/2021	
Oral TMT	Paper Survey	30/May/2021	
Reruitment Poster	Recruitment Materials	30/May/2021	
Instagram Post Caption	Recruitment Materials	30/May/2021	
Email Script_May 30	Email Script	30/May/2021	
Demographic and Pain History Interview Guide	Interview Guide	05/Jun/2021	
Research Plan__June 24	Protocol	24/Jun/2021	
Debriefing Form__June 24	End of Study Letter	24/Jun/2021	
Pelvic Pain LOI__June 24	Written Consent/Assent	24/Jun/2021	

Documents Acknowledged:

Document Name	Document Type	Document Date	Document Version
APA References_May 30	References	30/May/2021	clean Copy

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the

Appendix I: Instagram Posts Approved by Western University Ethics Board

Appendix J: Recruitment Poster

Western

Assessing Executive Functioning in Females Living with Chronic Pelvic Pain: A Pilot Study

PARTICIPANTS NEEDED FOR RESEARCH IN COGNITION & PELVIC PAIN

We are looking for volunteers to take part in a study assessing cognitive abilities who:

1. Identify as female
2. Are between the ages of 18-40
3. Read, write & speak English
4. Have been experiencing constant or occasional **pain in the pelvic region** for at least 6 months (e.g., this includes painful menstrual periods, abdominal, pelvic, tailbone, hip or low back pain, pain with sex, penetration or arousal, diagnosed pelvic pain conditions like endometriosis, interstitial cystitis and more).

If you are interested and agree to participate you would be asked to:

- Attend one 60-90 minute online video session with the study investigator to review your medical history and to complete a number of cognitive and pain questionnaires

For more information about this study, to volunteer to participate, or to ask about eligibility please contact Nicole Guitar.

Nicole Guitar, PhD(c), MPT, MSc, BSc
Study Investigator
The School of Physical Therapy at Western University

Denise M. Connelly, PhD, PT
Principal Investigator
The School of Physical Therapy at Western University

Appendix K: Study 3 Letter of Information

Assessing Executive Functioning in Females Living with Chronic Pelvic Pain: A Pilot Study

Letter of Information

Principal Investigator:
Denise M. Connelly, PhD, PT
Associate Professor
School of Physical Therapy
Western University

Study Investigator:
Nicole A. Guitar PhD Candidate
MPT, MSc, BSc(Hons)
School of Physical Therapy
Western University

Introduction

You are being invited to participate in this study because you are living with Chronic Pelvic Pain (i.e., pain in the region of your pelvis). The purpose of this letter is to provide you with detailed information required for you to make an informed decision about whether or not to participate in this research. Once you understand the study, you will be asked orally to indicate this on the consent form if you wish to participate. Please take your time to make your decision and feel free to ask questions via email or phone.

Research suggests that impairments in executive functioning are prevalent in people living with chronic pain. Executive functioning refers to cognitive abilities involved in decision-making and self-regulation (i.e., control of one's behaviour in pursuit of long-term goals). It includes the abilities needed to plan, judge, reason, solve problems and organize. People living with chronic pain are commonly seen by physiotherapists, and research shows that pain should be treated from a biopsychosocial perspective that incorporates awareness of the biological (e.g., bone, tendon or ligament injury), psychological (e.g., cognition, behaviour, mood) and social (e.g., cultural) components of a person's pain.

The Chronic Pelvic Pain population has not been included in previous research examining the relationship between chronic musculoskeletal pain and executive functioning. Chronic Pelvic Pain is a major problem identified throughout the world by the International Continence Society and the recent American College of Obstetricians and Gynaecologists clinical practice guideline update. Physiotherapists need to understand the impact of executive functioning impairments on rehabilitation in order to develop strategies to minimize those impacts through interdisciplinary collaboration.

Purpose

The purpose of this study is to examine the feasibility of recruitment, retention, assessment procedures and data collection for research examining executive functioning in females living with chronic pelvic pain. Additionally, we seek to understand: (1) if descriptive patterns in executive functioning assessment measures suggest the presence of executive functioning impairments in this sample; and (2) how self-reported scores on pain catastrophizing, central sensitization, depression, anxiety and stress compare to normative age and sex matched data. These objectives will be addressed by conducting virtual interviews with people living with Chronic Pelvic Pain.

Eligibility

You are eligible to participate in this study if you are between 18-40 years of age, identify as female, are able to read and write in the English language and if you have been experiencing constant or intermittent pain in your pelvic region for ≥ 6 months (e.g., pain that is always present or that comes and goes over the last six months that includes abdominal, pelvic, tailbone, hip or low back pain, menstrual pain, pain with sex, penetration or arousal). Your pain does not have to be officially diagnosed, but you are still eligible if it has been diagnosed. Common Chronic Pelvic Pain conditions include dyspareunia (pain with intercourse), endometriosis, dysmenorrhea (painful menstrual periods) and interstitial cystitis (also known as painful bladder syndrome). Interested participants will be selected for participation based on the order in which they reach out for more information on the study and a maximum of 16 interviews will occur per week. The study will run for 12-weeks in total.

People will be excluded from participating in this study if they report being diagnosed with cognitive impairment, terminal cancer, a stroke, neurological or demyelization disease, myopathies or another illness likely to influence cognitive function measurements. Potential participants will also be excluded if they report reaching premature menopause (i.e., they have not had a menstrual period in the last 12-months, are not using hormone therapy, and have not been diagnosed with another condition that would explain the absence of a menstrual cycle such as Polycystic Ovarian Syndrome, also known as PCOS). In addition, people currently undergoing physiotherapy treatment with the Study Investigator are not eligible for participation in this study.

Participating in this study will involve attending one 60–90-minute session virtually with the Study Investigator to provide information about your past medical history, pelvic pain and demographic characteristics, and completing a series of assessment measures virtually with the Study Investigator.

Study Procedures

You will have received an email from Nicole Guitar containing this Letter of Information. If you are interested in participating in the study, please email Nicole Guitar (Study Investigator) to schedule an interview at a time that is convenient for you. At the beginning of the interview, you will have 15-minutes to ask questions about this Letter of Information before your consent to participate will be confirmed. The interview will include questions about your medical history and your pelvic pain. In addition, we will complete numerous assessment measures of executive functioning (i.e., the Oral Trail-Making Test (TMT), Verbal Fluency Test (PFT: FAS-test), and Executive Skills Questionnaire Revised (ESQ-R)), pain (i.e., the Pain Catastrophizing Scale (PCS), Central Sensitization Inventory (CSI), Numeric Pain Rating Scale (NPRS)), and the short form of the Depression, Anxiety and Stress Scale (DASS). At the end of the interview, if you are interested, you will be provided with a handout about *Understanding Pain,* and you will have the option to learn how to perform deep breathing as a pain reduction technique. This is not part of the study procedure.

The interview will last approximately 60-90 minutes and will be conducted by the Study Investigator using Western's licensed Zoom platform. Zoom is a cloud-based peer-to-peer software platform that is used for teleconferencing, telecommuting, distance education, and social relations. It has been found that the Zoom platform is adequate in terms of encrypting data in transit. Western's contract with Zoom prohibits the selling of our community's data to third parties. You will be emailed a secure zoom link invitation and password for the day and time of your interview. If you do not have an existing Zoom account, you will be automatically prompted to download the software and create a profile by using your email address. The interview will be audio-recorded using the record feature on Zoom in order to ensure your responses are accurately collected and interpreted. Although Zoom will automatically record using video and audio, only the audio-recorded file will be saved and the file containing video will be deleted immediately. The audio-recording will be stored securely and will only be accessible to the research team for analysis. These audio recordings will only be transcribed by Nicole Guitar in the event that data needs to be confirmed or is missing from the written paper questionnaires. The Study Investigator will conduct the interview from a private environment.

Confidentiality

All information will be kept confidential to the best of our ability. Audio-recorded interviews will not include any personal identifiers including the person's name or workplace. Interview transcripts will be given a personal identification number (PIN). Only PINs will be used to identify data, and results will be presented in aggregate form in eventual publications and presentations. Electronic data will be stored on Western One Drive on the study coordinator's password protected and encrypted computer. To minimize movement during the COVID-19 pandemic, hard copies of study data will be retained in a locked filing cabinet at the Study Investigators home until the study is completed. When the study is completed after 3-months, the hard copies will be transported in the Study Investigators personal vehicle to be stored in the office of the principal investigator at Western University. The data may be transported to Western University prior to the study being completed for viewing by the PI. Study data will be kept for seven years, as per Western policy, and will then be destroyed. Representatives of the Western University Health Sciences Research Ethics Board may require access to your study-related records or follow-up with you to monitor the conduct of this research.

Voluntary Participation

Participating in this study is completely voluntary and does not prevent you from participating in any other research studies at the present time or future. No legal rights are waived by signing the consent form. You may refuse to participate, refuse to answer questions or withdraw from the study at any time. Should you choose to withdraw from this study, you will have the option to revoke all data or allow use of data collected up to the point that you chose to withdraw with no further data collected. If you would like to withdraw from this study, you will need to provide written or verbal confirmation to the study coordinator: Nicole Guitar at email:________, phone: ________.

Risks

All data will be secured, but there is a remote chance of a privacy breach, in which case you will be immediately informed. There have been reports of something called "Zoombombing" happening in other uses of Zoom. This practice is related to someone gaining entry to a session and hijacking the meeting with malicious videos and/or audio/chat content. Typically, this practice happens when a large gathering is happening where the host may not have a full grasp on who is in the meeting. To avoid this, please do not share the private link or password for your interview. In the event this should happen, the interview will be immediately stopped, and a new link and password will be emailed to resume the interview.

You may feel psychological distress as a result of completing questionnaires about your cognition, pain, depression, anxiety and/or stress. If you are experiencing distress at any point during the study, please contact: telehealth Ontario, a free confidential service you can call to get health advice or information, at 1-866-797-0000; Crisis Services Canada, for suicide prevention and support, at 1-833-456-4566; or ConnexOntario, a free and confidential 24-hour health service for people experiencing problems with alcohol and drugs, mental health and/or gambling, at 1-866-531-2600

If you have scores categorized in the “extremely severe” symptoms category of depression, anxiety or stress as measured by the short-version of the Depression, Anxiety and Stress Scale, we will inform you and provide you a minimum of three options for counselling services in your city. As a result of learning about a your pain and past medical history, the Study Investigator may suspect an undiagnosed medical condition and will share this information with you.

Benefits

There are no known benefits to participants for participating in this study.

Costs

There is no cost associated with your participation in this study.

Compensation

There is no compensation associated with your participation in this survey.

After Study Completion

After study completion, your obligations as a participant will be complete.

Questions About the Study

If you have any questions regarding participating in this study, please contact Nicole Guitar at _________ or _________ (Study Investigator) or Dr. Denise Connelly (Principal Investigator) at__________. If you have questions before signing the consent form, please contact Nicole Guitar. Please understand that email is not a secure form of communication.

Contact for Concerns about the Rights of Research Participants:

If you have any questions about your rights as a research participant or the conduct of this survey, you may contact The Office of Research Ethics (519) 661-3036, email: ethics@uwo.ca.

Consent Form

Study Title: Assessing Executive Functioning in Females Living with Chronic Pelvic Pain: A Pilot Study

I (participant) have read the Letter of Information, have had the nature of the study explained to me and I agree to provide verbal consent to participate in this study. All questions have been answered to my satisfaction. I (participant) will retain a copy of the Letter of Information for future reference.

Verbal Consent

I (person obtaining consent) have confirmed informed consent with participant prior to completing the interview.

Printed Name of Participant

Printed Name of Person Obtaining Consent	Signature of Person Obtaining Consent	Date

Appendix L: Study 3 Screening Questions

Screening Questions

1. Do you identify as female?

☐ yes
☐ no

2. Are you between 18-40 years of age?

☐ yes
☐ no

3. Can you read, speak and write in English?

☐ yes
☐ no

4. Do you have any diagnosed neurological conditions or disorders? If yes, explain.

☐ yes:-
____
☐ no

5. Do you have any diagnosed cognitive impairments? If yes, explain.

☐ yes: -
____
☐ no

6. Have you had a menstrual cycle in the last 12-months?

☐ yes
☐ no – answer question 7

7. If no was selected for question 6 please indicate if you have not had a menstrual cycle in the last 12-months if this because you are purposefully using a hormone therapy (e.g., birth control) to prevent it?

☐ yes
☐ no

8. Do you have pain or discomfort in your “pelvic region” that has either been constant or that comes and goes over the last six months? Pain in the “pelvic region” includes but is not limited to abdominal, pelvic, tailbone, hip or low back pain, menstrual pain, pain with sex, penetration, or arousal. If yes, briefly explain.

☐ yes: -

☐ no

Appendix M: Study 3 Demographic and Pain History Interview Guide

Demographic and Pain History Interview Guide

1. Review all screening questions

☐ complete

2. Has informed consent been obtained, and the participant provided the opportunity to ask questions?

☐ complete

3. Confirm the participant understands they will be audio recorded.

☐ complete

4. Collect participant's age

Age: ___________________

5. Years of education: ____
6. Please describe the pelvic pain you experience:
7. When did you start to notice your pelvic pain?
8. Is it always there or does it come and go?
9. What makes it better?
10. What makes it worse?
11. How long does it usually last?
12. Have you received any previous treatment or care for your pelvic pain? If so, please explain.
13. On a scale from 0-10, how much does your pelvic pain **bother** you over the last 6-months? /10
14. On a scale from 0-10, how **motivated** are you to change your pelvic pain? /10
15. On a scale from 0-10, what would you rate your pelvic pain on **average** over the last 6-months? (0 = no pain at all, 10 = the worst pain you could imagine)? /10
16. On a scale from 0-10, what would you rate your pelvic pain at its **worst** over the last 6-months? (0 = no pain at all, 10 = the worst pain you could imagine)? /10
17. On a scale from 0-10, what would you rate your pelvic pain at its **best** over the last 6-months? (0 = no pain at all, 10 = the worst pain you could imagine)? /10
18. If you did not have this pelvic pain, what would you be doing in your life now that you are not doing?
19. Have you ever birthed any children? If so, please consider sharing what year they were born, how much the baby weighed, whether forceps or vacuums used, if you remember having an episiotomy, tearing or stitches, how long you pushed for, and whether there were any complications?

20. How would you describe your menstrual cycle? Please include information such as your cycles length, any symptoms you experience when you are menstruating and whether you are on birth control medication.
21. Please list any conditions you have ever been diagnosed with and the year you were diagnosed.
22. Please list any medications you are currently taking (including prescription and non-prescription medications).
23. Are you satisfied with your current sleep? Please include information such as the number of hours per night you sleep, if you find it difficult to fall asleep or stay asleep and if you feel rested when you wake up.
24. Do you currently live with any other individuals? If so, please outline your relationships with these individuals.
25. Are you employed? If so, please describe your work and role.

Appendix N: Central Sensitization Inventory

Part A

Please circle the best response to the right of each statement

I feel un-refreshed when I wake up in the morning.	Never	Rarely	Sometimes	Often	Always
My muscles feel stiff and achy.	Never	Rarely	Sometimes	Often	Always
I have anxiety attacks.	Never	Rarely	Sometimes	Often	Always
I grind or clench my teeth.	Never	Rarely	Sometimes	Often	Always
I have problems with diarrhea and/or constipation.	Never	Rarely	Sometimes	Often	Always
I need help in performing my daily activities.	Never	Rarely	Sometimes	Often	Always
I am sensitive to bright lights.	Never	Rarely	Sometimes	Often	Always
I get tired very easily when I am physically active.	Never	Rarely	Sometimes	Often	Always
I feel pain all over my body.	Never	Rarely	Sometimes	Often	Always
I have headaches.	Never	Rarely	Sometimes	Often	Always
I feel discomfort in my bladder and/or burning when I urinate.	Never	Rarely	Sometimes	Often	Always
I do not sleep well.	Never	Rarely	Sometimes	Often	Always
I have difficulty concentrating.	Never	Rarely	Sometimes	Often	Always
I have skin problems such as dryness, itchiness or rashes.	Never	Rarely	Sometimes	Often	Always
Stress makes my physical symptoms get worse.	Never	Rarely	Sometimes	Often	Always
I feel sad or depressed.	Never	Rarely	Sometimes	Often	Always
I have low energy.	Never	Rarely	Sometimes	Often	Always
I have muscle tension in my neck and shoulders.	Never	Rarely	Sometimes	Often	Always
I have pain in my jaw.	Never	Rarely	Sometimes	Often	Always
Certain smells, such as perfumes, make me feel dizzy and nauseated.	Never	Rarely	Sometimes	Often	Always
I have to urinate frequently.	Never	Rarely	Sometimes	Often	Always

My legs feel uncomfortable and restless when I am trying to go to sleep at night.	Never	Rarely	Sometimes	Often	Always
I have difficulty remembering things.	Never	Rarely	Sometimes	Often	Always
I suffered trauma as a child.	Never	Rarely	Sometimes	Often	Always
I have pain in my pelvic area.	Never	Rarely	Sometimes	Often	Always

Central Sensitization Inventory: Part B

Have you been diagnosed by a doctor with any of the following disorders?

	No	Yes	Diagnosed
1. Restless leg syndrome			
2. Chronic fatigue syndrome			
3. Fibromyalgia			
4. Temporomandibular joint disorder (TMJ)			
5. Irritable bowel syndrome			
6. Multiple chemical sensitivities			
7. Neck injury (including whiplash)			
9. Anxiety or panic attacks			
10. Depression			

Appendix O: Pain Catastrophizing Questionnaire

PCS Questionnaire

Everyone experiences painful situations at some point in their lives. Such experiences may include headaches, tooth pain, joint or muscle pain. People are often exposed to situations that may cause pain such as illness, injury, dental procedures or surgery.

We are interested in the types of thoughts and feelings that you have when you are in pain. Listed below are 13 statements describing different thoughts and feelings that may be associated with pain. Using the following scale, please indicate the degree to which you have these thoughts and feelings when you experience pain.
0 = not at all 1 = to a slight degree 2 = to a moderate degree 3 = to a great degree 4 = all the time

When I'm in pain………

(H) _______ I worry all the time about whether the pain will end

(H) _______ I feel I can't go on

(H) _______ It's terrible and I think it's never going to get any better

(H) _______ It's awful and I feel that it overwhelms me

(H) _______ I feel I can't stand it anymore

(M) _______ I become afraid that the pain will get worse

(M) _______ I keep thinking of other painful events

(R) _______ I anxiously want the pain to go away

(R) _______ I can't seem to keep it out of my mind

____

(R) _______ I keep thinking about how much it hurts

(R) _______ I keep thinking about how badly I want the pain to stop

(H) _______ There’s nothing I can do to reduce the intensity of my pain

(M) _______ I wonder whether something serious will happen

TOTAL: _______

Appendix P: Depression, Anxiety and Stress Scale

DASS Questionnaire

Please read each statement and circle a number, o, 1, 2, or 3, which indicates how much the statement applied to you *over the past week*. There are no right or wrong answers. Do not spend too much time on any statement.

S = _____ A = _____ D = _____

0 = It did not apply to me at all
1 = Applied to me to some degree or some of the time
2 = Applied to me a considerable degree, or a good part of the time
3 = Applied to me very much, or most of the time

I find it hard to wind down	S	0	1	2	3
I was aware of dryness of my mouth	A	0	1	2	3
I could not seem to experience any feeling at all	D	0	1	2	3
I experienced breathing difficulty (e.g. excessively rapid breathing, breathlessness in the absence of physical exertion	A	0	1	2	3
I found it difficult to work up the initiative to do things	D	0	1	2	3
I tended to over-react to situations	S	0	1	2	3
I experienced trembling (e.g. hands)	A	0	1	2	3
I felt that I was using a lot of nervous energy	S	0	1	2	3
I was worried about situations in which I might panic and make a fool of myself	A	0	1	2	3
I felt that I had nothing to look forward to	D	0	1	2	3
I found myself getting agitated	S	0	1	2	3
I found it difficult to relax	S	0	1	2	3
I felt down-hearted and blue	D	0	1	2	3
I was intolerant of anything that kept me from getting on with what I was doing	S	0	1	2	3

I felt I was close to panic	A	0	1	2	3
I was unable to become enthusiastic about anything	D	0	1	2	3
I felt I was not much of a person	D	0	1	2	3
I felt that I was rather touchy	S	0	1	2	3
I was aware of the action of my heart in the absence of physical exertion (e.g. sense of heart rate increase, heart missing a beat)	A	0	1	2	3
I felt scared without any good reason	A	0	1	2	3
I felt that life was meaningless	D	0	1	2	3

Appendix Q: Oral Trail-Making Test

Oral Trail Making Test Scoring

Oral TMT-A

Read the instructions are as follows: “I’d like you to count from 1 to 25 as quickly as you can. 1, 2, 3, 4, and so on. Ready? [confirm understanding with participant]. Begin [examiner starts a timer]”.

If a mistake is made, the examiner stops the participant and points out the last correct item. Then, the participant continues with the series from the corrected number. The total time required to complete the series, including the time to offer corrections, is recorded.

TMT-A Time total (seconds): ________

Oral TMT-B

Read the instructions are as follows: “Now I’d like you to switch between numbers and letter when you count. 1, A, 2, B, 3, C, and so on until you reach the number 13.”

If the participant makes an error, the examiner identifies the last correct item and tells the participant to continue the series from that item. The total time required to complete the series, including the time to offer corrections, is recorded.

TMT-B Time total (seconds): ________

Appendix R: FAS-test

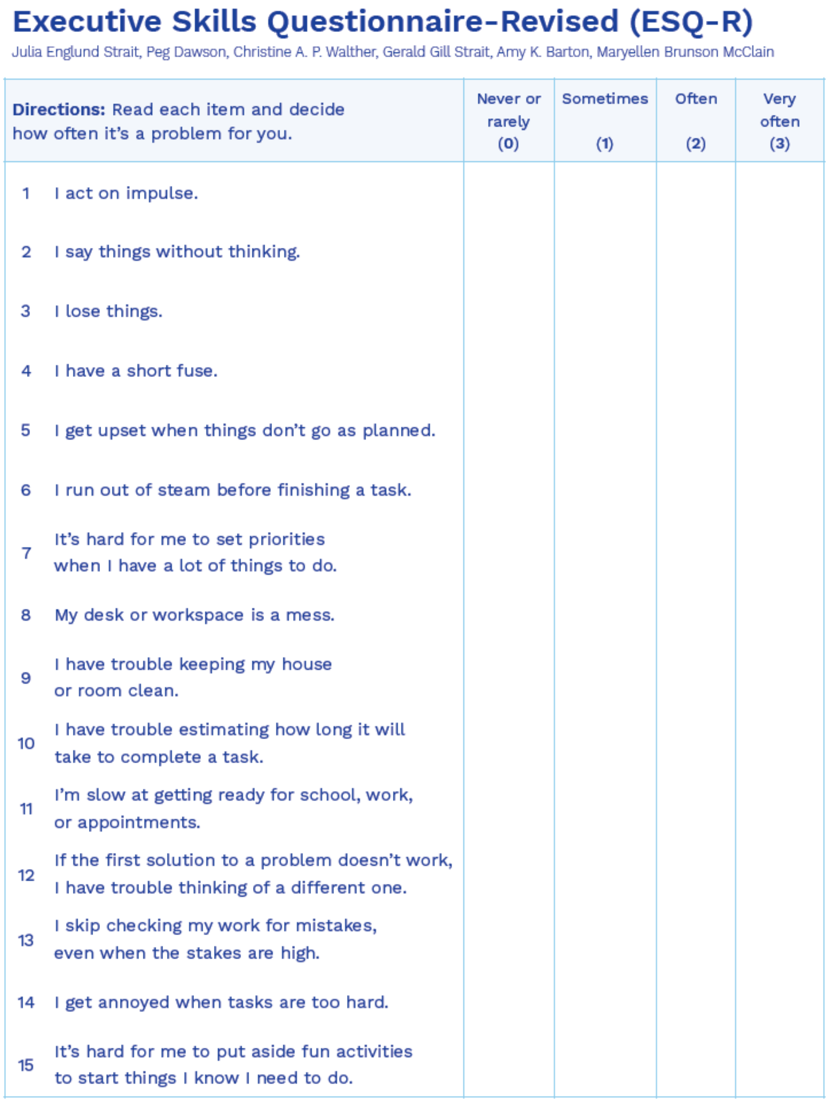
Using a stopwatch have the participant comfortably seated before giving the following instructions: “I will say a letter of the alphabet. Then I want you to give me as many words that begin with that letter as quickly as you can. For example, if I say ‘B’ you might say ‘bad,’ ‘battle,’ and ‘bed.’ I do not want you to use words that are proper names such as ‘Boston,’ ‘Bob’ or ‘Buick.’ Also, do not use the same word with different endings such as ‘eat’ and ‘eating.’ Any questions? (pause for questions). Begin when I say the letter. The first letter is ‘F’, go ahead.”

Begin timing the participant immediately.

Allow one-minute for each letter (F, A and S). Say “fine” or “good” after each one-minute performance. If the participant stops before the end of the minute, encourage them to try to think of more words. If there is a silence of 15-seconds, repeat the basic instructions and the letter. For scoring purposes write down the actual words in the order in which they were produced. If repetitions occur that may be acceptable if an alternate meaning was intended by the examinee (e.g., “four” and “for”, “sun” and “son”), ask what was meant by this word at the end of the one-minute period. Administer all three letters.

Scoring phonemic fluency. The total score is the sum of all admissible words for the three letters. Slang terms and foreign words that are part of standard English (e.g., “faux pas” or “lasagna”) are acceptable. Inadmissible words under these instructions (e.g. proper names, wrong words, variations, repetitions) are not counted as correct.

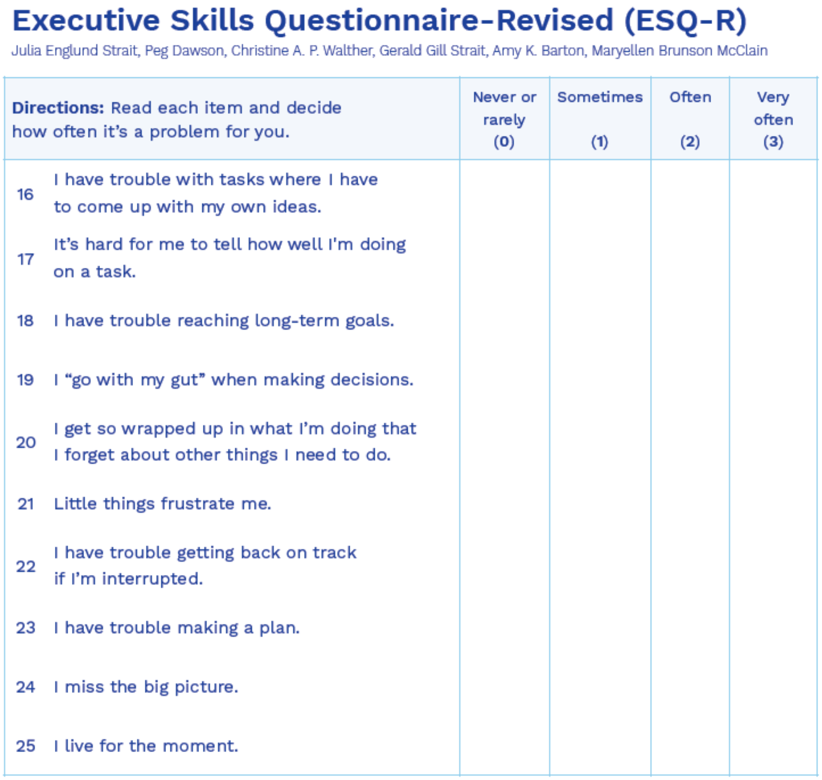
Appendix S: Executive Skills Questionnaire-Revised



Executive Skills Questionnaire-Revised (ESQ-R)

Julia Englund Strait, Peg Dawson, Christine A. P. Walther, Gerald Gill Strait, Amy K. Barton, Maryellen Brunson McClain

	Directions: Read each item and decide how often it's a problem for you.	Never or rarely (0)	Sometimes (1)	Often (2)	Very often (3)
1	I act on impulse.				
2	I say things without thinking.				
3	I lose things.				
4	I have a short fuse.				
5	I get upset when things don't go as planned.				
6	I run out of steam before finishing a task.				
7	It's hard for me to set priorities when I have a lot of things to do.				
8	My desk or workspace is a mess.				
9	I have trouble keeping my house or room clean.				
10	I have trouble estimating how long it will take to complete a task.				
11	I'm slow at getting ready for school, work, or appointments.				
12	If the first solution to a problem doesn't work, I have trouble thinking of a different one.				
13	I skip checking my work for mistakes, even when the stakes are high.				
14	I get annoyed when tasks are too hard.				
15	It's hard for me to put aside fun activities to start things I know I need to do.				



Executive Skills Questionnaire-Revised (ESQ-R)

Julia Englund Strait, Peg Dawson, Christine A. P. Walther, Gerald Gill Strait, Amy K. Barton, Maryellen Brunson McClain

	Directions: Read each item and decide how often it's a problem for you.	Never or rarely (0)	Sometimes (1)	Often (2)	Very often (3)
16	I have trouble with tasks where I have to come up with my own ideas.				
17	It's hard for me to tell how well I'm doing on a task.				
18	I have trouble reaching long-term goals.				
19	I "go with my gut" when making decisions.				
20	I get so wrapped up in what I'm doing that I forget about other things I need to do.				
21	Little things frustrate me.				
22	I have trouble getting back on track if I'm interrupted.				
23	I have trouble making a plan.				
24	I miss the big picture.				
25	I live for the moment.				

Appendix T: Frequencies of Reported Descriptions for each Category

Frequencies of reported descriptions for each category.

Pelvic pain type	**Frequency of response**	**%**
Endometriosis	25	71.43
Dyspareunia	14	40.00
Dysmenorrhea	12	34.29
Polycystic Ovarian Syndrome (PCOS)	8	22.86
Adenomyosis	6	17.14
Uterine fibroids	4	11.43
Vestibulodynia/ Vulvodynia	4	11.43
Interstitial Cystitis (IC)	2	5.71
Lichen’s Sclerosis (LS)	1	2.86
Pain descriptive words		
Sharp/ stabbing/ shooting	19	54.29
Cramping	10	28.57
Heaviness/ fullness	6	17.14
Burning/ fire/ hot	5	14.29
Dull	5	14.29
Ache	3	8.57
Contraction-like	2	5.71
Pulling	2	5.71
Dragging	1	2.86
Location (i.e., aside from “pelvis”)		
Low back	15	42.86
Abdomen	9	25.71
Hip(s)	5	14.29
Leg(s)	5	14.29
Vulva	4	11.43
Comorbidities		
Anxiety or panic attacks	21	60.00
Irritable Bowel Syndrome (IBS)	16	45.71
Depression	14	40.00
Temporomandibular Joint Dysfunction (TMJ)	9	25.71
Chronic headaches or migraines	7	20.00
Previous concussion	6	17.14
Restless Leg Syndrome	3	8.57
Fibromyalgia	3	8.57
Hypermobility	2	5.71
Scoliosis	2	5.71

Chronic Fatigue Syndrome	2	5.71
Lymphoma	1	2.86
Pelvic Girdle Pain	1	2.86
Carpal Tunnel Syndrome	1	2.86
Postural Orthostatic Tachycardia Syndrome (POTS)	1	2.86
Ehler's Danlos Syndrome (EDS)	1	2.86
Chronic Regional Pain Syndrome (CRPS)	1	2.86
Arthritis	1	2.86
Celiac Disease	1	2.86
Obsessive Compulsive Disorder (OCD)	1	2.86
Tachycardia	1	2.86
Hypothyroidism	1	2.86
Skin issues (e.g., eczema, psoriasis)	1	2.86
Easing Factors		
Heat	30	85.71
Non-steroidal anti-inflammatory drugs (NSAIDS)	17	48.57
Rest or not moving	8	22.86
Cannabidiol (CBD; inhalation or topical)	7	20.00
Transcutaneous Electrical Nerve Stimulation (TENS)	6	17.14
Walks or gentle movement	5	14.29
Meditation	1	2.86
Dimenhydrinate oral (e.g., Gravol)	1	2.86
Iron	1	2.86
Magnesium	1	2.86
Herbal tea	1	2.86
Acupuncture	1	2.86
Rubefacient topical (e.g., Rub A535)	1	2.86
Aggravating factors		
Stress	9	25.71
Alcohol	9	25.71
Penetrative Intercourse	8	22.86
Sugar	7	20.00
Dairy	7	20.00
High-fat foods	6	17.14
Caffeine	6	17.14
Movement	6	17.14
Prolonged positions	5	14.29
Gluten	4	11.43

Eating	4	11.43
Irritable Bowel Syndrome flares	1	2.86
Hot weather	1	2.86
Prescribed medications		
Prozac	2	5.71
Visanne	1	2.86
Marvelon	1	2.86
Proton Pump Inhibitor (brand unknown)	1	2.86
Beta Blocker (brand unknown)	1	2.86
Wellbutrin	1	2.86
Tramadol	1	2.86
Mefenamic Acid	1	2.86
Lyrica	1	2.86
Symbalta	1	2.86
Occupation		
Graduate student	8	22.86
Administrative Assistant	5	14.29
Unemployed	5	14.29
Nurse	3	8.57
Event Coordinator	2	5.71
Educational Assistant	1	2.86
Speech-language Pathologist	1	2.86
Photographer	1	2.86
Government employee	1	2.86
Disability (e.g., ODSP)	1	2.86
Social Worker	1	2.86
Personal Trainer	1	2.86
Optometry Technician	1	2.86
Data Analyst	1	2.86
Writer	1	2.86
Childcare coordinator	1	2.86
Lecturer	1	2.86
Nutritionist	1	2.86
Living Arrangement		
With family members*	13	37.14
With married partner	7	20.00
With married partner and children	5	14.29
With partner	5	14.29
With friends	3	8.57
With no other individuals	2	5.71

Note. *family members are not married partners or children.

Curriculum Vitae

Name:	Nicole Guitar
Post-secondary Education and Degrees:	The University of Western Ontario London, Ontario, Canada 2010-2014 BSc Psychology
	The University of Western Ontario London, Ontario, Canada 2014-2016 MSc Psychology
	The University of Western Ontario London, Ontario, Canada 2018-2020 MPT Physical Therapy
	The University of Western Ontario London, Ontario, Canada 2016-2021 anticipated PhD Physical Therapy
Honors and Awards:	Western University Continuing Entrance Scholarship, $10,000 annually 2010-2014
	Queen Elizabeth II Aiming for the Top Scholarship, $13,000 annually 2010-2014
	Western University Faculty of Social Science Alumni Award, $1,000 2012
	Royal Bank of Canada (RBC) Collaborative Community Project Award, $1,000 2014

Royal Bank of Canada (RBC) Community Professor Award, $1,000
2014

Ron Weisman Outstanding Student Presentation Award, 23rd International Conference on Comparative Cognition, $75
2016

Province of Ontario Graduate Scholarship (OGS), $15,000
2017-2018
2018-2019
2019-2020
2020-2021

Tri-Council Mentorship Program Canadian Institute of Health Research (CIHR) Incentive, Western University, $1,000
2017

International Alzheimer's Association & The International Society to Advance Alzheimer's Research and Treatment (ISTAART) Student Award, $8,000
2017

Canadian Physiotherapy Association Student Award, $500
2019

London Health Research Day First Place PhD Poster Award, $50
2019

Ontario Women's Health Scholars Award Western University School of Graduate and Postdoctoral Studies Nomination
2020-2021

Peer-Reviewed Publications: [h-index: 5, total citations: 101]

Guitar, N. A., Connelly, D. M., Murray, L. & Hunter, S. W. (2021). A systematic review of normative data for the interpretation of executive functioning in older adults: Clock drawing, fluency, and trail-making tests. Submitted to *The Canadian Journal on Aging* [contribution: 90%; impact factor: 10.39]

Harriss., A., **Guitar, N. A.,** & Dickey, J. P. (2021). The impact of COVID-19 on second-year Physiotherapy students' confidence in professional competencies: A national Canadian survey. Submitted to *Physiotherapy Canada* [contribution: 40%; impact factor: 2.47]

Guitar, N. A., Connelly, D. M., Murray, L. & Hunter, S. W. (2021). A survey of Canadian physiotherapists and physiotherapy students' knowledge and use of executive functioning assessments in clinical practice. Accepted to *Physiotherapy Canada* August 10th, 2021. ID: PTC-2021-0020. [contribution: 90%; impact factor: 1.4]

Guitar, N. A. & Connelly, D. M. (2020). What outcome measures are used to evaluate interprofessional learning by health care professional students during clinical experiences? A systematic review. *Evaluation and the Health Professions, 1-9.* [contribution: 70%; impact factor: 1.6]

Guitar, N. A., Connelly, D. M., Nagamatsu, L., Orange, J. B., & Hunter, S. W. (2018). The effects of physical exercise on executive function in community-dwelling older adults living with Alzheimer's type dementia: A systematic review. *Ageing Research Reviews*, 47, 159-167. [contribution: 80%; impact factor: 8.9; citations: 48]

Guitar, N. A., Sherry, D. F (2018). Decreased neurogenesis increases spatial reversal errors in chickadees (Poecile atricapillus). *Developmental Neurobiology*, *78*(12), 1206-1217. https://doi.org/10.1002/dneu.22641 [contribution: 80%; impact factor: 2.59; citations: 3]

Guitar, N. A., MacDougall, A., Connelly, D. M., & Knight, E. (2017). Is a Fitbit workplace sedentary behaviour intervention effective? *Health and Safety at Work*, *66*(5), 218-222. https://doi.org/10.1177/2165079917738264. [contribution: 60%; impact factor: 1.56; citations: 12]

Guitar, N. A., Strang, C. J., Course, C. J., & Sherry, D. F. (2017). Chickadees neither win-shift nor win-stay when foraging? *Animal Behavior*, *133*, 73-82. [contribution: 70%; impact factor: 3.06; citations: 4]

Guitar, N. A. (2017). Why can't clients last the wait? Predictors for substance use waiting list attrition. *The University of Western Ontario Medical Journal, 86*(2). [contribution: 100%; citations: 1]

Guitar, N. A., & Molinaro, M. (2017). Vicarious trauma and secondary traumatic stress in health care professionals. *The University of Western Ontario Medical Journal,86*(2). [contribution: 50%; citations: 6]

Roberts, W. A., **Guitar, N. A.,** Marsh, H., & MacDonald, H (2016). Memory systems in the rat: Effects of reward probability, context, and congruency between working and reference memory. *Animal Cognition, 19*(3), 593-604. [contribution: 30%; impact factor: 2.80; citations: 8]

Guitar, N. A., & Roberts, W. A. (2014). The interaction between working and reference spatial memories in rats on a radial maze. *Behavioral Processes, 112*, 100-107. [contribution: 80%; impact factor: 1.55; citations: 18]

Peer-Reviewed Conference Publications

Guitar, N. A., Connelly, D. M., Nagamatsu, L., Orange, J. B., & Hunter, S. W. (2018). The Effects of Physical Exercise on Executive Function in Community-Dwelling Older Adults Living with Alzheimer's-Type Dementia: A Systematic Review. *Alzheimer's & Dementia, 14*(7S Part 18), P984-P985. Available from https://alz journals.onlinelibrary.wiley.com/doi/10.1016/j.jalz.2018.06.1329

Guitar, N. A. & Roberts, W. A. (2015). The Interaction Between Working and Reference Spatial Memories in a Maze with Rats. *Canadian Journal of Experimental Psychology, 69*(4), 375-375.

Guitar, N. A., Strang, C. G., Course, C. J., & Sherry, D. F. (2016). Black-capped chickadees do not flexibly employ win-shift or win-stay strategies in a spatial working memory task. *Proceedings of the International Conference on Comparative Cognition, 15*, 6 & 35.

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Working Manuscripts

Guitar, N. A., Connelly, D. M., Murray, L., & Hunter, S. W. (2021). Assessing Executive Functioning in Females Living with Chronic Pelvic Pain: A Pilot Study.

Conference Presentations:

Oral presentations

Guitar, N. A., Connelly, D. M., Mahamend, W., Patel, H., Truong, R., Wark, R., Zhou, Y., Booth, R., & Sinclair, B. (2019). Virtual simulation applications for interprofessional education for health care professional students: A scoping review. Collaborating Across Borders: Crossroads of Collaboration. Indianapolis, Indiana, October 20-23rd, 2019. Oral Presentation.

Guitar, N. A. & Connelly, D. M. (2019). What outcome measures are used to evaluate interprofessional learning by health care professional students during clinical experiences? A systematic review. Collaborating Across Borders: Crossroads of Collaboration. Indianapolis, Indiana, October 20-23rd, 2019. Oral Presentation.

Guitar, N. A. & Connelly, D. M. (2019). The Effects of Physical Exercise on Executive Function in Community-Dwelling Older Adults Living with Alzheimer's-Type Dementia: A Systematic Review. Canadian Physiotherapy Association FORUM: Maximizing Potential and Promoting Health Aging. Charlottetown, Prince Edward Island, June 27-29th, 2019. Oral and Poster Presentation.

Guitar, N. A. & Connelly, D. M. (2017). Developing an Exercise Recommendation to Slow the Functional and Cognitive Decline Associated with Alzheimer Disease: A Longitudinal Design. *Health and Rehabilitation Sciences Graduate Student Conference.* The University of Western Ontario, February 1st, 2017. 10-minute talk. Best Oral Presentation Award.

Guitar, N. A. & Sherry, D. F. (2016). Adult Hippocampal Neurogenesis Aids Pattern Separation in Black-capped Chickadees. *23rd International Conference on Comparative Cognition.* Melbourne, Florida, April 16-19th, 2016. Ron Weisman Outstanding Student Presentation Award 5-minute talk.

Guitar, N. A. & Roberts, W. A. (2015). The Interaction Between Working and Reference Spatial Memories in a Maze with Rats. *Canadian Society for Brain, Behavior and Cognitive Science (CSBBCS)*. Ottawa, Canada, June 5-7th, 2015.10-minute talk.

Guitar, N. A. & Roberts, W. A. (2015). The Interaction Between Working and Reference Spatial Memories in a Maze with Rats. *22nd International Conference on Comparative Cognition.* Melbourne, Florida, April 15-18th, 2015. 5-minute talk.

Poster presentations

Guitar, N. A., Connelly, D. M., Murray, L. & Hunter, S. W. (2021). A survey of Canadian physiotherapists and physiotherapy students' knowledge and use of executive functioning assessments in clinical practice. *London Health Research Day.* Lawson Health Research Institute, May 8th, 2021. Poster Presentation.

Guitar, N. A. & Connelly, D. M. (2020). A survey of Canadian physiotherapists and physiotherapy student's knowledge and use of executive functioning assessments in clinical practice. *Canadian Association on Gerontology.* Regina, Saskatchewan, October 22-24th, 2020. Poster Presentation. *Conference cancelled due to COVID-19 outbreak.*

Guitar, N. A. & Connelly, D. M., Nagamatsu, L., Orange, J. B., & Hunter, S. W (2018). The Effects of Physical Exercise on Executive Function in Community-Dwelling Older Adults Living with Alzheimer's-Type Dementia: A Systematic Review. *Alzheimer's Association International Conference.* Chicago, Illinois, July 22-25th, 2018. Poster Presentation.

Guitar, N. A. & Connelly, D. M. (2018). The Effects of Physical Exercise on Executive Function in Community-Dwelling Older Adults Living with Alzheimer's-Type Dementia: A Systematic Review. *London Health Research Day.* Lawson Health Research Institute, May 10th, 2018. Poster Presentation.

Guitar, N. A. & Connelly, D. M. (2017). Developing an Exercise Recommendation to Slow the Functional and Cognitive Decline Associated with Alzheimer Disease: A Longitudinal Design. *London Health Research Day*. Lawson Health Research Institute, March 28th, 2017. Poster Presentation.

Guitar, N. A., Strang, C. G., Course, C. J., & Sherry, D. F. (2016). Black-capped chickadees do not flexibly employ win-shift or win-stay strategies in a spatial working memory task. *23rd International Conference on Comparative Cognition.* Melbourne, Florida, April 16-19th, 2016. Poster presentation.

Teaching Assistantships:

Physiotherapy Clinics, The University of Western Ontario, January 2021– April 2021.

Physiotherapy Acute Care, The University of Western Ontario, January 2021– April 2021.

Public Health Practice, MPH 9015, The University of Western Ontario, September 2020 – April 2021. See Table 1.

Public Health Practice, MPH 9015, The University of Western Ontario, September 2019 – April 2020.

Introduction to Biology, Biology 1201, The University of Western Ontario, January 2019 – April 2019. See Table 2.

Introduction to Biology, Biology 1001, The University of Western Ontario, September 2018 – December 2018.

Health Communication*, Health Sciences 3210, The University of Western Ontario, September 2016 – December 2016. *Society of Graduate Students TA Award Nomination.*

Animal Cognition, Psychology 2210, The University of Western Ontario, January 2016 – April 2016.

Animal Behavior*, Psychology 3221, The University of Western Ontario, September 2014 – December 2015. *Society of Graduate Students TA Award Nomination.*

Introductory Psychology, Psychology 1000, The University of Western Ontario, September 2014 – April 2015.

Invited Lectures:

Guitar, N. A. (2019). Writing for Health Sciences. Guest Lecture, Graduate Program in Public Health. *Schulich School of Medicine & Dentistry Master of Public Health Program,* October 18th, 2019. 80-minute interactive oral lecture.

Guitar, N. A. (2018). Health Pros Tell All: A Panel Discussion. *Canadian Medical Hall of Fame,* Discovery Days in Health Sciences. Western University, May 4th, 2018. 45-minute oral presentation.

Guitar, N. A. (2017). Graduate Student Q&A: A panel discussion. Undergraduate Research Methods. *Brescia University College*, April 3, 2017. 60-minute oral presentation.

Guitar, N. A. (2016). A Presentation on how to do Presentations: Guest Lecture, Undergraduate Health Communication 3210 *Western University*, November 11th, 2016. 30-minute oral presentation.

Guitar, N. A. (2016). Studying memory in Black-capped Chickadee's: Guest Lecture, Undergraduate Animal Cognition Psychology 2210 *Western University*, February 3rd, 2016. 60-minute oral presentation.

Guitar, N. A. (2014). Memory and Memory Interactions: Guest Lecture, Undergraduate Introductory Psychology 1000 *Western University*, November 27th, 2014. 60-minute oral presentation.

Guitar, N. A. (2014). Why can't clients last the wait? Predictors for substance use waiting list attrition: Guest Lecture, Undergraduate Psychology 3315 Addictions Theory and Research *Western University*, September 9th, 2014. 60-minute oral presentation.

Guitar, N. A. (2014). Why can't clients last the wait? Predictors for substance use waiting list attrition: Guest Speaker, *Professional Network Forum*, The Student Success Centre at Western University, October 16th, 2014. 20-minute oral presentation.

Peer-Review Contributions:
2020-03-14 *Frontiers in Aging Neuroscience*
2021-04-09 *Clinical Gerontologist*
2021-05-28 *Evaluation & The Health Professions*