Sit-to-stand ability with dual task among older adults with mild cognitive impairment

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ความสามารถในการลุกขึ้นยืนร่วมกับการทำงานสองอย่างในเวลาเดียวกันในผู้สูงอายุที่มีภาวะการรู้คิดบกพร่องเล็กน้อย

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พีระยุทธ ฉิมสุวรรณ : ความสามารถในการลุกขึ้นยืนร่วมกับการทำงานสองอย่างในเวลาเดียวกันในผู้สูงอายุที่มีภาวะการรู้คิดบกพร่องเล็กน้อย. (Sit-to-stand ability with dual task among older adults with mild cognitive impairment) อ.ที่ปรึกษาหลัก : ดร.ดวงพร สุริยาอมฤทธิ์, อ.ที่ปรึกษาร่วม : ผศ. นพ.ดารุจ อนิวรรตนพงศ์

การลุกขึ้นมายืนจากท่านั่งเป็นการเคลื่อนไหวพื้นฐานที่มีความสัมพันธ์กับคุณภาพชีวิต ผู้สูงอายุที่มีภาวะการรู้คิดบกพร่องเล็กน้อยจะมีรูปแบบการเคลื่อนไหวของร่างกายที่เปลี่ยนแปลงไป นอกไปจากนั้นการใช้การทำงานของสองอย่างพร้อมกันจะไปรบกวนการทำงานของการรู้คิดและส่งผลให้มีการลดลงของความสามารถในการเคลื่อนไหว อย่างไรก็ตามยังไม่มีข้อมูลหลักฐานเชิงประจักษ์ที่เกี่ยวกับค่าเวลาในการเคลื่อนไหว มุม และแรงขณะเคลื่อนไหวในท่าทางการลุกขึ้นมายืนจากท่านั่ง การศึกษานี้มีวัตถุประสงค์เพื่อประเมินความสามารถในการลุกขึ้นยืน ร่วมกับการทำงานสองอย่างในเวลาเดียวกันในผู้สูงอายุที่มีภาวะการรู้คิดบกพร่องเล็กน้อย การศึกษานี้เป็นการศึกษาแบบตัดขวาง ผู้เข้าร่วมงานวิจัยทั้งหมด 70 คน แบ่งออกเป็นผู้สูงอายุที่มีภาวการรู้คิดบกพร่องเล็กน้อย จำนวน 35 คน และผู้สูงอายุสุขภาพดี จำนวน 35คน อาสาสมัครทุกคนจะลุกขึ้นยืนจากเก้าอี้ด้วยรูปแบบที่เลือกเองในสองรูปแบบ คือลุกขึ้นยืนอย่างเดียวและลุกขึ้นยืนร่วมกับการถือถาดที่มีแก้วน้ำในเวลาเดียวกันโดยระดับความสูงเก้าอี้จะถูกปรับให้พอดีกับความยาวขาส่วนล่างของแต่ละคน ตัวแปรที่ใช้ในการศึกษานี้จะประกอบไปด้วยเวลาที่ใช้ในการเคลื่อนไหว ค่ามุมองศาของลำตัว เชิงกราน ข้อสะโพก ข้อเข่า และข้อเท้า ค่าแรงปฏิกิริยาสูงสุด ค่าแรงที่ใช้ในการเหยียดข้อสะโพก ข้อเข่า และข้อเท้า การศึกษาพบว่าผู้สูงอายุที่มีภาวการรู้คิดบกพร่องเล็กน้อยในขณะที่ลุกขึ้นยืนพร้อมกับการถือแก้วน้ำจะมีค่ามุมของการงอลำตัวที่มากที่สุด และจากการศึกษานี้พบว่าการลุกขึ้นยืนร่วมกับการทำงานสองอย่างในเวลาเดียวกันใช้เวลาในการเคลื่อนไหวที่มากกว่าการลุกขึ้นยืนเพียงอย่างเดียว อีกทั้งในขณะที่ลุกขึ้นยืนทั้งสองรูปแบบอาสาสมัครทั้งสองกลุ่มมีค่ามุมของขาทั้งสองข้างที่แตกต่าง โดยในขาข้างที่ถนัดจะมีมุมการงอเข่า และข้อเท้าที่มากกว่าขาข้างที่ไม่ถนัด นอกจากนี้ในกลุ่มผู้สูงอายุสุขภาพดีในการลุกขึ้นยืนเพียงอย่างเดียว มีค่าของแรงที่ใช้ในการเหยียดข้อสะโพก และการถีบปลายเท้าที่มากกว่าเมื่อเทียบกับการลุกขึ้นยืนร่วมกับร่วมกับการถือถาดที่มีแก้วน้ำในเวลาเดียวกัน

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Perayut Chimsuwan : Sit-to-stand ability with dual task among older adults with mild cognitive impairment. Advisor: DUANGPORN SURIYAAMARIT, Ph.D. Co-advisor: Asst. Prof. DARUJ ANIWATTANAPONG, M.D.

Sit to stand (STS) is the basic mobility related to the quality of life. Older adults with mild cognitive impairment (MCI) have a movement pattern change in motor function. Moreover, the dual task can interfere with cognitive ability, leading to reduced motor performance. However, there was a lack of evidence of movement time, kinematics, and kinetics while performing STS tasks. This study aims to evaluate the STS ability in older adults with and without MCI while performing in single and dual conditions. This study was cross-sectional. Seventy older adults (35 older adults with MCI and 35 controls) participated in this study. All participants were asked to perform STS in both conditions (STS alone and STS with carrying the tray of glass that fill the water) with preferred movement patterns. The chair height was set for individuals as lower leg length. The variables consisted of movement time, kinematics variables (trunk, pelvis, hip, knee, and ankle joint), peak vertical ground reaction force, and kinetics variables (hip extension, knee extension, plantar flexion moment) were collected. The study found the highest values of trunk flexion angles were found in older adults with MCI during STS with carrying a tray of glass filled with water. Moreover, the STS with dual tasks took a greater movement time than single conditions in both groups. Also, both groups found a difference in the dominant and non-dominant leg. The dominant leg has a greater knee flexion angle and ankles plantar flexion angles than the non-dominant leg. For the kinetics variables, older adults without MCI have a greater hip extension moment and plantar flexion moment during STS alone than STS with carrying the tray of glass that fill the water.

Field of Study:	Physical Therapy	Student's Signature ....
Academic Year:	2022	Advisor's Signature ....
		Co-advisor's Signature ....

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LIST OF ABBREVIATIONS

MCI	=	Mild cognitive impairment
MoCA	=	Montreal Cognitive Assessment test
MMSE	=	Mini-Mental State Examination test
CDR	=	Clinical Dementia Rating scale
TMSE	=	Thai-Mini-Mental State Examination
Barthel ADL	=	Barthel Index for Activities of Daily Living
TGDS	=	Thai Geriatric Depression Scale
DSM-5 TR	=	Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision
STS	=	Sit to stand
FTSTS	=	Five times sit-to-stand test
PVGF	=	Peak vertical ground reaction force

CHAPTER 1
INTRODUCTION

1.1 Background and Rationale

Mild cognitive impairment (MCI) was an intermediate stage of declining cognitive function related to aging. MCI can be reversible to the normal age-related or transition to dementia (Petersen, 2004). The global prevalence of older adults with MCI was 6.7 % to 25.2 % (Petersen et al., 2018). In Thailand, the prevalence ranged from 16.7 % to 71.4 %, depending on the area studied (Deetong-on et al., 2013; Griffiths et al., 2020; Kengsakul et al., 2015; Sangsirilak, 2016). Previous studies showed that the decline of cognition functions in older adults with MCI is related to motor incoordination and impaired in the disinhibition subscale of the Cambridge Neurological Inventory (Li et al., 2012) . In addition, older adults with MCI have a longer time to plan movements while performing finger movements over a clear touch screen test than healthy older adults (Salek et al., 2011). These impairments in older adults with MCI might be led to a decrease of lower-extremity function (Eggermont et al., 2010), postural control (Borges et al., 2015), and gait speed (Verghese et al., 2008). In addition, a previous study found that older adults with MCI have an increased right knee peak extension angle and a decrease of right knee heel strike angle during walking when compared with older adults without MCI (Zhong et al., 2021). Although there is a wide description of motor function in older with MCI in the literature, most studies assessed in walking. However, one of the simplest functional activities that an individual often performs each day is standing up from a chair still lacking the information.

Sit-to-stand (STS) is a transitional movement from sitting to a standing position. This movement is an essential activity that is a fundamental component in functional routines' tasks. In older adults, this task accounted for 12% of falls (Lehtola et al., 2006). To perform STS tasks, individuals required high levels of the nervous system's processes including sensing, perceiving, interpreting, conceptualization, planning, and activation to regulate the horizontal and vertical momentum transfer and control both the body segment's stability and alignment(Woollacott & Majorie, 2016). Successful STS tasks resulted in the rotation of all body joints and the generation of joint torque in the lower extremities, which may be greater than other tasks such as ascending stairs (Ploutz-Snyder et al., 2002). Furthermore, previous adult studies found that the joint moments of both lower extremities were asymmetrical while performing the STS task (Lundin et al., 1995) . This asymmetry may be due to the different functions of the lower extremities, such as dominant and non-dominant legs (Sadeghi et al., 2000). The decline of cognitive function including attention, mental processing speed, visuospatial abilities, and executive functions in older adults with MCI (Griffiths et al., 2020), may contribute to the change of movement pattern during STS. However, there is a lack of evidence of the kinematic and kinetic data during STS in older adults with MCI compared with older adults without MCI.

Typically, humans are usually capable of dual or multi tasks performing in daily life such as standing up while carrying a cup of water. In this situation, other tasks coming in will either reduce the ability to do secondary tasks or decrease primary and secondary tasks due to the limited information perceptive ability (Yogev-Seligmann et al., 2008). The secondary task could be either cognitive or motor task. Previous study found that older adults with MCI decreased in gait performance under dual task conditions (Montero-Odasso et al., 2014). This might occur from the impairment in executive function and the reducing attention capacity in older adults with MCI (Kirova et al., 2015). Although significant cognitive dual task interference has been demonstrated in older adults with MCI (Goyal et al., 2019; Hunter et al., 2018; Montero-Odasso et al., 2012), studies on the effects of motor dual task in MCI have not been reported. Motor dual-tasks are also important to be considered since in many daily activities, people are required to complete a secondary motor task in conjunction with a primary motor task. To the best of our knowledge, no study has investigated the STS ability in terms of movement time, kinetics, and kinetics in older adults with MCI while performing STS under single- and dual-task conditions as well as effects of the dominant and non-dominant legs.

1.2 Research questions

1.2.1 Does movement time while performing STS under single- and dual-task conditions differ in older adults with and without MCI?

1.2.2 What are the differences in kinematic and kinetic data while performing STS under single- and dual-task conditions in older adults with and without MCI?

1.3 Objectives of the study

1.3.1 To compare the movement time in older adults with and without MCI while performing STS under single- and dual-task conditions.

1.3.2 To study the differences in kinematic and kinetic data in older adults with and without MCI while performing STS between single- and dual-task conditions.

1.4 Hypotheses of the study

1.4.1 Movement time while performing STS under single- and dual-task conditions are different between older adults with and without MCI.

1.4.2 Both kinematic and kinetic data while performing STS under single- and dual-task conditions are different between older adults with and without MCI.

1.5 Outcomes of the study

1.5.1 Primary outcomes

- Movement time; total movement time and movement time in each phase

1.5.2 Secondary outcomes

- Kinematics; angular displacements at each time point of trunk, pelvis, hip, knee, and ankle of dominant and non-dominant lower extremities.

- Kinetics; peak vertical ground reaction force of dominant and non-dominant lower extremities and maximum moments of the hip, knee, and ankle of dominant and non-dominant lower extremities.

1.6 Scope of the study

The present study investigated the differences in STS ability under single- and dual-task conditions between older adults with and without MCI. This study focused on movement time, kinematics, and kinetics. The data was collected using a 3-dimensional motion analysis system with two force platforms.

1.7 Expected benefits

This study provided information on the differences in movement time while performing STS task between older adults with and without MCI, total movement time, and movement time in each phase. Moreover, this study provided information on kinematics data (trunk pelvis, hip, knee, and ankle angle) and kinetics data, hip extension, knee extension, and ankle extension moment under single and dual-task conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 Motor control

The emergence of movement resulted from the interaction of three factors: the individual, the task, and the environment. Movement originated from the interaction of sensory or perceptual, neurological, and motor or action systems in the individual elements. The sensory or perceptual systems played numerous roles in movement control. First, they supported the position and movement of the body in space relative to the environment. Secondly, triggers for reflexive movement were sensory inputs. Third, sensory inputs had a significant role in modifying movement output. Important sensory systems for movement include the somatosensory, visual, and vestibular systems. Sensory strategies used to organize movement depend on the tasks. The nervous system is related to perception, action, and cognition. Many structures of the brain, such as the brainstem, cerebellum, and cerebrum, are involved in processing information. The processes in the nervous system that related to movement included sensing, perceiving, interpreting, conceptualization, planning, and activation. In addition, attention, motivation, and emotional aspects were also related to the control of movement. The motor or action systems ensured the production of sufficient coordinated force in the proper muscles to regulate the position and movement of the body. Movement was efficiently produced by the motor systems comprising the higher-level planning system (frontal and motor cortex), the coordination system (brainstem and spinal networks), and the generation of forces (motor neurons and musculoskeletal) (Woollacott & Majorie, 2016).

Regarding task factors, the type of task being performed has a great impact on the neural organization of movement. The classification scheme for different types of tasks consisted of discrete/continuous, closed/open, stability/mobility, and manipulation/non-manipulation tasks. Thus, understanding motor control required an awareness of how the tasks were performed (Woollacott & Majorie, 2016).

Tasks were performed in a wide range of environments. The environmental factors could either support or obstruct the performance of the task. Therefore, the environment was one of the factors related to movement. The environment could be divided into regulatory and non-regulatory features. The regulatory features constituted a distinct environment that could be identified based on factors such as the type of supporting surface. The non-regulatory features included nonspecific environments such as the moving of the background (Woollacott & Majorie, 2016).

In the present study, the individual factor is older adults with mild cognitive impairment. These will be studied when transferring from a sitting to a standing task in the laboratory.

2.2 Mild cognitive impairment

2.2.1 The definition of mild cognitive impairment

Petersen et al. first defined mild cognitive impairment (MCI) in 1997 to represent the stage of cognitive loss between normal age-related decline and dementia. This stage is not severe enough to interfere with daily life, nor does it fit the criteria for dementia (Petersen et al., 1997). According to Petersen et al. (1997), individuals with MCI (1) report symptoms of cognitive decline (or their families do); (2) report a decline in cognitive function relative to previous abilities; (3) exhibit signs of cognitive disorders as evidenced by clinical evaluation (memory impairment or another cognitive domain); (4) do not suffer major repercussions regarding their daily lives (although difficulties concerning complex day-to-day activities may be reported); and (5) do not suffer from dementia.

DSM-5 identifies six important domains of neurocognitive function: perceptual-motor function, executive function, complex attention, social cognition, learning and memory, and language (Figure 1) (Sachdev et al., 2014). In older people with MCI, impaired cognition is not only limited to the learning and memory domain; it can involve other cognitive domains (clinically and psychometrically) (Petersen et al., 2014) and can interfere with day-to-day activities such as walking, maintaining balance, and other motor functions (Micarelli et al., 2019; Montero-Odasso et al., 2014). Declining motor function in patients with MCI can lead to an increased risk of falling and is useful for early detection of dementia and planning treatment before the disease progresses (Roberts et al., 2014).

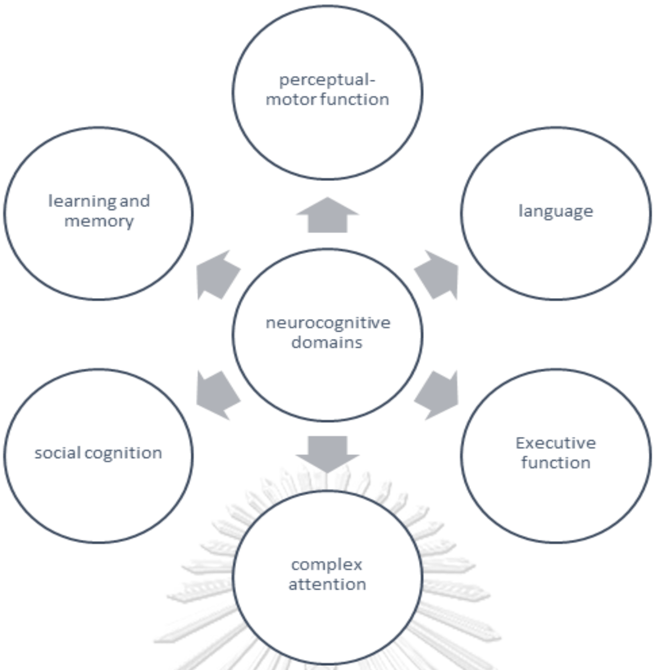


Figure 1 Neurocognitive domains

2.2.2 Prevalence

The prevalence of MCI in adults aged 60 and older is estimated to be between 6.7% and 25.2% globally (Petersen et al., 2018). The American Academy of Neurology (AAN) practice guidelines data, the prevalence of MCI in adults increases with age. For individuals aged 60–64, it was 6.7%, 65–69 was 8.4%, 70–74 was 10.1%, 75–79 was 14.8%, and for adults aged 80–84 the prevalence was 25.2% (Petersen et al., 2018). Petersen et al. (2010) investigated the prevalence of MCI in 1,969 adults aged 70–89 years old and found that 16% (n=329) showed symptoms of MCI. The most common type of MCI was amnestic MCI, which was found in 11.1% of the patients, whereas non-amnestic MCI was found in 4.9%. Their study determined that MCI prevalence increases with age and low level of education, and was more common in men, whose odd ratio was 1.54 (Petersen et al., 2010).

In central Thailand, the percentage of adults with MCI was reported to range between 16.7% and 43.5% (Deetong-on et al., 2013; Kengsakul et al., 2015; Sangsirilak, 2016). Moreover, the prevalence of MCI in older people in rural areas was 71.4% and was associated with low education levels and underlying health conditions (Griffiths et al., 2020). Possible reasons for the variation in the prevalence of MCI might depend on the varying definitions of MCI and the area of study. MCI was significantly associated with age, sex, low education levels, and chronic diseases including heart problems, high blood pressure, and diabetes (Deetong-on et al., 2013; Ganguli et al., 2011; Griffiths et al., 2020; Kengsakul et al., 2015; Petersen et al., 2010; Sangsirilak, 2016).

2.2.3 Types of mild cognitive impairment

The subtype of MCI is dependent on the cognitive domain deficit. Malek-Ahmadi and colleges (2016) classified MCI as either amnestic mild cognitive impairment (aMCI) or non-amnestic mild cognitive impairment (naMCI) (Malek-Ahmadi, 2016). Moreover, they are classified by the number of cognitive domains that decline, single or multiple domains (Petersen et al., 2018). The aMCI is predominantly associated with memory dysfunction or reduced memory recall. If it only affects the memory domain, it is known as a single aMCI; if it affects multiple domains, it is known as multiple aMCI. By contrast, naMCI can affect multiple cognitive domains but not the memory domain. The previous study reported that aMCI was more prevalent than naMCI by a ratio of about 2:1 (Petersen et al., 2010). Furthermore, studies show that aMCI can progress to Alzheimer's disease (A.D.); therefore, the MCI can be detected early before progressing to A.D. (Lopez et al., 2012).

2.2.4 Cause of mild cognitive impairment

The etiology of MCI is currently unclear. However, numerous medical disorders are significantly associated with MCI, including Parkinson's disease, Huntington's disease, traumatic brain injury, HIV infection, stroke, cerebrovascular accidents, and the human immunodeficiency virus (HIV). Some disorders primarily affect cognition, such as Alzheimer's disease, vascular dementia, Lewy body disease, and frontotemporal dementia (Mitchell et al., 2002). Studies show that aMCI that progresses to A.D. has medial temporal lobe atrophy. In addition, dementia with Lewy bodies can stem from aMCI related to hippocampal atrophy (DeCarli, 2003; Gauthier et al., 2006).

Some causes of MCI can be treated, and normal cognition can be restored, although some are irreversible. A study by Sanford (2017) reported that some reversible causes of MCI include polypharmacy, hypotension, depression, hypothyroidism, vitamin B12 deficiency, hypo/hyperglycemia, dehydration, obstructive sleep apnea, normal pressure hydrocephalus, and infection (Sanford, 2017). Moreover, a study by Shimada et al. (2019) assessed the association between lifestyle activity and the reversion of MCI. They found that the specific lifestyle choices, such as driving a car, using maps, reading books or newspapers, taking evening classes, attending community meetings, participating in hobbies, or sporting activities, and working in fields or gardening can all contribute to MCI reversion in older adults (Shimada et al., 2019).

2.2.5 Screening and diagnosis

Petersen and colleagues established and developed the criteria for diagnosis of MCI. MCI is characterized by (1) Subjective cognitive complaint by the subject, caregiver, family, or a clinician (2) Objective cognitive impairment in one or more domains (learning and memory, executive function, complex attention, perceptual-motor function, language, and social cognition), (3) Independently in activity daily living (ADL), and (4) No clinically criteria for dementia. Apart from Petersen's criteria, one of the most used criteria is the criteria of the National Institute on Aging-Alzheimer's Association workgroups (Albert et al., 2011). In this criteria, MCI is characterized by (1) the change in cognition while compared with a previous level, informed by a patient, family, or the clinician, (2) impairment in one or more cognitive domains, lower performance while compared with a patient's age and education background, or the decline of performance while repeated the assessments, (3) preservation of independence in functional abilities, the patients have a problem with complex functional tasks, using a longer time than the previous to perform, and (4) not demented, no significant impairment in social or occupational functioning (Albert et al., 2011).

Many cognitive function assessment tools have been used to screen cognitive function, including the Montreal Cognitive Assessment (MoCA) test, the Mini-Mental State Examination (MMSE) test, and the Clinical Dementia Rating (CDR). However, the most commonly used screening tool is the MoCA test.

The MoCA is a brief cognitive screening tool to detect MCI and early stages of dementia. This test can be assessed in multiple cognitive domains, including memory, language, executive functions, visuospatial skills, calculation, abstraction, attention, concentration, and orientation. In addition, the MoCA test can evaluate the development of MCI to dementia with the 35% developed within 6 months (Nasreddine et al., 2005). This screening tool was first developed by Nasreddine and collaborators in 2005 (Nasreddine et al., 2005) and translated to many languages. The total score is 30 points, which the lower score indicated poor ability of cognitive function. The previous study showed that the MoCA score with the cutoff 26 had a high sensitivity (90%) and specificity (87%) for the detection of MCI (Nasreddine et al., 2005).

The MoCA- Thai test was an applicable and appropriate assessment cognitive tool for detecting the MCI in Thai populations with good validity, test-retest reliability, and internal consistency (Hemrungrojn et al., 2021). The MoCA Thai version was translated and validated by Tangwongchai and colleagues in 2009 (Tangwongchai et al., 2009). The cut-off scores for detecting MCI were less than 25 points (Larner et al., 2017).

2.3 The impact of mild cognitive impairment on motor performance

Motor performance is the ability to perform a motor task in relation to three components: individual, task, and environment. The individual component consists of motor/action, sensory/perception, and cognitive components. The sensory or perception system sends a signal through the ascending pathway for the information to respond and to command the action system through descending pathways by the decision of cognition systems (Woollacott & Majorie, 2016). Before the descending signal is sent, the cognitive system uses all of the sensory information to interpret and plan related tasks and environments. Many studies report that a deterioration in cognitive function, such as executive function and attention, leads to difficulty walking and reduces the ability to control posture (Booth et al., 2016; Laws et al., 2016).

Shin et al. (2011) used posturography to investigate the effect of MCI on balance control. They found a significant difference in mediolateral sway speed and distance in the MCI group compared with the non-MCI group, whether the subjects' eyes were closed or not (Shin et al., 2011). Similar to Micarelli (2018), they compared the postural balance in subjects with MCI and healthy control subjects and found significantly higher mediolateral sway in the MCI group (Micarelli et al., 2019). Both studies show that providing a balance-training program for the MCI group can improve the compensatory system and reduce the risk of falling.

Walking, or gait, has always been considered an automatic motor task. However, a recent study has shown that gait control requires the integration of sensory input, motor planning, and cognitive execution. Furthermore, gait has been assessed to identify potential cognitive decline (Cosentino et al., 2020) and early-stage dementia. Studies have found that gait impairment and the risk of falling increase with cognitive impairment (Zhang et al., 2019). Subjects in MCI groups exhibit changes in gait in terms of decreased gait velocity (Montero-Odasso et al., 2014; Muir, Gopaul, et al., 2012; Muir, Speechley, et al., 2012), decreased stride length (Verghese et al., 2008), increased stride time (Montero-Odasso et al., 2012), and increased coefficient of variation of stride time (Montero-Odasso et al., 2014; Muir, Speechley, et al., 2012).

One of the possible causes of decreased motor performance in MCI patients is a deterioration in cognitive function. Motor performance is associated with the motor, sensory, and cognitive domains, with a decline in one of the domains leading to decreased motor performance. In the study by Herman et al. (2010), the deficit in executive function ability has been associated with falling in elderly people (Herman et al., 2010). However, their research does not discuss motor performance in other tasks such as sit-to-stand movements. Therefore, this study aims to investigate whether there is a difference in sit-to-stand movements in both healthy elderly individuals and those with MCI.

2.4 Sit to Stand

Sit-to-stand (STS) is an essential motor function. The critical ability from STS is the mobility-related quality of life. A previous study shows the strong association between the STS test and the health status, functional status, and daily physical activity of older adults (van Lummel et al., 2016). Moreover, the STS task correlated with exercise capacity, strength, and functional tests can predict the risk of falling (Frykberg & Häger, 2015).

The body is able to generate sufficient joint torque, maintain sufficient stability to move the center of mass from the chair to the feet, and alter posture and movement strategies depending on the environment (Woollacott & Majorie, 2016). The STS movements require a multi-working component to complete the tasks of head and trunk movement, joint angle, stability maintenance, and lower limb muscle strength (Frykberg & Häger, 2015). In addition, to understand the biomechanics of STS function, a previous study determined the time to complete the phase and task, the kinetic information through joint force and moments, the kinematic through the joint angle, the velocity, displacement of the center of mass, and the muscle activity during STS transfer.

During the STS movement, the muscle activity involves the cooperation of both the agonist and antagonist muscles and differences in the point of time interest. Firstly, the upper body moves forward to generate momentum by activating the erector spinae muscle. Then the buttocks lift off the seat using the coactivation of hip and knee extensors including the gluteus maximus, biceps femoris, vastus medialis, and rectus femoris. After preparation, the extensor muscle group extends the body into a quiet stance (Woollacott & Majorie, 2016).

Rising from sitting to standing is an essential function in daily life and can help clinicians to make clinical assessments (Frykberg & Häger, 2015). In addition, understanding the definition of STS, the muscle activity, and the phases can help them to investigate and focus on any differences from the normal STS activity (Hirschfeld et al., 1999; Kralj et al., 1990; Roebroeck et al., 1994; Schenkman et al., 1990).

2.4.1 Phase of sit to stand

To analyze the biomechanics of the STS task, the researcher divides an STS into phases. Dividing a phase of STS movements is essential to decide an understanding researcher into a movement analysis. The previous study describes it in 3 ways using kinematic, kinetic, and lastly, using the torque, momentum, and velocity of COM.

The kinematic method of STS movement uses the angle of the joint. The previous study investigates the Trunk, Pelvis, Hip, Knee, and Ankle angle in the Sagittal plane during sit-to-stand movement (Schenkman et al., 1990). They were divided into 4 points of time T0, T1, T2, and T3. T0 is the beginning of the task. The times of T0 to T1 are called flexion momentum phase. The trunk forward flexion and ends detect this phase until the buttock lifts off the chair. During the flexion momentum phase, the mass and velocity producing the momentum are related with upper-body kinetic energy—next, the momentum transfer phase begins while the buttock lifts off the chair and ends to the maximum ankle dorsiflexion on both sides. During this phase, the momentum transfers from the first upper-body part to the total body and moves upward and anteriorly. Then, the third phrase is an extension phase. This phase begins after the maximum ankle dorsiflexion. During this phase, the head, knee, and hip start to extend and end at the full hip extension, and the point of the angular velocity of the hip reaches 0 degrees/sec, the head and knee stop extended. Lastly, the stabilization phase begins when the hip-extension velocity reaches 0 degrees/sec and stabilizes the body sway in both anteroposterior and mediolateral direction. This phase's endpoint is not easily identified because, typically, the subjects have body sway during a quiet stance.

In conclusion, dividing the STS phase using kinematics data is divided into 4 phases: flexion momentum phase, momentum transfer phase, extension phase, and stabilizing phase. First, they used a lift-off of the buttock from the chair to define the end of phase 1 (flexion momentum phase). Then, using maximum ankle dorsiflexion to identify the endpoint of phase 2 (momentum-transfer phase). Moreover, they used the full hip extension to define the endpoint of phase 3 (extension phase). Phase 4 (stabilizing phase) is not easily defined because the subject typically has body sway in a quiet stance (Schenkman et al., 1990).

Helga and colleagues use a four-force plate (AMTI, Advanced Mechanical Technology; model MC818-6-1,000; size 457 3 203 mm; accuracy 0.25N) beneath the buttock and feet to determine a coordinate ground force buttock and feet for weight transfer during sit to stand (Hirschfeld et al., 1999). They categorize the phase of sit to stand into two phases. Preparatory phases define from onset first anterior and posterior force to seat-off. Then the rising phases define from seat off to the vertical velocity of the COM is zero. They were using a COM and force to analyze the movement pattern. In the beginning, the baseline reports 85 percent of body weight in the buttock and 15 percent of body weight on the feet (initial sitting posture). Firstly, the preparatory phase's beginning increases the vertical force and backward direction force from the buttock. The study shows the correlation between the buttock's force and the forwardly direct force from feet before the rising phase. The buttock generates a propulsive impulse to lift off the body. The hip adductor muscle plays an important role in controlling knee displacement in the frontal plane. After that, A vertical force decreases from 52.6 ± 7% B.W. in the rising phase. The feet exert steady, outward, and forward direct force. The end of the rising phase is detected by the decreasing vertical velocity of COM reaching to zero (Hirschfeld et al., 1999).

Kralj and colleagues (1990) provide the normative data and analyze the movement of sitting to the standing position and then sitting down from the standing position. This study uses a goniometric and force plate to collect the biomechanics data (Kralj et al., 1990). This study investigates the movement by dividing it into 6 phases on sitting to standing (quite sitting, initiation, seat unloading, ascending, stabilization, and quiet standing phases) and 6 phases on standing to sit position (quiet standing, initiation, descending, seat loading, stabilization, and quite sitting phases). They were using the change of force to divide the event and phases (Kralj et al., 1990).

Moreover, the phase of STS movement can be divided by using a mass center of the body (MCB) displacement (Roebroeck et al., 1994). They divide into 3 phases based on the pattern in horizontal and vertical velocity, the acceleration phase, the transition phase, and the deceleration phase. Begin, the acceleration phase defines that MCB moves horizontally and accelerates and reaches maximal horizontal velocity. Then, the transition phase begins when the horizontal velocity decelerates, and the vertical velocity accelerates to reach the maximal vertical velocity of MCB. Lastly, the deceleration phase defines the maximal vertical velocity of MCB until the end of sit to stand movement.

Although the dividing phases of sit to stand are various, the data collection methodology is different. Therefore, in this study, for ultimately the data, using both kinetics and kinematics methods and dividing the phases of sit to stand into 4 phases (five-point of time; T0, T1, T2, T3, T4). Firstly, the time of T0 to T1 is called the flexion momentum phase. This phase begins with the starting position and is detected by the shoulder-moving marker with a horizontal velocity greater than or equal to 0.01 m/second and the end of this phase when the greater trochanter marker moves vertical displacement away 0.1 cm from the seat. Secondly, the momentum transfer phase defines a change of ground reaction force, which ends when the time of ground reaction force reaches maximum force. Next, the extension phase begins after the maximum ground reaction force and extends the hip, knee, and plantar flexion. At the end of this phase, the body moves to a stand position and is detected by the shoulder-marker moving vertical direction velocity less than or equal to 0.01 m/second. Lastly, the stabilizing phase begins after the hip marker velocity after the hip extension is less than or equal to 0.01 m/second (Mapaisansin et al., 2020).

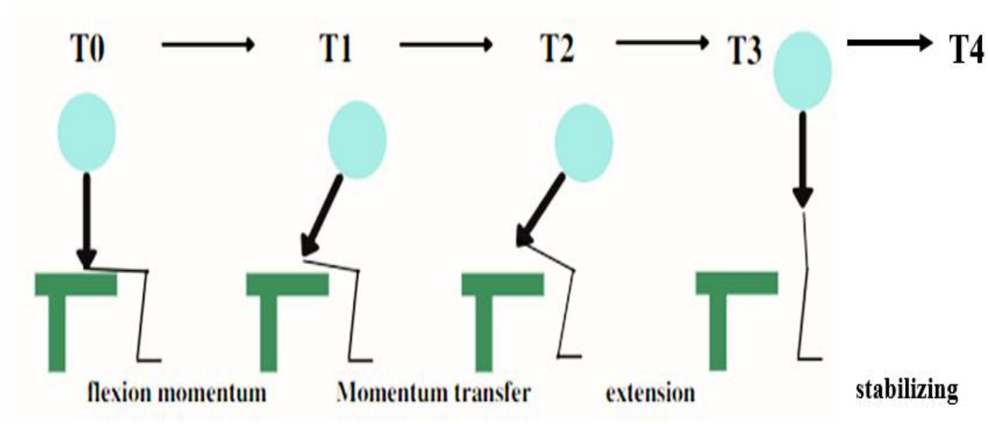


Figure 2 The phase of sit to stand

2.4.2 The factors influenced on the sit to stand performance

The researcher investigated factors related to STS performance and divided them into three components: subject-related, chair-related, and strategy-related (Janssen et al., 2002). The subject-related components include age, weight and height, muscle strength, balance, sensitivity, and psychological status. Many studies have investigated STS ability in older adults and found that STS performance was altered in various ways. Poor STS performance observed in older people may be associated with and can be predictive of the likelihood of falling (Campbell et al., 1989). Age-related deficits in visuomotor adaptation, spatial working memory, and motor sequencing can result in motor performance deficits (Langan & Seidler, 2011). Moreover, a study by Whitney in 2005 compared the time taken to perform the STS movements between younger and older adults and found that younger adults performed STS more quickly than older adults (Whitney et al., 2005).

Weight and height related to the displacement of and change in COM can lead to a change in strategy and performance. Likewise, the STS performs similarly to another movement, using muscle strength and balance ability during the COM movement out of BOS and generating the muscle power necessary to stand. In addition, the sensitivity related to sensory information is afferent to the higher brain centers of planning and executing; lacking this information leads to reduced performance. Furthermore, several studies have also reported that cognitive status correlates with cognitive decline and STS performance.

The design and height of the chair are also associated with STS performance. Chair height can change the time taken to perform the STS, the angular velocity, and the joint movement. In addition, the chair design, such as the seat angle, can also affect the STS task. The last component, the strategy for performing the STS, includes foot position, the different strategies (flexion momentum, zero momentum, and armrest momentum), and arm movements. The flexion momentum strategy uses strength and coordinates with upper-body movement before lifting off the seat. Eccentric contractions of the hip and trunk were required to interrupt the force, along with the hip and knee extension's concentric contractions for vertical propulsion. The zero-momentum strategy was often used by people with poor balance control who required more stability while performing a task. This strategy also uses a large amount of force for lift-off, by the trunk flexion moving the COM out of BOS before lifting off the seat. Thus, this uses the lower extremity in the vertical plane rather than the flexion momentum strategy. Lastly, armrest momentum used less strength from the lower body but more from the upper body. The most force was required to push off the armrest and lift the body to a standing position (Janssen et al., 2002).

MCI does not significantly impair day-to-day activities, but changes in motor function when performing a single task were slightly different for healthy patients and those with MCI. Therefore, the use of dual-task assessment can better evaluate the effect of MCI on motor function (Montero-Odasso et al., 2014).

2.5 Dual-task paradigm

In everyday life, we perform cognitive and motor tasks simultaneously, such as walking while chatting with someone else, walking while carrying a cup of coffee, and standing from sitting while carrying a cup of water. These are all known as dual tasks. A dual-task is where two tasks are performed during an overlapping time frame. The tasks can be performed independently, measured separately, and have distinct goals (McIsaac et al., 2015). A dual-task uses an executive function and more attention or working memory compared with a single task. The second task is likely to be either another motor or a cognitive task, consisting of several tasks, including mental tracking, verbal fluency, discrimination and decision-making, and reaction time. Simultaneous motor tasks are known as motor dual tasks. The dual-task paradigm can be used as a clinical marker for cognitive impairment and falling risk.

The mechanism of dual tasks has been clarified in several theories. The most commonly accepted theories are the capacity sharing theory, the bottleneck theory, and the crosstalk theory (Bayot et al., 2018). Firstly, the capacity-sharing theory is based on the assumption that attention resources are limited. While performing two or more tasks, the resource to processing is shared among the tasks, and limited or lower capacity may lead to the performance of at least one of the tasks being impaired. The bottleneck and crosstalk theories were based on the amount of attention needed while performing simultaneous tasks. The bottleneck theory describes how the performance of one or both tasks can be limited because processing the task needs the same neural networks, leading to a delay in information processed on the tasks because of the competition. By contrast, the crosstalk theory describes when two tasks use the same neural pathway and increase processing efficiency by using less attention resource capacity (Pashler, 1994).

Montero-Odasso et al. (2012) investigated the effect of dual tasks on gait performance between elderly people with MCI and a healthy control group using gait velocity, stride time, and gait variability. They found that gait velocity decreased, and gait variability increased in both groups when a secondary task was added, but that the differences were greater in the MCI group. The high stride time variability reflected the deficits in the executive function and attention domains. They concluded that using a dual-task assessment is more sensitive than the single-task measurement (Montero-Odasso et al., 2012).

Goyal et al. (2019) investigated the effect of dual task on gait in individuals with MCI. They used secondary motor tasks such as carrying a glass of water, and cognitive tasks such as reciting the alphabet. Their results showed significant differences in gait performance in both secondary motor and cognitive tasks in the MCI group compared with healthy older adults (Goyal et al., 2019).

Hunter et al. (2018) used dual-task gait testing to evaluate changes in velocity and cognitive cost for different secondary tasks in people with MCI. Their results showed that gait velocity decreased during both the motor and cognitive secondary tasks and that the cognitive cost in the MCI group was greater than in the healthy control groups. The current study confirms that adding low complexity tasks such as carrying a glass of water can interfere with motor performance in people with MCI (Hunter et al., 2018).

2.6 Conceptual framework

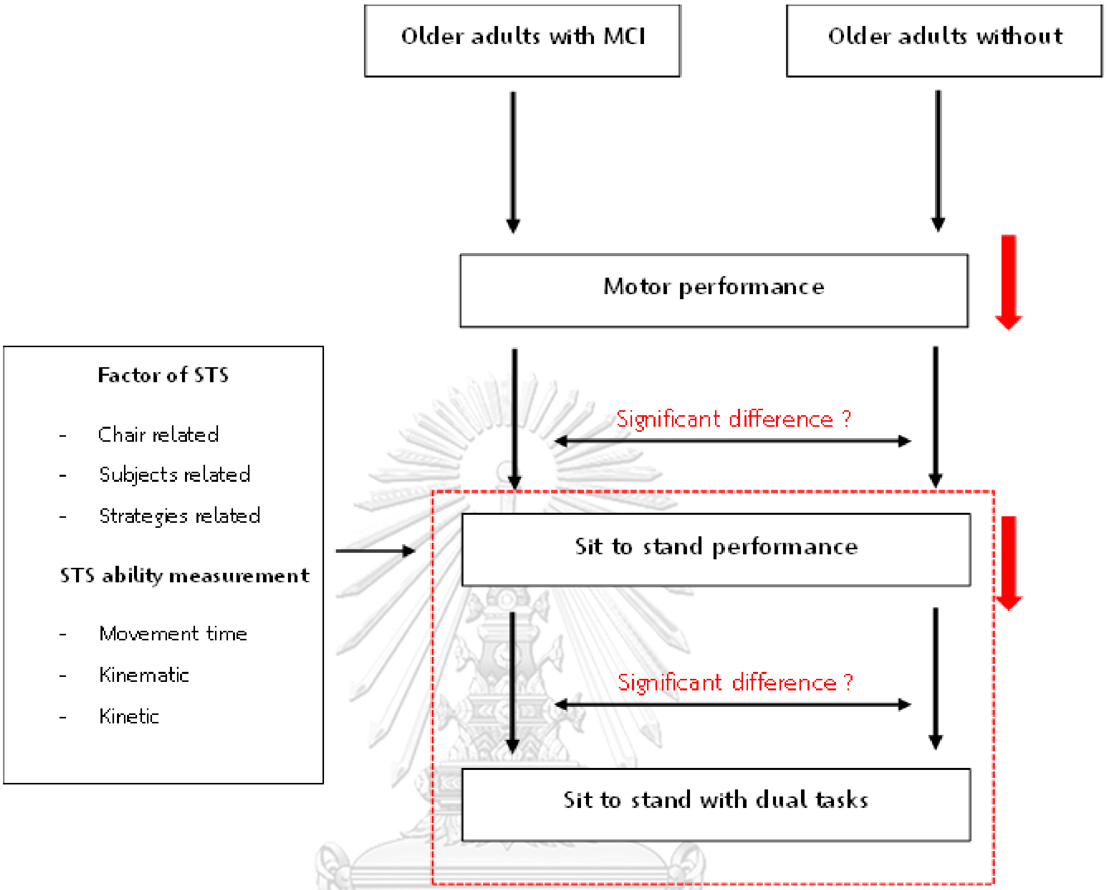


Figure 3 Conceptual framework

CHAPTER 3

MATERIALS AND METHOD

3.1 Study design

A cross-sectional study

3.2 Population

Older adults aged more than 60 years who visit the Comprehensive Geriatric Clinic, 4th floor, Sor Thor building, Chulalongkorn hospital, and volunteers from the announcement who are interested in joining the study.

3.2.1 Target Population: Older adults with MCI

3.2.2 Control population: Older adults without MCI

Participants in both groups were selected by matching based on the age (± 1 year) and gender to control the inter-subject differences.

3.3 Inclusion criteria

Participants aged 60 years or older were recruited in this study. The participants consisted of two groups, including older adults with MCI and older adults without MCI. The criteria for the participants' recruitment are as follows.

<u>The older adults with MCI were included if they had:</u>

1. diagnosis of MCI according to DSM-5-TR criteria and clinical diagnosis by consensus of evaluation teams led by the clinician.

2. no history of clinical dementia.

3. mild cognitive impairment based on the Montreal Cognitive Assessment (MoCA) score of fewer than 25 points (Appendix C).

4. generally independence in everyday functioning based on the Barthel Index for Activities of Daily Living (Barthel ADL) equal or more than 12 (Appendix B).

<u>The older adults without MCI were included if they had:</u>

1. no history of MCI and clinical dementia

2. the MoCA score more than 25 points

3. generally independence in everyday functioning based on the Barthel Index for Activities of Daily Living (Barthel ADL) equal or more than 12.

3.4 Exclusion criteria

Both groups of participants were excluded if they had:

1. neurological conditions (e.g., cerebrovascular disease, multiple sclerosis, and Parkinson's disease, etc.) or chronic diseases (e.g., severe cardiovascular disease, poorly controlled hypertension, and crippling arthritis) which affect cognitive function, gait and balance, which was reported by the participants.

2. depressive symptoms based on the Thai Geriatric Depression Scale (TGDS) score more than 12 (Appendix D).

3. visual problem (except for participants who could be corrected with eyeglasses or contact lenses).

4. a problem to complete the task testing.

3.5 Sample size and sample size calculation

Seventy participants (35 participants in older adults with MCI and 35 participants in older adults without MCI) were recruited. The sample size was calculated by using the G*Power 3.1.9 based on the small effect size (0.14; partial eta square 0.02). The type I (Alpha) and type II (Beta) errors were set at 0.05 and 0.20, respectively. The number of groups was set at 2, and the number of the measurement was set at 4 (based on the condition of the testing) (Figure 5). From the G*Power, the total number of participants was 70.

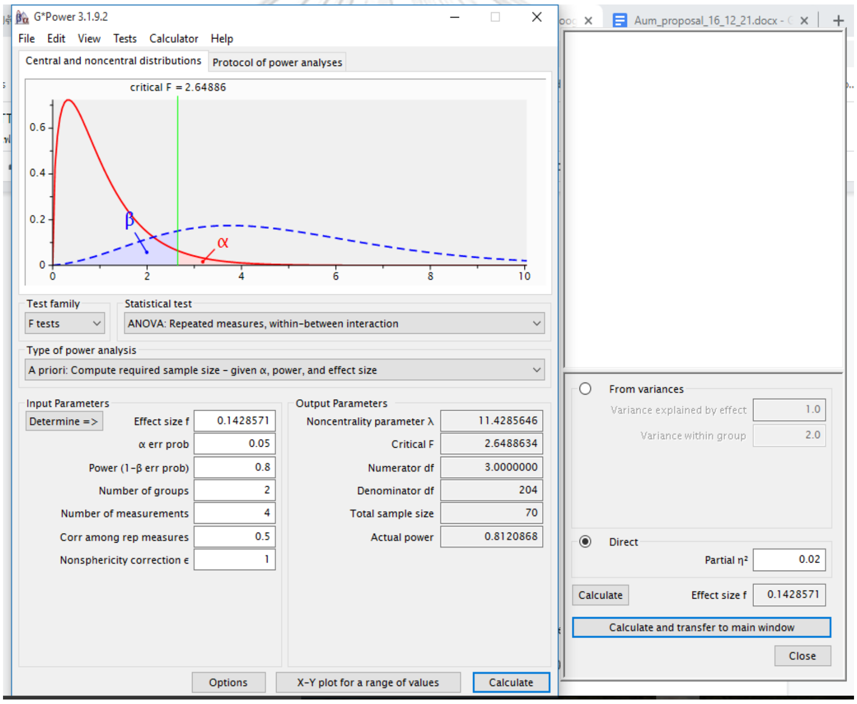


Figure 4 Sample size calculation

3.6 Screening tools

3.6.1 Screening questionnaire (Appendix A)

3.6.2 Montreal Cognitive Assessment

Montreal Cognitive Assessment (MoCA) is a cognitive screening tool that was developed by Nasreddine and colleagues in 2004 (Nasreddine et al., 2005). This test was used to assess multiple cognitive functions to detect MCI. The MoCA test comprises seven domains: visuospatial/ executive, naming, memory, attention, language, abstraction and orientation. It was translated into Thai and validated by Tangwongchai and colleagues in 2009 (Tangwongchai et al., 2009). The cut-off scores for detecting MCI were less than 25 points (Larner et al., 2017).

3.6.3 Barthel index score

Mahoney and Barthel first developed the Barthel index score in 1965 (Mahoney, 1965). The purpose of this assessment tool was to measure the functional ability independently in the activity of daily living (ADL), including feeding, bathing, grooming, dressing, bowel control, bladder control, toileting, chair transfer, ambulation, and stair climbing. This assessment can indicate the need for a caregiver and assistance care. Later, Collin and colleagues modified the assessment into 10 items and scored 0-1, 0-2, 0-3, and the ranging score was 0-20 (Collin et al., 1988). A higher score reflected the greater ability to perform ADL independently. In contrast, the lower score indicated the need for caregivers and assistance.

3.6.4 Thai Geriatric Depression scale

The Thai Geriatric Depression scale (TGDS) was developed by The Brain Forum Committee-Siriraj Hospital Gazette (1994) (Poungvarin & Committee, 1994). The TGDS is a depression self-rating scale for elderly adults. The TGDS consists of 30 items and takes about 10 minutes to administer. The answer consists of two choices: "YES" or "NO". The total score is 30 points. Scores below 13 indicate normal depression, scores between 13 and 18 indicate mild depression, scores 19 to 24 indicate moderate depression, and scores >25 indicate severe depression.

3.7 Instrumentations

3.7.1 Three-dimensional motion analysis system

Eight motion capture cameras (Raptor E, Motion Analysis Corporation, Santa Rosa, CA, USA) were used in the present study (Figure 5). The markers' trajectories were collected using the CortexTM program (v. 8.1), and the data were analyzed using the Kintool RT software. A sampling rate of 120 Hz was used, with a shutter speed of 1/1000 second.

Figure 5 Three-dimensional motion analysis system

3.7.2 Force platforms

Force data were collected using the two Bertec force platforms (Bertec Corp Columbus, OH) with a sample rate of 1200 Hz (Figure 6).

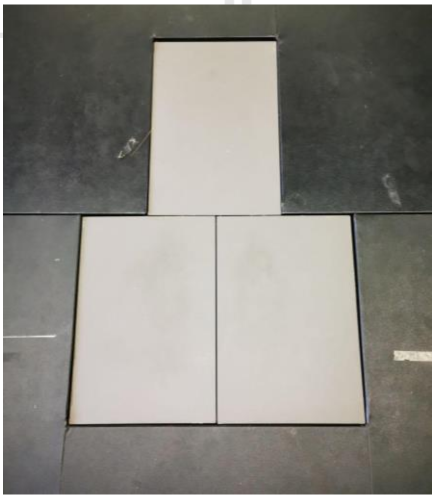


Figure 6 Force platforms

3.7.3 Reflective markers

In this study, thirty-three reflective markers were applied. The markers were 12.5 mm in diameter (Figure 7). The participant's body was marked with 31 reflective markers, and the chair was marked with two reflective markers.

Figure 7 Reflective markers

3.7.4 Chair

This study used a chair without an armrest and a backrest. The height of the chair can be adjusted for individual participants. The height can be set between 27 to 50 centimeters (Figure 8).

Figure 8 Chair

3.7.5 Measuring tape

Figure 9 Measuring tape

3.7.6 Cup and tray

Figure 10 Cup and Tray

3.8 Procedures

The participants and their guardians were informed about this study's purposes and testing procedures before signing and informed contents before experimental testing. Before data collection, this study protocol was sought from the Institutional Review Board Faculty of Medicine, Chulalongkorn University. All data were collected in the Motor Control and Motion Analysis Research Laboratory at the Department of Physical therapy, Faculty of Allied Health Science, Chulalongkorn University. Before the testing, all participants were recorded the demographic data. Then, the anthropometric data and markers were measured and the markers were attached, respectively. The details of these procedures were explained in the next session. After the markers were attached, the participants were asked to perform the testing. After finishing the testing, all participants were examined functional muscle strength by using the five times sit-to-stand test (FTSTS), which moderates concurrent validity (r = 0.59) ($p < 0.001$) and good intrarater (ICC (3,2) = 0.99) and inter-rater (ICC (2,2) = 1.00) reliability (Appendix G). The overall procedures are presented in Figure 11 (Appendix G).

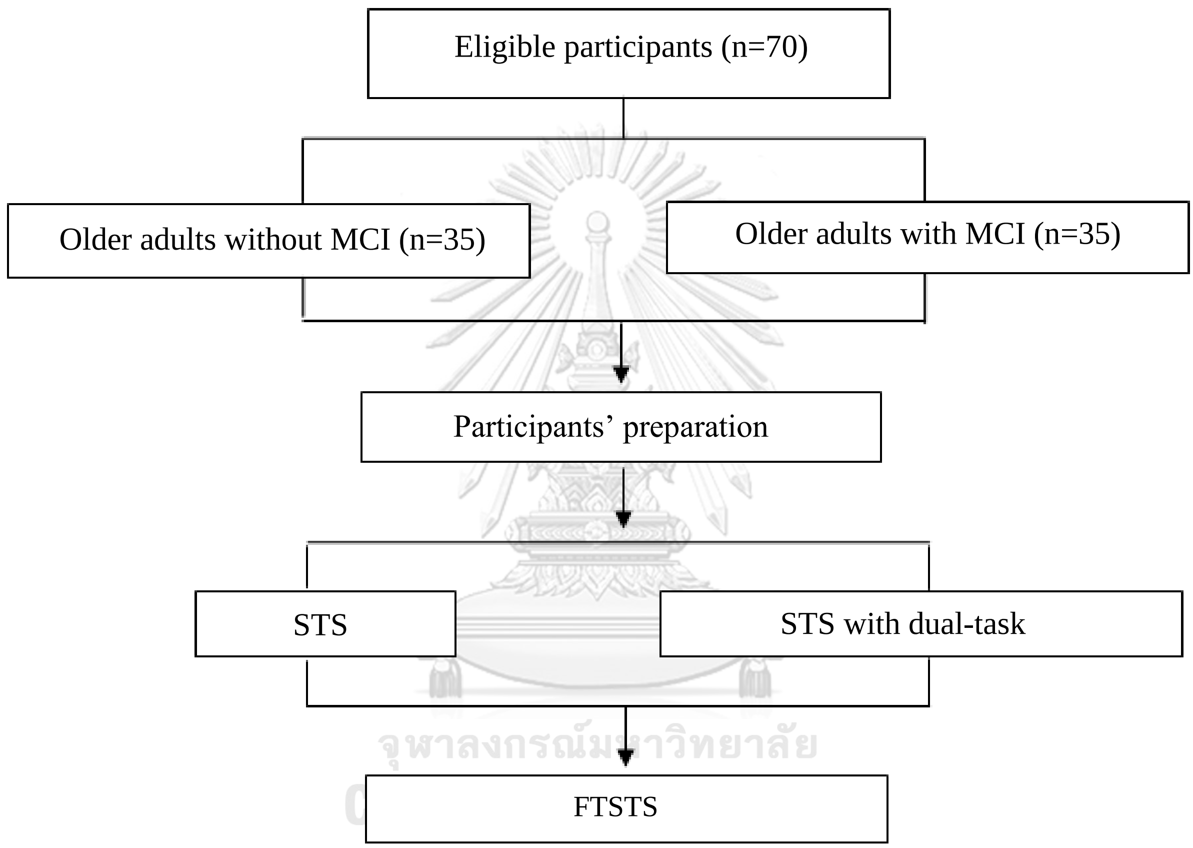


Figure 11 Procedure of the study

3.8.1 Participant's preparation

All participants were requested to change into tank tops, shorts, and swim caps provided by the researcher. Then, they measured anthropometric data, including weight (kg) and height (cm). These data were used for calculating the joint center in the KinTools RT software. After that, the thigh and lower leg length (cm) of the non-dominant leg was measured in a standing position. These lengths were used to set the starting position and adjust the chair's height. The thigh length was measured from the greater trochanter to the lateral femoral condyle. The lower leg length was measured from the knee joint space to the floor.

The dominant leg was determined by asking participants to do the following activities: kick a ball, pick up a small object from the floor, and trace the shape on the floor. These three tasks were chosen because they have a moderate to high level of reliability. The leg that performs at least two out of three tasks was designated as the dominant leg (Schneiders et al., 2010).

All data were recorded on the personal data collection form (Appendix F). Then, according to Helen Hayes' marker set model, twenty-nine reflexive markers were placed on the participant's body (Figure 12) (Appendix: E), and the additional marker was placed on the right and left greater trochanter. These additional markers were used to define the time when the buttock is off the chair.

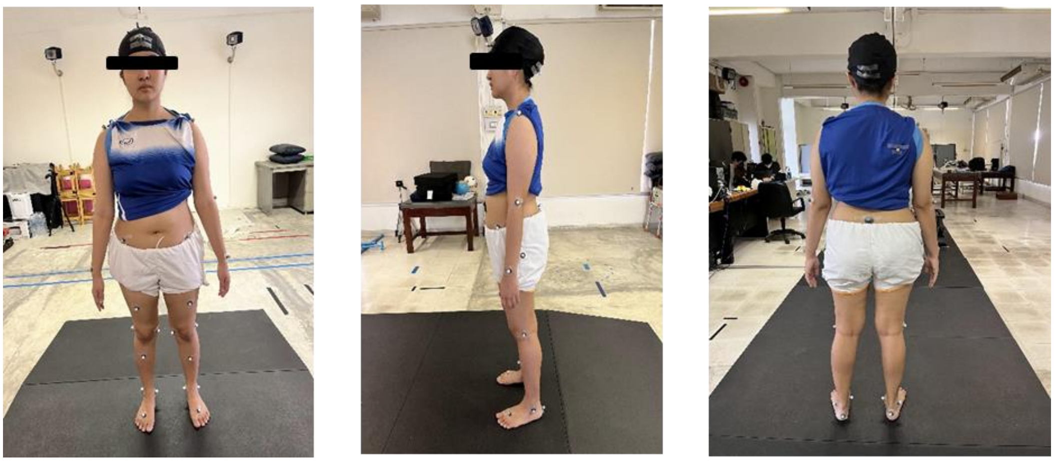


Figure 12 Helen Hayes' marker

3.8.2 Data collection

The participants performed STS in two conditions, including STS and STS with dual task (motor tasks). The sequence of the conditions was randomly assigned. In both conditions, the chair's height was set at 100% lower leg length in each participant (de Medeiros et al., 2015).

In the STS condition, the participants were sitting on the adjustable chair with arms relaxed beside the body and looking forward. Both feet were kept shoulder-width apart and placed on the force platforms. The lateral malleolus was set to align with the center of the knee joint (Figure 13). The seat depth was set at 30 % of thigh length (Diakhaté et al., 2013). After setting the starting position, the researcher marked the position of the feet and the location of the buttock. These marks were used to ensure that participants were set in the same position in every trial.

Figure 13 sit to stand starting position

In the condition of STS with motor dual task, all the positions were set at the same condition except the dominant hand, which carried a glass of water on the tray (elbow flexion 90 degrees). A glass of water was filled to 1 cm from the top of the glass (a water 230 ml) (Figure 14).

Figure 14 sit to stand with dual task starting position

In all conditions of the STS task, participants were asked to maintain his/her trunk and head in an upright position and then perform standing up with the preferred speed, standing steady for 3 seconds, and then sitting down. A few trials (2-3 trials) of STS tasks were allowed to make participants familiar with the study protocol. After the participants were ready, the motion capture started recording. Then, STS was promptly performed on command "standing up". During the STS task, participants do the task with a self–selected pattern in which the foot placement was constrained except to ensure that each foot was placed on each force platform. The three successful trials of STS tasks were collected. The participants were given at least a 5-minute rest period between the different conditions.

3.9 Data processing

The phase of STS was divided into 4 phases: flexion momentum (T0-T1), momentum transfer (T1-T2), extension phase (T2-T3), and stabilizing phase (T3-T4) (Mapaisansin et al., 2020). Firstly, the flexion momentum phase (phase1) began while the initiation of movement (T0) detected by the shoulder marker, or the ankle marker move and the horizontal velocity greater than 0.01m/sec and the end of this phase was the seat off (T1) detected by the greater trochanter marker of both sides moved vertical displacement away 0.1 cm from the seat.

Second, the momentum transfer phase (phase2), using a ground reaction force to be detected, the beginning of this phase was the time after the seat off the chair and end until reached maximum vertical ground reaction force (T2).

Then, the extension phase (phase3) begins after the reach of the vertical ground reaction force and ended until the end of the movement that was detected by the shoulder marker or the ankle marker move and the vertical velocity less than 0.01m/sec.

Lastly, the last phase, stabilizing phase, begins after the hip marker velocity after the hip extension is less than or equal to 0.01 m/second.

3.9.1 Movement time

Movement time was recorded in 2 parts: total movement time and movement time in each phase, which reports the percent of movement time in 4 phases. The total movement time was recorded from the beginning of STS (T0) until the end of the movement (T4). The percent of movement time in each phase consists of time in phase 1 (T0-T1), time in phase 2 (T1-T2), time in phase 3 (T2-T3), and time in phase 4 (T3-T4)

3.9.2 Angular displacement

The five segments model used in this study consists of the trunk, pelvis, thigh, shank, and foot (Figure 15).

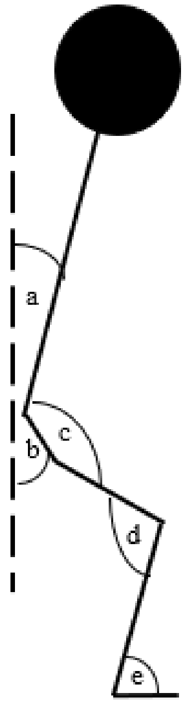


Figure 15 The body segments and the angles of measurement , a) trunk angle, b) pelvis angle, c) hip angle; d) knee angle, and e) ankle angle

The average angle degrees of trunk, pelvis, hip, knee, and ankle from three trials in each limb were computed. The angle degree divides into the absolute angle and relative angle. Trunk and pelvic angle (a,b) used the absolute angle of the segments, the vertical line global reference coordinate system. Hip, knee, and ankle used the relative angle of the segments. The hip angle (c) was defined as the angle of pelvis relative to thigh segments. The knee angle (d) was defined as the angle of thigh relative to shank segments. The ankle angle (e) was defined as the angle of shanks relative to the foot segments. The initial angle of the movement, angle in each time point of trunk, pelvis, hip, knee, and ankle joint, and the maximum angle of trunk flexion, anterior pelvic tilt, hip flexion, knee flexion , and ankle dorsi flexion in the sagittal plane during STS were calculated for further analysis. The kinematic data was normalized by time with initial movement at 0% and the end of the movement at 100% of the task, which present in the graph.

3.9.3 Peak vertical ground reaction force

The peak vertical ground reaction force was recorded during the seat off, the time of greatest value force exerted by the ground on body contact. This value was corrected and normalized with respect to the body weight (N/kg).

3.9.4 Joint moment

The maximum joint moments of hip, knee, and ankle joint were calculated and normalized with respect to the body weight (N.m/kg). The maximum moment of hip and knee extension, and ankle plantar flexion after seat-off (T1) were used for further analysis.

3.10 Data analysis

The data analysis was performed with SPSS (SPSS Inc, 233 S Wacker Dr, 11th Fl, and Chicago, IL 60606) version 28 for Windows. The Shapiro-Wilk test showed the normal data distribution for all variables. The significance level was set at $P < 0.05$. The participant's characteristic was reported using descriptive statistic. The independent t-test and Chi-square test were used for comparing demographic data between older adults with and without MCI.

Two-way mixed repeated measures ANOVA were used to compare the difference in movement time, the angular displacement of trunk and pelvis between groups (older adults with MCI VS older adults without MCI), and conditions (single STS VS dual STS). In addition, three-way mixed repeated measures ANOVA were used to compare the difference of angular displacement, the maximum joint moment of the hip, knee, and ankle, as well as peak vertical ground reaction force of dominant and non-dominant lower extremities between groups (older adults with MCI VS older adults without MCI) and conditions (single STS VS-dominant leg, single STS -non-dominant leg, dual STS -dominant leg, and dual STS -non-dominant leg). A Bonferroni post hoc analysis was used for pairwise comparisons if the analysis showed significant differences.

3.11 Ethical Consideration

Respect for person: The participants must be well informed and given consent before beginning the research protocol. If participants decide to withdraw from the study, they can do so at any time.

Non-maleficence: Risks to subjects are minimized. The markers and physical tests are non-invasive. Recorded data are anonymized. If data loss were to occur, there would be a low risk due to the nature of the recordings.

Justice: The subjects would be enrolled conveniently according to the defined inclusion and exclusion criteria.

CHAPTER 4

RESULTS

4.1 Introduction

This study examined differences in STS ability between older adults with and without MCI under single-task and dual-task conditions. This chapter presents the study results in terms of movement time, kinematics, and kinetics.

4.2 Participant characteristics

The 70 participants included in this study were divided into two groups: those with MCI and those without MCI. The characteristics of the participants are presented in Table 1. The independent sample t-test and chi-square test were used to compare differences in participant characteristics between groups. Statistical analysis showed that lower leg length and MoCA score significantly differed between groups. The older adults without MCI who comprised the control group had larger values for lower leg length and higher MoCA scores than the older adults with MCI. The details of the individual MoCA domain scores (Julayanont et al., 2014) for the older adults with MCI are shown in Table 2.

Table 1 Characteristics of the study participants (n = 70)

Characteristics	MCI (n = 35)	Control (n = 35)	p-value
Age (years); mean (SD)	67.31 (4.08)	67.22 (4.41)	0.93
Gender (female: male); n	4:31	4:31	1.00
Weight (kg); mean (SD)	56.68 (8.83)	58.85 (10.38)	0.35

Height (cm); mean (SD)	156.66 (5.90)	158.17 (5.51)	0.27
BMI (kg/m^2); mean (SD)	23.07 (3.12)	22.77 (5.35)	0.78
Leg length (cm); mean (SD)	78.06 (2.30)	78.98 (2.58)	0.12
Upper leg length (cm); mean (SD)	37.03 (1.43)	36.98 (1.65)	0.87
Lower leg length (cm); mean (SD)	39.45 (1.45)	40.29 (1.39)	0.02*
FTSTS (s); mean (SD)	10.14 (2.00)	10.18 (1.59)	0.91
Medical conditions; n (%)			
- **Hypertension**	10 (28.57)	7 (20)	0.39
- **Hyperlipidemia**	17 (48.57)	14 (40)	
- **Diabetes**	10 (28.57)	3 (8.57)	
History of falls; n (%)			
- **Falls**	13 (37.14)	8 (22.86)	0.19
- **No falls**	22 (62.86)	27 (77.14)	
Exercise; n (%)			
- **Exercise**	15 (42.86)	19 (54.29)	0.34
- **No exercise**	20 (57.14)	16 (45.71)	
MoCA scores; mean (SD)	22.08 (1.84)	26.51 (1.88)	< 0.001*

Note: *$p < 0.05$; gender, medical conditions, falls, exercise = chi-squared test; age, weight, height, BMI, leg length, upper leg length, lower leg length, (five time sit-to-stand test) FTSTS, MoCA score = independent t-test; n = number of participants.

Table 2 MoCA domain scores for older adults with MCI (n = 35)

MoCA domain (total score)	Mean (SD)	Range
Memory Index Score (15)	10.03 (2.48)	4–14
Executive Index Score (13)	10.94 (1.55)	8–14
Visuospatial Index Score (7)	5.77 (1.00)	3–7
Language Index Score (6)	4.31 (1.30)	0–6
Attention Index Score (18)	15.91 (1.31)	13–18
Orientation Index Score (6)	5.94 (0.23)	5–6

4.3 Movement time

Movement time encompassed total movement time and the percentage of the movement time spent in each phase (phases 1, 2, 3, and 4). The means and standard deviations of these variables for both groups are shown in Table 3.

Table 3 Total movement time and percent of movement time in each phase

Variables	Single condition		Dual condition	
	MCI	**Control**	**MCI**	**Control**
Total movement time (s)	1.97 (0.35)	1.92 (0.26)	2.11 (0.39)	2.02 (0.26)
Phase 1 (%)	15.71 (10.07)	18.84 (8.70)	13.96 (7.98)	18.11 (9.48)
Phase 2 (%)	15.89 (5.54)	14.84 (0.26)	18.04 (6.39)	17.03 (6.53)
Phase 3 (%)	27.74 (8.56)	26.12 (7.32)	28.85 (8.47)	27.24 (8.61)
Phase 4 (%)	40.66 (7.47)	40.19 (6.79)	39.16 (9.92)	37.62 (6.69)

A main effect of condition was found only on total movement time and percent of movement time in phase 2. There were significant main effects of condition on total movement time (F (1,68) = 6.11, p = 0.016) and percent of movement time in phase 2 (F (1,68) = 7.16, p = 0.009). The total movement time and percent of movement time in phase 2 of the dual-task condition were greater than those of the single-task condition (Figures 16 and 17).

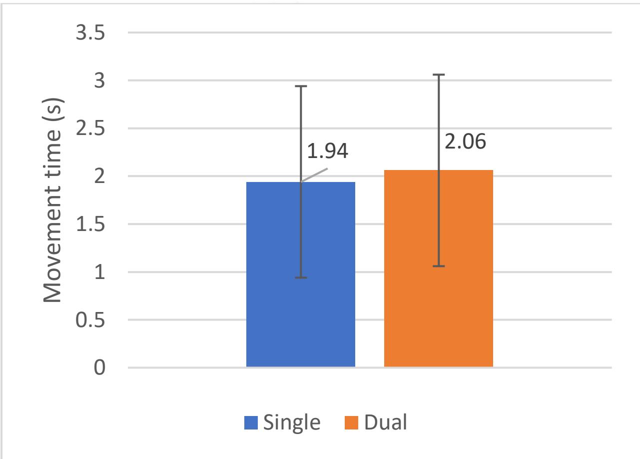


Figure 16 Total movement time of the single- and dual-task conditions

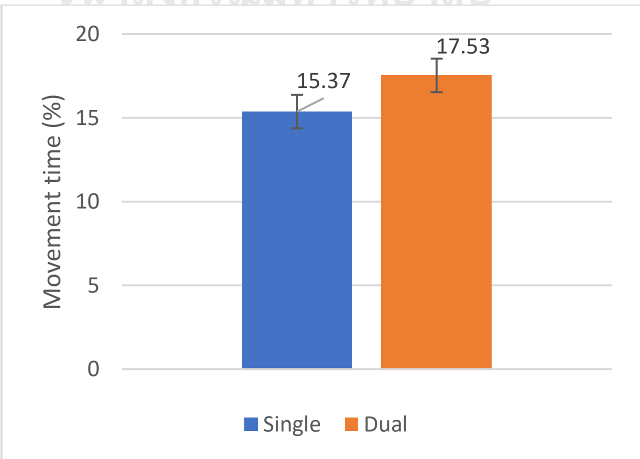


Figure 17 Percent of movement time in phase 2 of the single- and dual-task conditions

4.4 Kinematics

The means and standard deviations of the trunk and pelvic angles at each time point (T0–T4), the maximum trunk flexion angle, and the maximum anterior pelvic tilt angle are presented in Table 4.

Table 4 Trunk and pelvis angles during STS in single- and dual-task conditions

Variables	Single condition		Dual condition	
	MCI	**Control**	**MCI**	**Control**
Trunk angle (º)				
Angle at T0	-1.47 (3.25)	-0.96 (3.25)	-2.30 (5.04)	0.38 (2.56)
Angle at T1	0.64 (4.25)	2.09 (5.29)	-1.13 (6.25)	3.55 (3.52)
Angle at T2	18.01 (9.36)	16.23 (11.31)	17.79 (9.05)	14.82 (8.56)
Angle at T3	8.08 (5.11)	10.79 (7.48)	9.72 (6.65)	9.48 (7.75)
Angle at T4	-3.85 (3.33)	-3.04 (3.66)	-2.82 (3.27)	-3.15 (3.66)
Maximum trunk flexion	25.28 (8.99)*	23.27 (7.85)	28.95 (8.59)*#	23.58 (6.98)
Pelvis angle (º)				
Angle at T0	-7.25 (8.09)	-4.94 (7.60)	-7.29 (8.09)	-3.94 (9.30)
Angle at T1	2.56 (9.12)	7.26 (9.03)	1.99 (9.04)	6.98 (10.26)
Angle at T2	18.12 (9.12)	22.30 (7.97)	17.52 (8.78)	20.91 (9.67)
Angle at T3	11.41 (7.15)	14.57 (8.31)	12.28 (6.42)	14.11 (8.61)
Angle at T4	4.58 (5.32)	6.08 (7.05)	4.75 (4.68)	5.75 (7.34)
Maximum anterior pelvic tilt	21.31 (8.49)	23.43 (8.61)	21.23 (7.89)	23.14 (8.65)

Note. Values are means ± SD; *Significant difference between groups in both conditions ($p < 0.05$); #Significant difference between conditions in MCI group ($p < 0.05$); T0 = starting point, T1 = seat-off, T2 = point of maximum vertical ground reaction force, T3 = highest shoulder level, T4 = end of movement, (-) = trunk extension and posterior pelvic tilt.

A two-way mixed, repeated measures ANOVA was used to compare differences in trunk and pelvic angles between conditions (single and dual) and groups (MCI and control).

For trunk angle, there were significant group main effects on the angle at T1 ($F(1,68) = 14.13$, $p < 0.001$), T2 ($F(1,68) = 19.25$, $p < 0.001$), and T3 ($F(1,68) = 24.56$, $p < 0.001$). A pairwise comparison showed that the older adults with MCI showed less trunk flexion at T1 and T3 and greater trunk flexion at T2 than the control group (Figures 18, 19, and 20). In addition, a significant group × condition interaction was found for maximum trunk flexion ($F(1,68) = 21.96$, $p < 0.001$). During both STS alone and STS with a dual task, the older adults with MCI had greater trunk flexion angles compared to the controls. Furthermore, the older adults with MCI had greater trunk flexion angles during STS with a dual task than during STS alone (Table 4 and Figure 21).

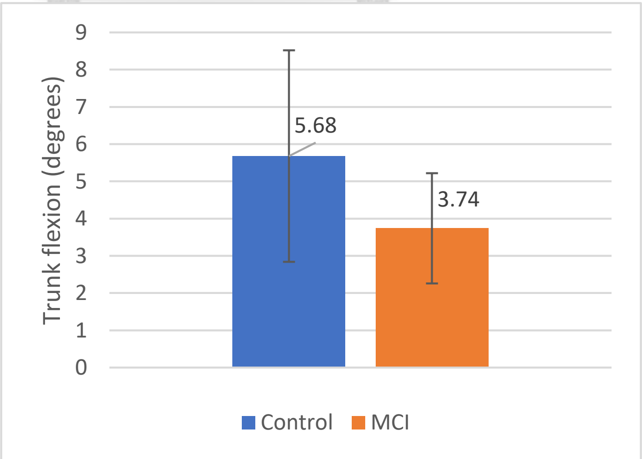


Figure 18 Trunk flexion angle at T1 in MCI and control groups

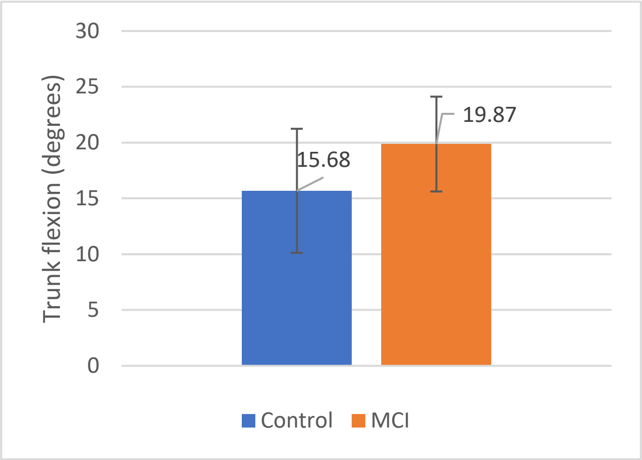


Figure 19 Trunk flexion angle at T2 in MCI and control groups

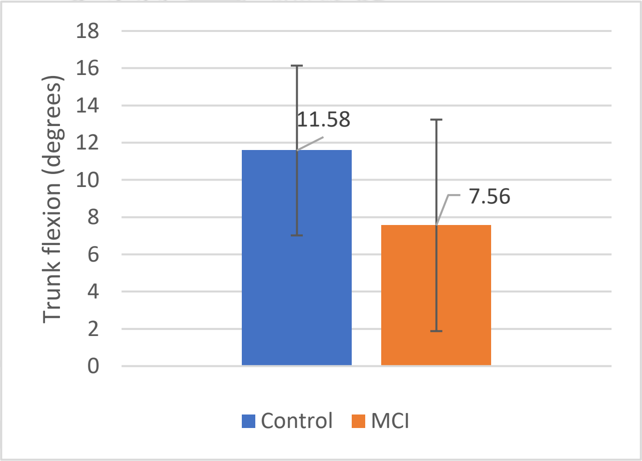


Figure 20 Trunk flexion angle at T3 in MCI and control groups

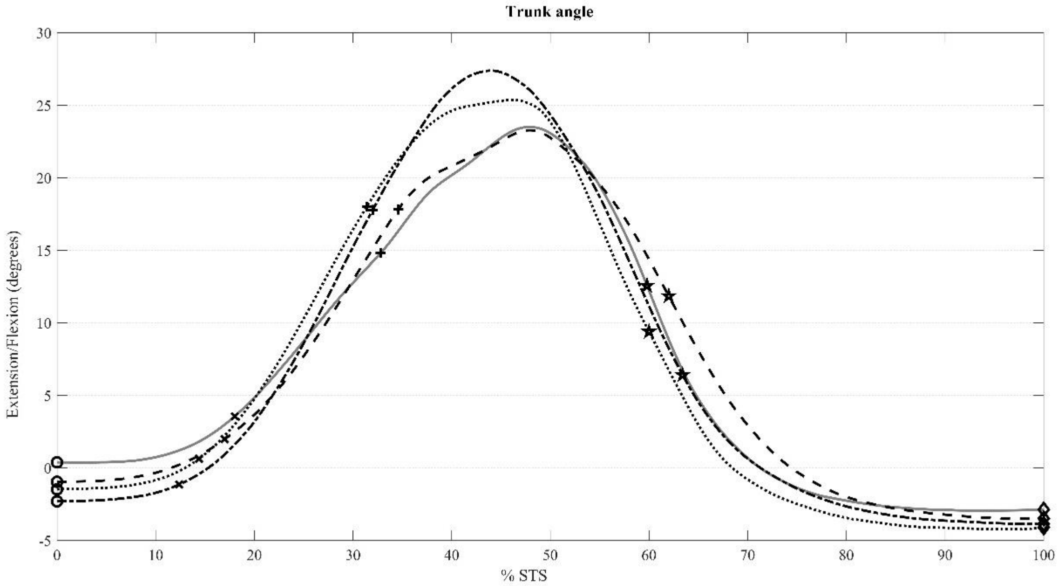


Figure 21 The movement of the trunk in control group during STS alone (solid line), control group during STS with dual task (dashed line), MCI group during STS alone (dot line), and MCI group during STS with dual task (dash-dot line). The symbol (○) represents T0 = starting point, (×) is T1 = seat-off, (+) is T2 = point of maximum vertical ground reaction force, (*) is T3 = highest shoulder level, and (♦) is T4 = end of movement.

For pelvic angle, there were no significant group × condition interactions, group main effects, or condition main effects at any time point or for maximum anterior pelvic tilt angle (Figure 22).

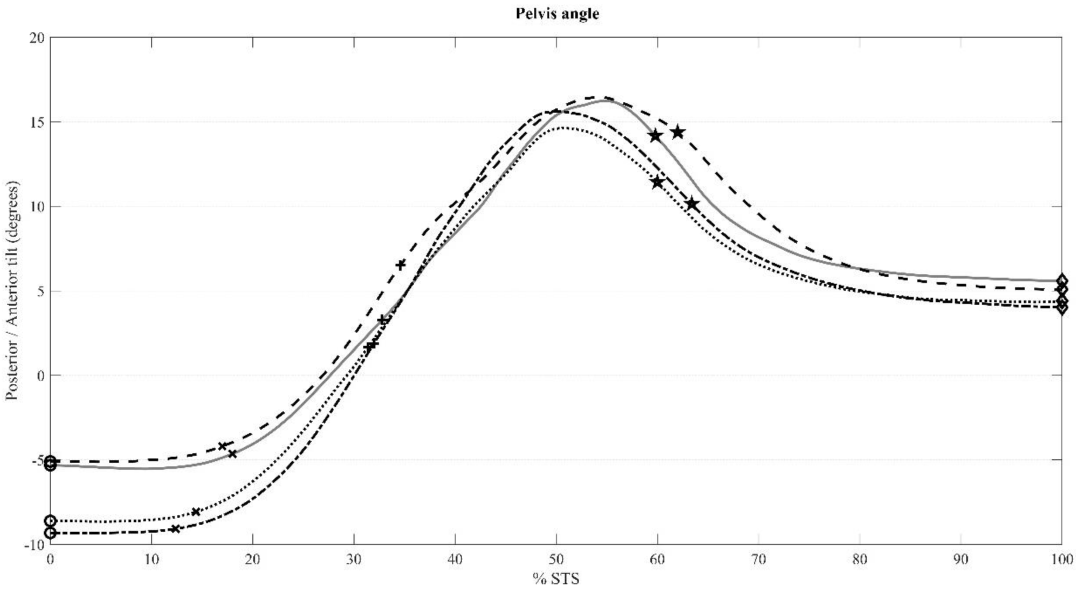


Figure 22 The movement of the pelvic in control group during STS alone (solid line), control group during STS with dual task (dashed line), MCI group during STS alone (dot line), and MCI group during STS with dual task (dash-dot line). The symbol (○) represents T0 = starting point, (×) is T1 = seat-off, (+) is T2 = point of maximum vertical ground reaction force, (*) is T3 = highest shoulder level, and (♦) is T4 = end of movement.

For hip, knee, and ankle angles, a three-way mixed, repeated measures ANOVA was employed to compare differences between conditions (single and dual), groups (MCI and control), and sides (dominant and non-dominant leg). The means and standard deviations of the hip, knee, and ankle angles at each time point (T0–T4) and the maximum hip flexion, knee flexion, and ankle dorsiflexion angles are displayed in Tables 5, 6, and 7, respectively.

For hip angle, a significant group × condition × side interaction was found only at T2 ($F(1,68) = 6.49$, $p = 0.013$). During STS alone, the control group had greater hip flexion angles on the dominant leg than on the non-dominant leg. In addition, the control group demonstrated greater hip flexion angles of the dominant leg during STS alone than during STS with a dual task. Furthermore, during both STS alone and STS with a dual task, the older adults with MCI demonstrated more hip flexion of the dominant leg than the non-dominant leg (Table 5).

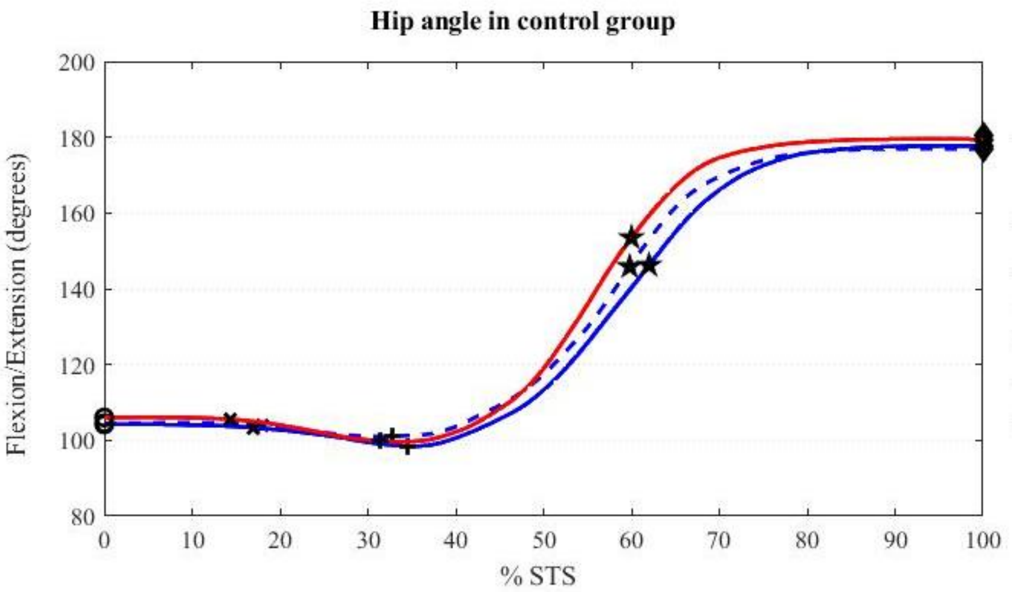


Figure 23 The movement of the hip in control group in dominant leg during STS alone (blue solid line), dominant leg during STS with dual task (blue dashed line), non-dominant leg during STS alone (red solid line), and non-dominant leg during STS with dual task (red dash line). The symbol (O) represents T0 = starting point, (×) is T1 = seat-off, (+) is T2 = point of maximum vertical ground reaction force, (*) is T3 = highest shoulder level, and (♦) is T4 = end of movement.

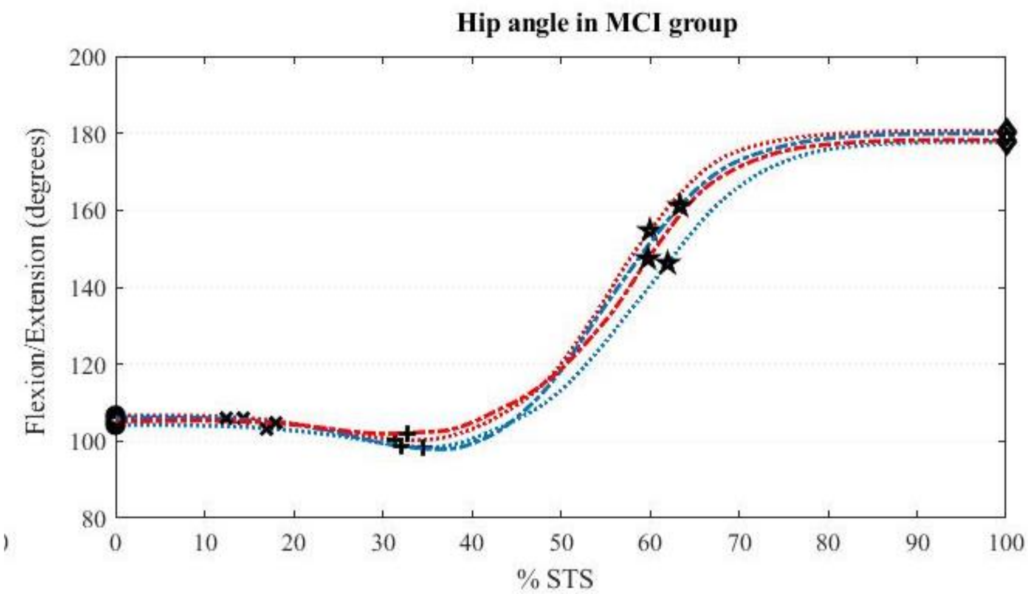


Figure 24 The movement of the hip in MCI group in dominant leg during STS alone (blue dot line), dominant leg during STS with dual task (blue dashed line), non-dominant leg during STS alone (red dot line), and non-dominant leg during STS with dual task (red dash line). The symbol (○) represents T0 = starting point, (×) is T1 = seat-off, (+) is T2 = point of maximum vertical ground reaction force, (*) is T3 = highest shoulder level, and (♦) is T4 = end of movement.

For knee angle, a significant group × condition × side interaction was found at T3 ($F(1,68) = 4.90$, $p = 0.03$) and for maximum knee flexion angle ($F(1,68) = 24.22$, $p < 0.001$). In both the older adults with MCI and controls, during STS alone and STS with a dual task, the dominant leg had a greater maximum knee flexion angle than the non-dominant leg. On the other hand, at T3 during STS alone and STS with a dual task, both groups demonstrated less knee flexion of the non-dominant leg than the dominant leg (Table 6).

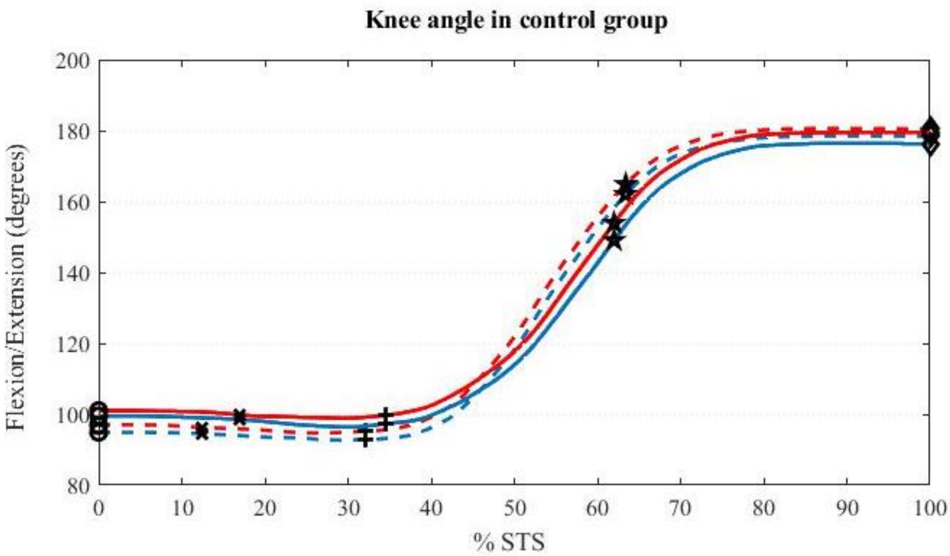


Figure 25 The movement of the knee in control group in dominant leg during STS alone (blue solid line), dominant leg during STS with dual task (blue dashed line), non-dominant leg during STS alone (red solid line), and non-dominant leg during STS with dual task (red dash line). The symbol (○) represents T0 = starting point, (×) is T1 = seat-off, (+) is T2 = point of maximum vertical ground reaction force, (*) is T3 = highest shoulder level, and (♦) is T4 = end of movement.

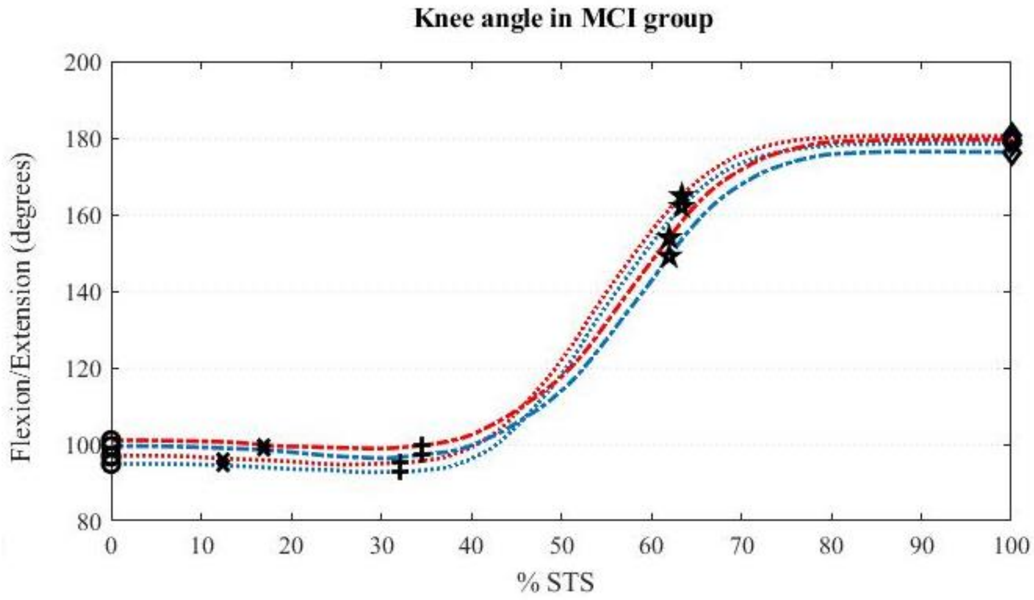


Figure 26 The movement of the knee in MCI group in dominant leg during STS alone (blue dot line), dominant leg during STS with dual task (blue dashed line), non-dominant leg during STS alone (red dot line), and non-dominant leg during STS with dual task (red dash line). The symbol (○) represents T0 = starting point, (×) is T1 = seat-off, (+) is T2 = point of maximum vertical ground reaction force, (*) is T3 = highest shoulder level, and (♦) is T4 = end of movement.

For ankle angle, a significant group × condition × side interaction was found at T2 ($F(1,68) = 48.22$, $p < 0.001$) and for maximum ankle dorsiflexion angle ($F(1,68) = 51.52$, $p < 0.001$). In both older adults with MCI and controls, during STS alone and STS with a dual task, the dominant leg reached a greater ankle dorsiflexion angle at T2 and a greater maximum ankle dorsiflexion angle than the non-dominant leg (Table 7).

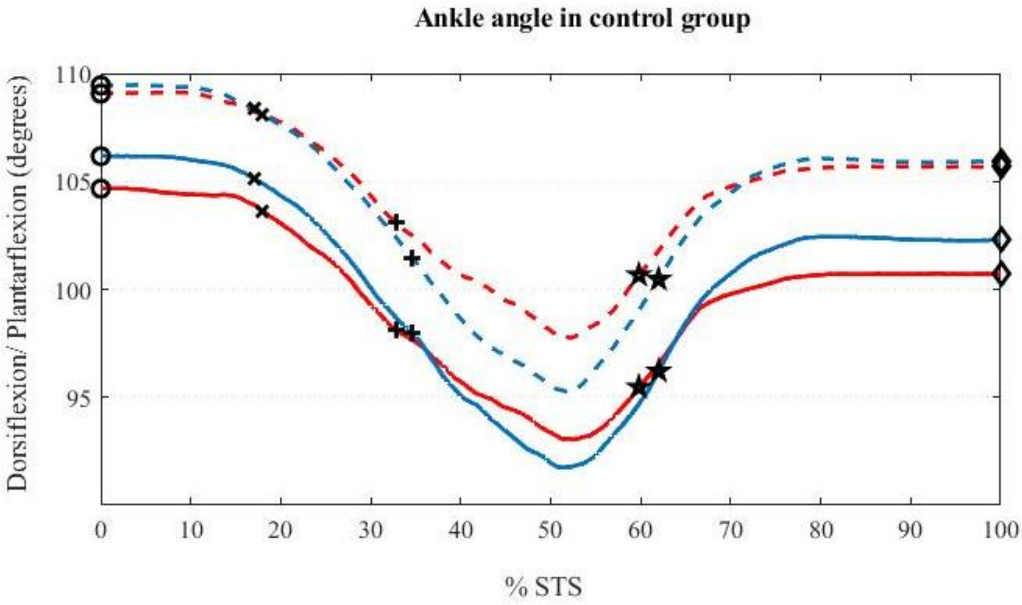


Figure 27 The movement of the ankle in control group in dominant leg during STS alone (blue solid line), dominant leg during STS with dual task (blue dashed line), non-dominant leg during STS alone (red solid line), and non-dominant leg during STS with dual task (red dash line). The symbol (O) represents T0 = starting point, (×) is T1 = seat-off, (+) is T2 = point of maximum vertical ground reaction force, (*) is T3 = highest shoulder level, and (♦) is T4 = end of movement.

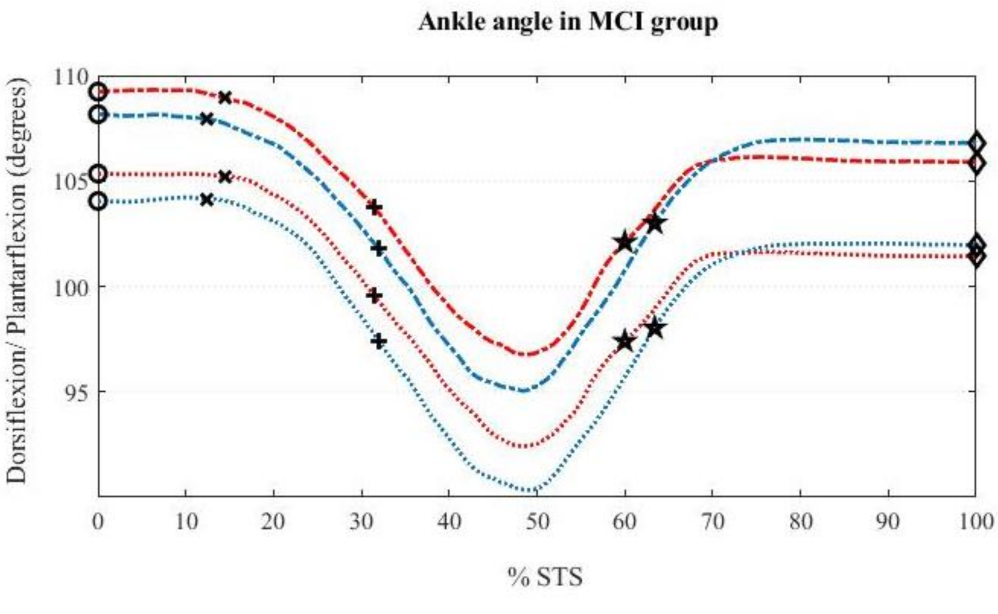


Figure 28 The movement of the ankle in MCI group in dominant leg during STS alone (blue dot line), dominant leg during STS with dual task (blue dashed line), non-dominant leg during STS alone (red dot line), and non-dominant leg during STS with dual task (red dash line). The symbol (O) represents T0 = starting point, (×) is T1 = seat-off, (+) is T2 = point of maximum vertical ground reaction force, (*) is T3 = highest shoulder level, and (♦) is T4 = end of movement.

Table 5 Hip angle during sit-to-stand in single- and dual-task

Variables	Single condition				Dual condition			
	MCI		Control		MCI		Control	
	D leg	ND leg	D leg	ND leg	D leg	ND leg	D leg	ND leg
Hip angle (°)								
Angle at T0	104.59 (9.29)	105.35 (9.24)	103.93 (9.30)	104.54 (9.55)	104.32 (8.49)	105.54 (8.29)	102.89 (9.96)	104.01 (9.89)
Angle at T1	96.86 (9.48)	97.81 (9.35)	94.76 (9.71)	96.00 (9.86)	97.61 (9.34)	99.39 (9.41)	95.96 (12.17)	96.91 (11.32)
Angle at T2	96.87 (12.69)	98.04 (12.61)*	94.79 (11.84)[a]	96.48 (11.38)*	97.33 (11.35)	99.08 (11.83)*	99.88 (14.21)[a]	99.74 (13.61)
Angle at T3	157.53 (11.82)	158.51 (11.83)	152.40 (13.69)	153.94 (14.13)	156.23 (10.95)	157.38 (11.17)	153.34 (14.21)	154.36 (14.73)
Angle at T4	180.00 (9.31)	180.88 (8.58)	177.16 (9.04)	178.06 (9.57)	179.73 (7.56)	180.15 (7.37)	177.33 (8.98)	177.80 (9.93)
Maximum hip flexion	90.14 (9.95)	91.31 (9.96)	88.47 (10.38)	90.11 (10.29)	90.94 (10.11)	92.13 (10.23)	90.21 (11.36)	91.38 (11.49)

Note. Values are means ± SD; *Significant difference between dominant and non-dominant legs ($p < 0.05$); [a] Significant difference between single- and dual-task conditions for the dominant leg in the control group ($p < 0.05$); T0 = starting point, T1 = seat-off, T2 = point of maximum vertical ground reaction force, T3 = highest shoulder level, T4 = end of movement, D = dominant leg, ND = non-dominant leg.

Table 6 Knee angle during sit-to-stand in single- and dual-task conditions

Variables	Single condition				Dual condition			
	MCI		Control		MCI		Control	
	D leg	ND leg	D leg	ND leg	D leg	ND leg	D leg	ND leg
Knee angle (º)								
Angle at T0	96.06 (7.12)	97.40 (6.82)	97.07 (5.87)	99.02 (6.32)	93.96 (6.79)	96.18 (6.48)	97.95 (11.15)	98.99 (8.00)
Angle at T1	92.20 (8.07)	94.87 (7.65)	93.88 (8.15)	97.33 (8.07)	91.78 (8.23)	94.45 (7.20)	94.65 (13.12)	96.52 (9.20)
Angle at T2	99.69 (9.51)	102.59 (9.60)	101.77 (9.29)	105.93 (8.34)	97.38 (7.75)	100.19 (7.76)	103.47 (12.14)	105.76 (9.64)
Angle at T3	160.57 (9.63)	163.17 (9.27)*	158.13 (7.66)	162.48 (10.106)*	159.36 (9.27)	163.13 (9.41)*	158.17 (8.47)	162.31 (10.18)*
Angle at T4	178.25 (6.67)	180.30 (5.56)	176.45 (5.73)	179.43 (5.89)	178.89 (6.50)	180.53 (5.82)	176.54 (5.41)	179.34 (5.82)
Maximum knee flexion	90.91 (7.83)	93.35 (7.94)*	91.48 (8.47)	94.78 (8.18)*	89.39 (8.48)	91.75 (7.80)*	91.27 (10.17)	93.92 (9.24)*

Note. Values are means ± SD; *Significant difference between dominant and non-dominant legs ($p < .05$); T0 = starting point, T1 = seat-off, T2 = point of maximum vertical ground reaction force, T3 = highest shoulder level, T4 = end of movement, D = dominant leg, ND = non-dominant leg.

Table 7 Ankle angle during sit-to-stand in single- and dual-task conditions

Variables	Single condition				Dual condition			
	MCI		Control		MCI		Control	
	D leg	ND leg	D leg	ND leg	D leg	ND leg	D leg	ND leg
Ankle angle (°)								
Angle at T0	104.62 (5.11)	108.03 (4.42)	104.27 (3.97)	107.58 (5.00)	103.66 (6.23)	106.88 (5.82)	104.98 (8.53)	107.31 (5.91)
Angle at T1	97.92 (8.10)	102.11 (6.84)	97.13 (8.66)	101.27 (8.33)	102.11 (6.84)	100.84 (7.77)	101.28 (8.33)	99.51 (9.04)
Angle at T2	90.35 (5.61)	94.44 (5.00)*	89.96 (6.79)	94.24 (7.06)*	91.71 (4.65)	94.44 (5.01)*	92.34 (7.04)	94.24 (7.06)*
Angle at T3	98.35 (5.63)	102.43 (4.21)	97.79 (3.90)	102.27 (4.89)	97.58 (5.59)	102.65 (4.19)	98.58 (9.05)	102.16 (5.04)
Angle at T4	101.58 (3.96)	105.95 (3.39)	100.90 (4.01)	105.13 (4.16)	101.97 (4.28)	106.47 (3.57)	102.47 (8.59)	105.71 (4.17)
Maximum ankle dorsiflexion	87.49 (5.43)	91.63 (4.49)*	86.97 (6.02)	91.88 (6.04)*	86.16 (5.88)	90.41 (4.87)*	86.91 (5.56)	90.68 (6.25)*

Note. Values are means ± SD; *Significant difference between dominant and non-dominant legs in both groups and conditions ($p < 0.05$); T0 = starting point, T1 = seat-off, T2 = point of maximum vertical ground reaction force, T3 = highest shoulder level, T4 = end of movement, D = dominant leg, ND = non-dominant leg.

Table 8 F test and p-value of angle joint position in sit to stand

	F	p-value
T0		
- Trunk		
Conditions	0.132	0.718
Conditions * Groups	0.216	0.644
Group	0.904	0.345
- Pelvis		
Conditions	0.520	0.473
Conditions * Groups	0.640	0.427
Groups	2.290	0.135
- Hip		
Conditions	11.842	<0.001
Conditions * Groups	0.054	0.818
Sides	0.335	0.564
Sides * groups	0.268	0.606
Groups	0.286	0.595
Conditions * Sides	6.542	0.313
Conditions * Sides * Groups	0.029	0.864
- Knee		
Conditions	7.111	0.010
Conditions * Groups	0.053	0.819
Sides	0.923	0.340
Sides * groups	2.630	0.110
Groups	2.457	0.122
Conditions * Sides	0.001	0.981
Conditions * Sides * Groups	1.373	0.245
- Ankle		
Conditions	31.002	<0.001
Conditions * Groups	0.163	0.688
Sides	0.586	0.447

Sides * groups	1.300	0.258
Groups	0.060	0.807
Conditions * Sides	0.885	0.350
Conditions * Sides * Groups	0.256	0.615
T1		
- Trunk		
Conditions	14.050	<0.001
Conditions * Groups	0.062	0.805
Group	0.498	0.483
- Pelvis		
Conditions	0.553	0.460
Conditions * Groups	0.067	0.797
Groups	4.981	0.029
- Hip		
Conditions	13.426	<0.001
Conditions * Groups	0.155	0.695
Sides	1.817	0.182
Sides * groups	0.005	0.943
Groups	0.797	0.375
Conditions * Sides	0.700	0.406
Conditions * Sides * Groups	3.020	0.087
- Knee		
Conditions	19.724	<0.001
Conditions * Groups	0.000	0.994
Sides	0.131	0.718
Sides * groups	0.112	0.738
Groups	1.407	0.240
Conditions * Sides	1.240	0.269
Conditions * Sides * Groups	1.198	0.278
- Ankle		
Conditions	36.772	<0.001

Conditions * Groups	0.097	0.757
Sides	2.706	0.105
Sides * groups	0.016	0.899
Groups	0.217	0.643
Conditions * Sides	2.074	0.154
Conditions * Sides * Groups	0.249	0.619
T2		
- Trunk		
Conditions	12.834	<0.001
Conditions * Groups	2.082	0.154
Group	0.063	0.803
- Pelvis		
Conditions	3.410	0.069
Conditions * Groups	0.536	0.466
Groups	3.384	0.070
- Hip		
Conditions	15.955	<0.001
Conditions * Groups	0.072	0.790
Sides	3.200	0.078
Sides * groups	1.395	0.242
Groups	0.018	0.894
Conditions * Sides	0.216	0.643
Conditions * Sides * Groups	6.490	0.013
- Knee		
Conditions	23.051	<0.001
Conditions * Groups	0.084	0.772
Sides	0.733	0.395
Sides * groups	2.837	0.097
Groups	5.035	0.028
Conditions * Sides	1.896	0.173
Conditions * Sides * Groups	1.574	0.214

- Ankle		
Conditions	33.894	<0.001
Conditions * Groups	0.055	0.816
Sides	11.960	<0.001
Sides * groups	1.438	0.235
Groups	0.070	0.793
Conditions * Sides	0.966	0.329
Conditions * Sides * Groups	0.350	0.556
T3		
- Trunk		
Conditions	0.096	0.757
Conditions * Groups	7.350	0.008
Group	0.643	0.425
- Pelvis		
Conditions	0.288	0.593
Conditions * Groups	3.227	0.075
Groups	1.921	0.170
- Hip		
Conditions	13.911	<0.001
Conditions * Groups	0.177	0.734
Sides	0.126	0.724
Sides * groups	1.594	0.211
Groups	1.722	0.194
Conditions * Sides	0.703	0.405
Conditions * Sides * Groups	2.888	0.094
- Knee		
Conditions	41.044	<0.001
Conditions * Groups	0.824	0.367
Sides	0.220	0.641
Sides * groups	0.144	0.705
Groups	0.408	0.525

Conditions * Sides	2.354	0.130
Conditions * Sides * Groups	4.903	0.030
- Ankle		
Conditions	60.292	<0.001
Conditions * Groups	0.244	0.623
Sides	0.006	0.938
Sides * groups	0.477	0.492
Groups	0.002	0.961
Conditions * Sides	0.005	0.944
Conditions * Sides * Groups	2.093	0.153
T4		
- Trunk		
Conditions	2.022	0.160
Conditions * Groups	3.119	0.082
Group	0.106	0.746
- Pelvis		
Conditions	0.092	0.762
Conditions * Groups	0.785	0.379
Groups	0.735	0.394
- Hip		
Conditions	3.106	0.082
Conditions * Groups	0.002	0.965
Sides	0.394	0.532
Sides * groups	0.276	0.601
Groups	1.747	0.191
Conditions * Sides	3.480	0.066
Conditions * Sides * Groups	0.005	0.945
- Knee		
Conditions	15.591	<0.001
Conditions * Groups	0.777	0.381
Sides	0.547	0.462

Sides * groups	0.536	0.467
Groups	1.552	0.217
Conditions * Sides	1.034	0.313
Conditions * Sides * Groups	0.165	0.686
- Ankle		
Conditions	62.560	<0.001
Conditions * Groups	0.445	0.507
Sides	5.409	0.023
Sides * groups	0.896	0.347
Groups	0.234	0.630
Conditions * Sides	0.402	0.528
Conditions * Sides * Groups	0.684	0.411

4.5 Kinetics

For peak vertical ground reaction force (VGRF), maximum hip extension moment, maximum knee extension moment, and maximum ankle plantar flexion moment, a three-way mixed, repeated measures ANOVA was used to compare differences between conditions (single and dual), groups (MCI and control), and sides (dominant and non-dominant leg). The means and standard deviations of these variables are shown in Table 9.

A significant group × condition interaction was found for maximum hip extension moment ($F(1,68) = 6.41$, $p = 0.014$) and maximum ankle plantar flexion moment ($F(1,68) = 7.68$, $p = 0.007$). A pairwise comparison revealed that during STS alone, the control group had greater maximum hip extension and ankle plantarflexion moments than during STS with a dual task (Figures 29 and 30). A significant main effect of side was found on maximum knee extension moment ($F(1,68) = 22.85$, $p < 0.001$). Overall, during STS alone and with a dual task, both groups demonstrated a greater maximum knee extension moment on the dominant leg (0.69 [0.02] N.m/kg) than on the non-dominant leg (0.59 [0.020] N.m/kg) (Figure 31). For peak VGRF, there were no significant group × condition × side interactions or main effects of group, condition, or side.

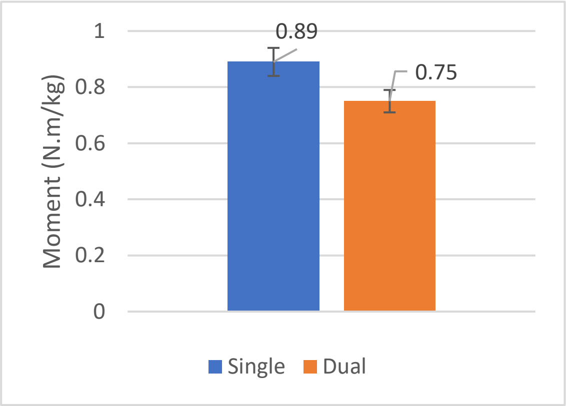


Figure 29 Maximum hip extension moment in single- and dual-task conditions in control group

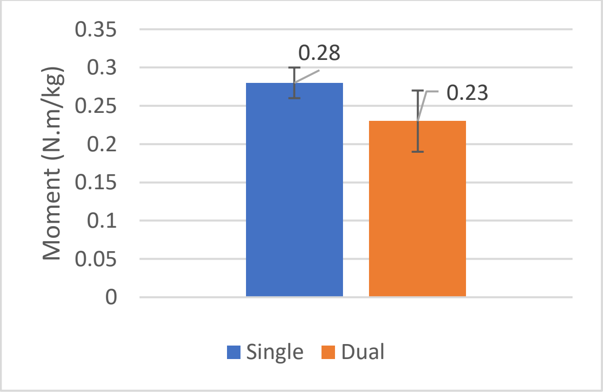


Figure 30 Maximum ankle plantar flexion moment in single- and dual-task conditions in control group

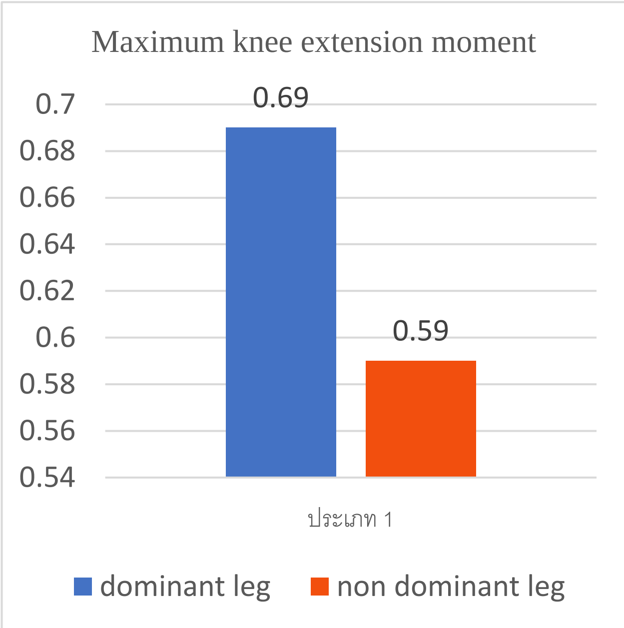


Figure 31 Maximum knee extension moment in dominant and non-dominant leg

Table 9 Maximum hip extension, knee extension, and ankle plantar flexion moments and peak vertical ground reaction force (VGRF)

Variables	Single condition				Dual condition			
	MCI		Control		MCI		Control	
	D leg	ND leg	D leg	ND leg	D leg	ND leg	D leg	ND leg
Max. hip extension (N.m/kg)	0.76 (0.24)	0.78 (0.24)	0.88 (0.38)	0.91 (0.31)	0.71 (0.25)	0.79 (0.18)	0.74 (0.30)	0.76 (0.25)
Max. knee extension (N.m/kg)	0.63 (0.21)	0.59 (0.18)	0.68 (0.17)	0.57 (0.16)	0.66 (0.19)	0.60 (0.20)	0.71 (0.15)	0.61 (0.17)
Max. plantar flexion (N.m/kg)	0.24 (0.13)	0.25 (0.08)	0.26 (0.15)	0.29 (0.14)	0.29 (0.13)	0.27 (0.11)	0.23 (0.12)	0.24 (0.13)
Peak VGRF (N/kg)	5.07 (0.79)	5.09 (0.78)	5.20 (1.21)	5.27 (0.83)	4.95 (0.87)	5.03 (0.92)	5.08 (0.91)	4.97 (0.75)

Note. Values are means ± SD; D = dominant leg, ND = non-dominant leg.

Table 10 F-test and p-value of maximum joint moments in sit to stand

	F	p-value
- Maximum hip extension		
Conditions	2.657	0.108
Conditions * Groups	0.140	0.710
Sides	13.275	<0.001
Sides * groups	6.413	0.014
Groups	1.258	0.266
Conditions * Sides	0.613	0.437
Conditions * Sides * Groups	0.858	0.358
- Maximum knee extension		
Conditions	22.853	<0.001
Conditions * Groups	0.548	0.462
Sides	1.308	0.257
Sides * groups	3.532	0.064
Groups	0.060	0.807
Conditions * Sides	1.694	0.197
Conditions * Sides * Groups	0.191	0.663
- Maximum ankle plantarflexion		
Conditions	0.231	0.632
Conditions * Groups	1.297	0.259
Sides	0.008	0.928
Sides * groups	7.687	0.007
Groups	0.102	0.751
Conditions * Sides	1.559	0.216
Conditions * Sides * Groups	0.132	0.717

CHAPTER 5

DISCUSSION

5.1 Discussion

This study aimed to compare STS ability among older adults with and without MCI during STS alone and STS with a dual motor task. To our knowledge, our study was the first to investigate and present the outcomes of movement time, kinematics, and kinetics. The results showed that the movement strategy during sit to stand among groups was different and both groups spent more time during STS with a dual motor task than during STS alone.

When the baseline characteristics of the participants of this study were compared, there were no differences between the two groups in any characteristics except lower leg length and MoCA score. The equivalence of the groups' baseline characteristics confirms that the performance of the tasks resulted from the abilities of the older adults in each group. Because lower leg length was used to set the chair height and was adjusted for each participant, the difference in lower leg length between the two groups may not affect the results of this study.

Surprisingly, our findings revealed no difference in movement time between older adults with and without MCI. This would imply that the total time to stand is invariant and thus a control parameter for this movement, as the duration of each phase was adjusted to maintain a constant total movement time. Previous research has found that lower limb muscle strength is one of the most important factors in successfully rising from a chair (Alexander et al., 1997), with increased STS duration accompanying reduced muscle strength (Spyropoulos et al., 2013). In this study, we assessed lower limb muscle strength using FTSTS and found no significant difference between groups, which could explain the lack of between-group differences in movement time. Although the total time spent moving was the same for both groups, the kinematic analysis showed that the two groups moved differently.

When considering overall movement patterns, this study found that older adults with MCI demonstrated the largest maximum trunk flexion angle during STS with a dual motor task. Previous studies have revealed that people with poor postural control (Borges et al., 2015) and older adults with a history of falls (Lin & Lee, 2022) frequently perform excessive trunk flexion during STS. In this sense, we might surmise that the older adults with MCI had poor postural control during STS, as postural control requires cognition to maintain the body's position (Woollacott & Majorie, 2016). For older adults with MCI, adding a secondary task may overload their cognitive capabilities, leading to decreased balance ability and movement pattern changes while performing the STS task .

Older adults with and without MCI performed distinct movement patterns with their dominant and non-dominant legs during STS in both conditions. The dominant leg had a greater maximum knee flexion angle and a greater ankle dorsi flexion angle than the non-dominant leg. This result is in accordance with a previous study's finding that during STS, lower limb symmetry cannot be assumed (Caruthers et al., 2016).

In addition, the largest maximum trunk flexion angle was observed in the older adults with MCI during STS with a dual motor task. During STS in both conditions, older adults with and without MCI demonstrated distinct movement patterns in their dominant and non-dominant legs, with the dominant leg having larger maximum knee flexion and ankle dorsi flexion angles than the non-dominant leg. During kinetic analysis, older adults without MCI demonstrated larger maximum hip extension and maximum ankle plantar flexion moments during STS alone than during STS with a dual motor task.

As expected, the current study's findings confirm that performing dual tasks can impair movement performance in older adults, as evidenced by the longer movement time observed during STS with a dual task. This result is consistent with the findings of a previous study conducted on older adults (Montero-Odasso et al., 2014). The bottleneck theory explains the longer movement time required for dual-task conditions compared to single-task conditions (Bayot et al., 2018). Delays in information processing during a dual task reduce the performance of one or both tasks. To compensate, the body slows the movement or changes the movement pattern (Griffiths et al., 2020).

As the biomechanical demands of each STS phase differ, we divided the STS task into four phases to assess differences between the groups in each phase. Phase 1, the flexion-momentum phase (T0–T1), begins with trunk flexion to generate upper-body momentum and lift the buttocks from the base of support (BOS) (Woollacott & Majorie, 2016). Before initiating the task, the individual cognitively plans the movement sequence based on the afferent information being supplied to the brain (Woollacott & Majorie, 2016). The older adults with MCI in this study performed less trunk flexion during this phase than the controls, which may be due to deficits in executive function and thus motor planning in older adults with MCI (Kirova et al., 2015), leading to insufficient trunk flexion during this phase.

During the momentum transfer phase (T1–T2), the momentum transfers from the upper body to the total body, postural control and co-contraction of the hamstrings and rectus femoris are required, and the BOS shifts from the buttocks and feet to only the feet (Kralj et al., 1990). At the end of this phase, the older adults with MCI in this study continued to perform trunk flexion while the control group did not. This might be related to the older adults with MCI requiring more momentum to lift the body vertically, particularly as their trunk flexion before phase 2 was insufficient. Moreover, the older adults with MCI performed more hip flexion on the dominant leg than on the non-dominant leg during both conditions, while the control group only had larger hip flexion angles on the dominant leg than on the non-dominant leg during STS alone. The hip flexion pattern of the adults with MCI may be the effect of the trunk flexion observed during this phase as well as the stability requirements of this phase (Woollacott & Majorie, 2016), which might lead to compensatory movement patterns to maintain stability while standing up. This result relates with the kinetics pattern of sit to stand, using less momentum during this phase in dual conditions, for carefully to perform the task completely.

During phase 3 (T2–T3), or the extension phase, which begins after the maximum ground reaction force is reached, the hip, knee, and ankle extend to achieve a standing position (Mapaisansin et al., 2020). Trunk flexion during this phase was less in the older adults with MCI than in the controls. These results agree with previous studies investigating STS movement in older adults (Van Lummel et al., 2018). Lummel and colleagues reported that older adults with less trunk flexion during the extension phase of STS demonstrated a more dynamic use of the trunk, reflecting impaired muscle strength (Van Lummel et al., 2018). Although the time to perform FTSTS was not significantly different between the groups in our study, movement time alone may not capture muscle strength adequately enough to rule out differences between the groups in muscle strength. However, this result confirms that older adults with MCI employ different movement patterns than older adults without MCI when performing STS tasks.

Finally, the stabilizing phase (T3–T4), defined as the end of the transfer, begins when the body adjusts to the standing position. This phase requires postural control and the ability to control the center of mass within the BOS. Our study showed no significant differences between the groups during phase 4. The results suggest that, while the group with MCI demonstrated a distinct movement pattern during the transfer to standing, both groups were able to adjust their balance and body position while in a standing position.

We performed kinetic analysis on peak VGRF and maximum hip, knee, and ankle moments. The older adults without MCI demonstrated greater hip extension and ankle plantar flexion moments during STS alone compared to STS with a dual task. The reduction in hip and ankle moments in this group during the dual-task condition may be due to the command to perform the STS task "as quickly as possible but safely"; when performing STS with a dual task, the movement needs to be performed more carefully, leading to reduced kinetic moments. This pattern was not found in the adults with MCI. This result, which is consistent with previous findings that adults with MCI had an impaired ability to adapt their gait speed from fast to slow (Boripuntakul et al., 2022), suggests that the adults with MCI were unable to adjust the kinetics of their movements to the distinct demands of the two conditions.

This study found a main effect of side on knee flexion moment in both groups, with the dominant leg having a greater knee flexion moment than the non-dominant leg. When considered alongside knee angle, the knee flexion angle on the dominant leg was greater than on the non-dominant leg, which supports a greater knee flexion moment on the dominant leg. There were no differences in peak VGRF between sides, conditions, and groups, as the sum of the forces was not different due to adjustments to position and balance when obtaining an upright position.

5.2 Limitations

Our research included some limitations that warrant mentioning. First, we did not compare different types of MCI (amnestic, non-amnestic, single-domain, multiple-domain). We suggest that future research should classify the characteristics of MCI into subgroups based on the cognitive domain deficit, as this may be a factor impacting STS performance. In addition, the STS movement was only investigated in the sagittal plane. Analysis of the frontal plane may be required together with the sagittal plane to fully quantify the STS movement.

5.3 Implication of study for clinical practice

This study provides the movement time and kinematic and kinetic patterns of STS in older adults with and without MCI under single- and dual-task conditions. Though older adults with MCI had a movement time similar to that of older adults without MCI, differences in movement patterns were observed between the groups. From our knowledge, the different in movement pattern maybe increase the risk of fall in older adults. Thus, clinicians should carefully assess patients with MCI to diagnose those at risk of falls. Moreover, the dual-task condition led to changes in movement patterns in both groups, which is clinically useful when developing challenges during treatment programs. The findings highlight the need to interpret STS performance in terms of not only the time to perform the task but also the pattern of movement.

CHAPTER 6

CONCLUSION

The present study determined the sit-to-stand ability with dual tasks in older adults with MCI. The results show no significant difference in movement time among groups but a significant difference among conditions, where dual conditions took greater time than single conditions. The kinematics data reveals that older adults with MCI groups have greater trunk flexion while performing STS with the dual task than STS alone. Moreover, healthy older adults reduced the moment of force in dual conditions compared to single conditions, whereas older adults with MCI did not. These results suggest that older adults with MCI have different movement patterns while performing STS tasks and are impaired in the planning of movement, increasing the risk of falling.

Appendix A

แบบสอบถามเพื่อคัดกรองอาสาสมัครเข้าร่วมงานวิจัย

Screening questionnaire

1. เกณฑ์การคัดเข้า

1.1. มีการเปลี่ยนแปลงความรู้คิดเมื่อเทียบกับระดับความสามารถก่อนหน้า (จากคนไข้ ญาติ หรือการวินิจฉัยแพทย์)

☐ มี ☐ ไม่มี

1.2. มีการลดลงของความสามารถในการรู้คิดมากกว่าหนึ่งโดเมน โดยมีคะแนนของแบบประเมิน **MoCA** น้อยกว่า **25** คะแนน

☐ มี ☐ ไม่มี

1.3. มีคะแนนแบบประเมินการทำกิจวัตรประจำวัน **(Barthel index)** $\geq$ **12** คะแนน

☐ ใช่ ☐ ไม่ใช่

1.4. ไม่มีประวัติภาวะสมองเสื่อม (**Dementia**)

☐ มี ☐ ไม่มี

2. เกณฑ์การคัดออก

2.1. มีปัญหาโรคทางระบบประสาท (เช่น โรคหลอดเลือดสมอง, โรคปลอกประสาทเสื่อมแข็ง, โรคพาร์กินสัน) หรือโรคเรื้อรังอื่นๆ (เช่น โรคทางระบบหัวใจและหลอดเลือดรุนแรง, ความดันโลหิตสูงที่ไม่สามารถควบคุมได้, โรคข้ออักเสบ) ที่ส่งผลต่อการรู้คิดหรือความสามารถในการทรงตัว

☐ มี ☐ ไม่มี

2.2. มีภาวะซึมเศร้าประเมินจากการทำแบบบประเมินภาวะซึมเศร้าในผู้สูงอายุไทย **(TGDS-30)** โดยมีคะแนน $\geq$ **12** คะแนน

☐ มี ☐ ไม่มี

2.3. มีปัญหาสายตาหรือการมองเห็นที่ยังไม่สามารถแก้ไขได้ด้วยการใส่แว่นสายตา

☐ มี ☐ ไม่มี

2.4. ไม่สามารถทำแบบทดสอบได้

☐ มี ☐ ไม่มี

สรุปผลการประเมิน ☐ ผ่าน ☐ ไม่ผ่าน

Appendix B

แบบประเมินความสามารถในการดำเนินชีวิตประจำวัน Barthel ADL

ข้อที่	รายละเอียด	คะแนนที่ทำได้
1.	**การรับประทานอาหารเมื่อเตรียมสำรับไว้ให้เรียบร้อยต่อหน้า (Feeding)** **0** ไม่สามารถตักอาหารเข้าปากเองได้ **1** ตักอาหารเองได้แต่ต้องมีคนช่วยเช่น ช่วยใช้ช้อนตักเตรียมไว้ให้หรือตัดเป็นชิ้นเล็กๆ ล่วงหน้า **2** ตักอาหารและช่วยตัวเองได้เป็นปกติ	
2.	**การล้างหน้า แปรงฟัน หวีผม (Grooming)** **0** ต้องการความช่วยเหลือ **1** ทำได้เอง(รวมทั้งที่ทำได้เองแม้เตรียมอุปกรณ์ไว้ให้)	
3.	**การลุกนั่งจากที่นอนหรือจากเตียงไปยังเก้าอี้ (Transfer)** **0** ไม่สามารถนั่งได้เอง(นั่งแล้วล้ม)หรือต้องใช้สองคนช่วยกันยกขึ้น **1** ต้องใช้คนแข็งแรงหรือมีทักษะ1คน/ใช้คนทั่วไป2คนพยุงดันขึ้นมาจึงจะนั่งอยู่ได้ **2** ต้องการความช่วยเหลือเล็กน้อย เช่นช่วยพยุงบางส่วน/ต้องมีคนดูแลเพื่อความปลอดภัย **3** ทำได้เอง	
4.	**การใช้ห้องน้ำ (Toilet use)** **0** ช่วยเหลือตัวเองไม่ได้ต้องใช้คนแข็งแรงหรือมีทักษะ1คน/ใช้คนทั่วไป2คนพยุงดันขึ้นมาจึงจะนั่งอยู่ได้ **1** ทำได้เองบางส่วน แต่ยังต้องการความช่วยเหลือในบางสิ่ง **2** ช่วยเหลือตัวเองได้ดี	
5.	**การเคลื่อนที่ภายในห้องหรือบ้าน (Mobility)** **0** เคลื่อนที่ไปไหนไม่ได้ **1** ใช้รถเข็นช่วยให้เคลื่อนที่ได้เอง (ไม่ต้องมีคนเข็น) เข้าออกมุมห้องหรือประตูได้ **2** เดินหรือเคลื่อนที่โดยมีคนช่วย เช่นพยุงเดิน **3** เดินหรือเคลื่อนที่ได้เอง	
6.	**การสวมใส่เสื้อผ้า (Dressing)** **0** ต้องมีคนสวมใส่ให้ ช่วยตัวเองแทบไม่ได้หรือได้น้อย	

	1 ช่วยตัวเองได้ดีประมาณร้อยละ**50** และต้องมีคนช่วย **2** ช่วยเหลือตัวเองได้ดี ติดกระดุมและรูดซิปได้เอง ใส่เสื้อผ้าที่ดัดแปลงให้เหมาะสมได้	
7.	การขึ้นลงบันได**1**ชั้น **0** ไม่สามารถทำได้เอง **1** ต้องการคนช่วย **2** ขึ้นลงได้เอง (ถ้าต้องใช้เครื่องช่วยเดินเช่น **walker**จะต้องเอาขึ้นลงได้เองด้วย)	
8.	การอาบน้ำ **0** ต้องมีคนช่วยหรือทำให้ **1** สามารถอาบน้ำได้เอง	
9.	การกลั้นอุจจาระ **0** กลั้นไม่ได้ หรือต้องการสวนอุจจาระอยู่เสมอ **1** กลั้นไม่ได้บางครั้ง (ไม่เกิน**1**ครั้งต่อสัปดาห์) **2** กลั้นได้เป็นปกติ	
10	การกลั้นปัสสาวะ **0** กลั้นไม่ได้ หรือใส่สายสวนปัสสาวะ แต่ไม่สามารถดูแลเองได้ **1** กลั้นไม่ได้บางครั้ง (ไม่เกินวันละ**1**ครั้ง) **2** กลั้นได้เป็นปกติ	
	รวมคะแนน	

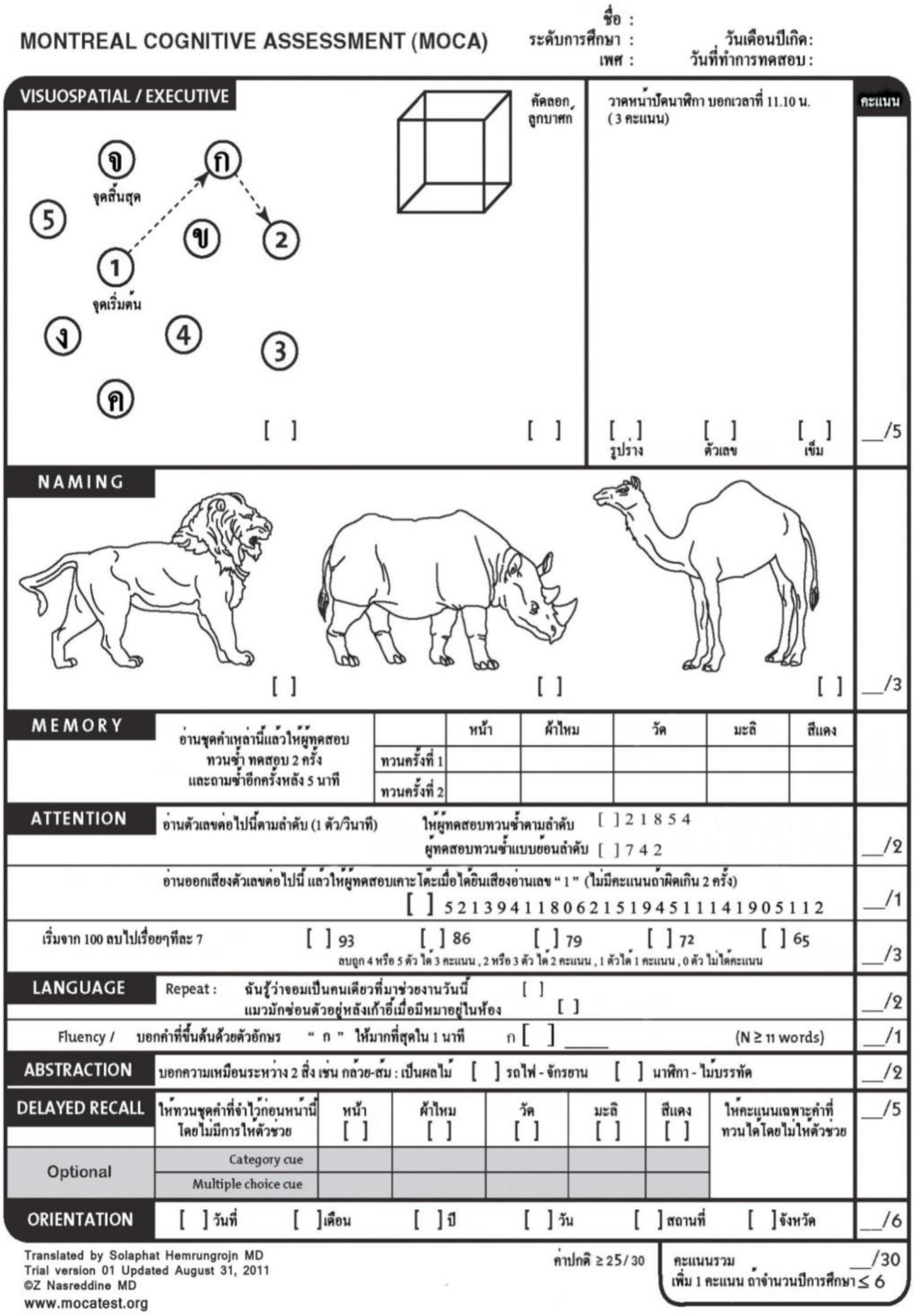
ตารางแปลผลการประเมิน

คะแนนรวม **ADL 20**คะแนน	แปลผล
00-04 คะแนน	ภาวะพึ่งพาโดยสมบูรณ์ **(Total dependence)**
05-08 คะแนน	ภาวะพึ่งพารุนแรง **(Severe dependence)**
09-11 คะแนน	ภาวะพึ่งพาปานกลาง **(Moderately severe dependence)**
12-20 คะแนน	ไม่เป็นการพึ่งพา **(Mildly severe dependence)**

Appendix C

แบบประเมินพุทธิปัญญาฉบับภาษาไทย

Montreal Cognitive Assessment (MoCA)



MONTREAL COGNITIVE ASSESSMENT (MOCA)

ชื่อ :
ระดับการศึกษา : วันเดือนปีเกิด:
เพศ : วันที่ทำการทดสอบ :

VISUOSPATIAL / EXECUTIVE | คะแนน

จ จุดสิ้นสุด, ก, 5, ข, 2, 1 จุดเริ่มต้น, ง, 4, 3, ค

[ ]

คัดลอก ลูกบาศก์ [ ]

วาดหน้าปัดนาฬิกา บอกเวลาที่ 11.10 น. (3 คะแนน)

[ ] รูปร่าง [ ] ตัวเลข [ ] เข็ม

___/5

NAMING

[ ] [ ] [ ]

___/3

MEMORY

อ่านชุดคำเหล่านี้แล้วให้ผู้ทดสอบทวนซ้ำ ทดสอบ 2 ครั้ง และถามซ้ำอีกครั้งหลัง 5 นาที

	หน้า	ผ้าไหม	วัด	มะลิ	สีแดง
ทวนครั้งที่ 1					
ทวนครั้งที่ 2					

ATTENTION

อ่านตัวเลขต่อไปนี้ตามลำดับ (1 ตัว/วินาที)
ให้ผู้ทดสอบทวนซ้ำตามลำดับ [ ] 2 1 8 5 4
ผู้ทดสอบทวนซ้ำแบบย้อนลำดับ [ ] 7 4 2
___/2

อ่านออกเสียงตัวเลขต่อไปนี้ แล้วให้ผู้ทดสอบเคาะโต๊ะเมื่อได้ยินเสียงอ่านเลข “ 1 ” (ไม่มีคะแนนถ้าผิดเกิน 2 ครั้ง)
[ ] 5 2 1 3 9 4 1 1 8 0 6 2 1 5 1 9 4 5 1 1 1 4 1 9 0 5 1 1 2
___/1

เริ่มจาก 100 ลบไปเรื่อยๆทีละ 7 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
ลบถูก 4 หรือ 5 ตัว ได้ 3 คะแนน , 2 หรือ 3 ตัว ได้ 2 คะแนน , 1 ตัวได้ 1 คะแนน , 0 ตัว ไม่ได้คะแนน
___/3

LANGUAGE

Repeat : ฉันรู้ว่าจอมเป็นคนเดียวที่มาช่วยงานวันนี้ [ ]
แมวมักซ่อนตัวอยู่หลังเก้าอี้เมื่อมีหมาอยู่ในห้อง [ ]
___/2

Fluency / บอกคำที่ขึ้นต้นด้วยตัวอักษร “ ก ” ให้มากที่สุดใน 1 นาที ก [ ] ____ (N ≥ 11 words)
___/1

ABSTRACTION

บอกความเหมือนระหว่าง 2 สิ่ง เช่น กล้วย-ส้ม : เป็นผลไม้ [ ] รถไฟ - จักรยาน [ ] นาฬิกา - ไม้บรรทัด
___/2

DELAYED RECALL

ให้ทวนชุดคำที่จำไว้ก่อนหน้านี้ โดยไม่มีการให้ตัวช่วย	หน้า [ ]	ผ้าไหม [ ]	วัด [ ]	มะลิ [ ]	สีแดง [ ]	ให้คะแนนเฉพาะคำที่ทวนได้โดยไม่ให้ตัวช่วย
Optional: Category cue						
Optional: Multiple choice cue						

___/5

ORIENTATION

[ ] วันที่ [ ] เดือน [ ] ปี [ ] วัน [ ] สถานที่ [ ] จังหวัด
___/6

ค่าปกติ ≥ 25/30
คะแนนรวม ___/30
เพิ่ม 1 คะแนน ถ้าจำนวนปีการศึกษา ≤ 6

Translated by Solaphat Hemrungrojn MD
Trial version 01 Updated August 31, 2011

www.mocatest.org

Appendix D

แบบวัดความซึมเศร้าในผู้สูงอายุไทย

Thai Geriatric Depression Scale (TGDS) scale

คำชี้แจง โปรดอ่านข้อความแต่ละข้ออย่างละเอียด และประเมินความรู้สึกของผู้สูงอายุในช่วงระยะเวลาหนึ่งสัปดาห์ที่ผ่านมา และให้ / ลงในช่องที่ตรงกับความรู้สึกของผู้สูงอายุ (ใช่, ไม่ใช่) กรณีที่ผู้สูงอายุสามารถอ่านออกเขียนได้ สามารถทำแบบประเมินนี้ได้ด้วยตนเอง

ลำดับ	ในช่วง1สัปดาห์ที่ผ่านมา	ใช่	ไม่ใช่	คะแนน
1.	ท่านพอใจกับชีวิตความเป็นอยู่ตอนนี้			
2.	ท่านไม่อยากทำในสิ่งที่เคยสนใจหรือเคยทำเป็นประจำ			
3.	ท่านรู้สึกชีวิตของท่านช่วงนี้ว่างเปล่าไม่รู้จะทำอะไร			
4.	ท่านรู้สึกเบื่อหน่ายบ่อยๆ			
5.	ท่านหวังว่าจะมีสิ่งดีเกิดขึ้นในวันหน้า			
6.	ท่านมีเรื่องกังวลตลอดเวลา และเลิกคิดไม่ได้			
7.	ส่วนใหญ่แล้วท่านรู้สึกอารมณ์ดี			
8.	ท่านรู้สึกกลัวว่าจะมีเรื่องไม่ดีเกิดขึ้นกับท่าน			
9.	ส่วนใหญ่ท่านรู้สึกมีความสุข			
10.	บ่อยครั้งที่ท่านรู้สึกไม่มีที่พึ่ง			
11.	ท่านรู้สึกกระวนกระวาย กระสับกระส่ายบ่อยๆ			
12.	ท่านชอบอยู่กับบ้านมากกว่าที่จะออกนอกบ้าน			
13.	บ่อยครั้งที่ท่านรู้สึกวิตกกังวลเกี่ยวกับชีวิตข้างหน้า			
14.	ท่านคิดว่าความจำท่านไม่ดีเท่าคนอื่น			
15.	การที่มีชีวิตอยู่ถึงปัจจุบันนี้เป็นเรื่องที่น่ายินดีหรือไม่			

16.	ท่านรู้สึกหมดกำลังใจหรือเศร้าใจบ่อยๆ			
17.	ท่านรู้สึกว่าชีวิตท่านค่อนข้างไม่มีคุณค่า			
18.	ท่านรู้สึกกังวลมากกับชีวิตที่ผ่านมา			
19.	ท่านรู้สึกว่าชีวิตนี้มีเรื่องน่าสนุกอีกมาก			
20.	ท่านรู้สึกลำบากที่จะเริ่มต้นทำอะไรใหม่			
21.	ท่านรู้สึกกระตือรือร้น			
22.	ท่านรู้สึกสิ้นหวัง			
23.	ท่านคิดว่าคนอื่นดีกว่าท่าน			
24.	ท่านอารมณ์เสียง่ายกับเรื่องเล็กๆน้อยๆอยู่เสมอ			
25.	ท่านรู้สึกอยากร้องไห้บ่อยๆ			
26.	ท่านมีความตั้งใจทำสิ่งใดสิ่งหนึ่งได้ไม่นาน			
27.	ท่านรู้สึกสดชื่นเวลาตื่นนอนตอนเช้า			
28.	ท่านรู้สึกไม่อยากพบปะพูดคุยกับคนอื่น			
29.	ท่านตัดสินใจอะไรได้เร็ว			
30.	ท่านมีจิตใจสบาย แจ่มใสเหมือนก่อน			
			รวมคะแนน	

แปลผลคะแนน (คะแนนรวม TGDS 30 คะแนน)	
0-12 คะแนน	ผู้สูงอายุปกติ (Normal)
13-18 คะแนน	ผู้สูงอายุมีความเศร้าเล็กน้อย (Mild depression)
19-24 คะแนน	ผู้สูงอายุมีความเศร้าปานกลาง (Moderate depression)
25-30 คะแนน	ผู้สูงอายุมีความเศร้ารุนแรง (Severe depression)

Appendix E

Helen Hayes marker reflective marker placement (Kadaba et al., 1990)

Marker positions	Marker placements
1. Top of the head	On the center top of the head, in line with the front and back markers
2. Back of the head 3. Front of the head	On the back and front of the head at the same height
4. Left shoulder 5. Right shoulder	Tip of acromion process
6. Left elbow 7. Right elbow	Lateral epicondyle of the humerus
8. Left wrist 9. Right wrist	Centre between the styloid processes of radius and ulna
10. Offset	Right scapula
11. Left ASIS 12. Right ASIS	Anterior superior iliac spine
13. Sacrum	Superior aspect at L5-sacral interface
14. Left thigh 15. Right thigh	On the lower thigh below the midpoint
16. Left lateral knee 17. Right lateral knee	Along the flexion/extension axis of rotation at lateral femoral condyle
18. Left shank 19. Right shank	On the lower shank below the midpoint, for greatest visibility by all cameras
20. Left lateral ankle	Along the flexion/extension axis of rotation at

21. Right lateral ankle	lateral malleolus
22. Left heel 23. Right heel	Posterior calcaneus at the same height from floor as toe
24. Left toe 25. Right toe	Centre of the 2nd and 3rd metatarsals
26. Left medial knee 27. Right medial knee	Medial femoral condyles
28. Left medial ankle 29. Right medial ankle	Medial malleolus

Appendix F

แบบฟอร์มบันทึกข้อมูล

The data collection form

รหัส...............

1. ข้อมูลทั่วไป

- เพศ ☐ ชาย ☐ หญิง

  อายุ.................ปี

- จำนวนปีที่ได้รับการศึกษา .... (ปี)

*หมายเหตุ 0ปี = ไม่ได้เรียนหนังสือ 6 ปี = จบประถมศึกษาปีที่6 (หรือเทียบเท่า)

9 ปี = จบมัธยมศึกษาปีที่3 (หรือเทียบเท่า) 12 ปี = จบมัธยมศึกษาปีที่6 (หรือเทียบเท่า)

16 ปี = จบปริญญาตรี (หรือเทียบเท่า) 18 ปี = จบปริญญาโท (หรือเทียบเท่า) 22 ปี = จบปริญญาเอก (หรือเทียบเท่า)

- น้ำหนัก .... กิโลกรัม ส่วนสูง ....เซนติเมตร BMI ....
- มือข้างที่ถนัด ☐ ซ้าย ☐ ขวา
- ขาข้างที่ถนัด ☐ ซ้าย ☐ ขวา
- ความยาวขา ซ้าย.................เซนติเมตร ขวา.................เซนติเมตร
- ความยาวขาส่วนบน ซ้าย.................เซนติเมตร ขวา.................เซนติเมตร
- ความยาวขาส่วนล่าง ซ้าย.................เซนติเมตร ขวา.................เซนติเมตร
- โรคประจำตัว ☐ มี ☐ ไม่มี

โปรดระบุ ☐ ความดันโลหิตสูง ☐ ไขมันโลหิตสูง ☐ เบาหวาน ☐ พาร์กินสัน

☐ จิตเวช ☐ โรคหลอดเลือดสมอง ☐ โรคระบบปอดและทางเดินหายใจ

☐ โรคทางระบบกระดูกและกล้ามเนื้อ

- ยาที่ใช้ ☐ มี ☐ ไม่มี

โปรดระบุ ☐ ความดันโลหิตสูง ☐ ไขมันโลหิตสูง ☐ เบาหวาน ☐ พาร์กินสัน

☐ จิตเวช ☐ โรคหลอดเลือดสมอง ☐ โรคระบบปอดและทางเดินหายใจ

☐ โรคทางระบบกระดูกและกล้ามเนื้อ

ประวัติการล้มใน 6 เดือนที่ผ่านมา ☐ มี ☐ ไม่มี ถ้ามีโปรดระบุ ……ครั้ง

- ระดับกิจกรรมทางกาย ☐ ออกกำลังกาย ☐ ไม่ออกกำลังกาย

ถ้าออกกำลังกาย ………... ครั้ง/สัปดาห์ (อย่างน้อยครั้งละ 30 นาที)

2. แบบบันทึกผลการทดสอบ

2.1. แบบประเมิน

2.1.1. B-ADL ……………. คะแนน

2.1.2. MoCA ……………. คะแนน

2.1.3. TGDS-30 ……………. คะแนน

2.2. ตารางบันทึกผลการประเมินความสามารถในการลุกขึ้นมายืน **5**ครั้ง

การประเมิน	เวลาที่ใช้ **(ครั้งที่1)**	เวลาที่ใช้ **(ครั้งที่2)**	ค่าเฉลี่ย
FTSTS			

2.3 ตารางบันทึกข้อมูลการเคลื่อนไหวในขณะลุกขึ้นยืน

Outcomes	STS				STS with dual task			
	trial 1	trial 2	trail 3	mean	trial 1	trial 2	trail 3	mean
Total movement time								
Movement time (phase 1)								
Movement time (phase 2)								
Movement time (phase 3)								
Peak VGRF (dominant)								
Peak VGRF (nondominant)								
Max. moment of hip extension (dominant)								
Max. moment of knee extension (dominant)								
Max. moment of ankle plantarflexion(dominant)								
Max. moment of of hip extension (non-dominant)								
Max. moment of knee extension (non-dominant)								
Max. moment of ankle plantarflexion(non-dominant)								
Trunk angle - T0 - T1 - T2 - T3 - T4								

Pelvis angle - T0 - T1 - T2 - T3 - T4								
Hip angle (dominant) - T0 - T1 - T2 - T3 - T4								
Knee angle (dominant) - T0 - T1 - T2 - T3 - T4								
Ankle angle (dominant) - T0 - T1 - T2 - T3 - T4								
Hip angle (non-dominant) - T0 - T1 - T2 - T3 - T4								
Knee angle (non-dominant) - T0 - T1 - T2 - T3 - T4								
Ankle angle (non-dominant) - T0 - T1 - T2 - T3 - T4								

Appendix G

Validity and reliability of five-times-sit-to-stand test with a dual task in older adults with mild cognitive impairment

Abstract

Introduction: Although the five-times-sit-to-stand test (FTSST) is commonly used to analyse functional capacity, in older adults with mild cognitive impairment (MCI), many activities of daily living, such as walking while holding objects, require the simultaneous performance of motor and motor tasks. Hence, the FTSST with a secondary task has been introduced, though there is a lack of evidence on its validity and reliability. This study aimed to examine the concurrent validity and reliability of the FTSST with a dual task in older adults with MCI.

Methods: Twenty-eight older adults with MCI participated in the study. All participants performed the FTSST, FTSST with a dual task and Timed Up and Go (TUG) test. The concurrent validity of the FTSST with a dual task was established with the TUG.

Results: Moderate concurrent validity was found between the FTSST with a dual task and the TUG, with Pearson's $r = 0.59$ ($p < 0.001$). The FTSST with a dual task exhibited good intrarater (ICC 3,2 = 0.99) and inter-rater (ICC 2,2 = 0.99) reliability. The standard error of measurement and minimal detectable change of the intra- and inter-rater reliability of the FTSST with a dual task were 0.22 and 0.18, respectively.

Conclusion: This study showed a significant correlation between the FTSST both with and without a dual task and the TUG as well as good inter- and intra-rater

reliability when used in older adults with MCI. These findings support using these tests as outcome measures in older adults with MCI.

Keywords: older adults; Mild cognitive impairment; sit-to-stand; reliability; validity

Introduction

Mild cognitive impairment (MCI) is a decline in cognitive performance that is considered to be related to ageing and constitutes a stage in the transition from normal cognitive ageing to dementia [1]. Globally, the prevalence of older adults with MCI ranges between 6.7% and 71.4% [2-6]. Impairments in cognitive ability in older adults can lead to changes in physical functions, including muscle strength [7], balance and functional mobility [8]. Changes in these areas of function are common factors found to increase the risk of falls [9]. In addition, a deficit in cognitive function has been found to be related to injuries or falls [10]. Currently, several tools are used to assess muscle strength, balance and functional mobility in older adults. One measurement tool frequently used in the clinical setting that evaluates all of these components is the five-times-sit57 to-stand test (FTSST) [11].

The FTSST measures how quickly an individual can change positions from sitting to standing back to sitting five times [12]. This test has been validated and has been established to have good reliability in numerous populations, including older adults with chronic obstructive pulmonary disease [13], Parkinson's disease [14] and cardiovascular disease [15], as well as community-dwelling older women [16]. Recently, the validity and reliability of the FTSST were studied in older adults with early cognitive loss, with results demonstrating the FTSST's moderate validity with gait speed and good reliability in this population [17]. Typically, humans are capable of performing dual or multiple tasks in daily life, such as when standing up while holding a cup of water. In this situation, the performance of multiple tasks will either reduce the ability to execute the secondary task or decrease the execution of both the primary and secondary tasks due to limitations in information perception ability [18]. The secondary task can be either a cognitive or motor task. A previous study found that older adults with MCI had decreased gait performance under dual-task conditions [19], which might be attributed to impairments in executive function and reduced attention capacity in this population [20]. Thus, modifying the FTSST by adding a secondary task might improve the test's ability to assess functional mobility in older adults with MCI. In both research and clinical practice, it is critical to identify outcome measures that are reliable and valid for specific populations. Unfortunately, the validity and reliability of the FTSST with dual tasks have not yet been investigated in older adults with MCI. Therefore, the objective of this study was to evaluate the concurrent validity and reliability of the FTSST with a dual-task component in older adults with MCI. We hypothesised that (1) the FTSST with a dual task would have moderate validity to detect physical function as assessed by the Timed Up and Go (TUG) test, and (2) the FTSST with a dual task would have good inter- and intra-rater reliability.

Subjects and Methods

Subjects

A convenience sample of twenty-eight older adults with MCI who were 60 years of age or older was recruited for this study. Participants were included if they (1) were diagnosed with MCI [1], (2) did not have a history of clinical dementia, (3) had a Montreal Cognitive Assessment score of fewer than 25 points [21] and (4) were generally independent in everyday functioning based on a Barthel Index for Activities of Daily Living score of at least 12 points. Eligible participants were excluded if they had (1) a diagnosis of a neurological condition or chronic disease that causes cognitive impairment or impaired walking ability, such as stroke, multiple sclerosis, Parkinson’s, cardiopulmonary disease, uncontrolled hypertension, rheumatoid arthritis or osteoarthritis; (2) depressive symptoms, as determined by a Thai Geriatric Depression Scale score of more than 12 5 [22]; (3) severe auditory and visual impairment or uncorrected auditory and visual impairment; or (4) a problem with completing the tasks required for testing. Research related to human use has complied with all relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the ethical board of the university. Informed consent has been obtained from all individuals included in this study or from their legal guardians. The characteristics of all participants are shown in Table 1. Insert Table 1 here The sample size was calculated based on the result of a previous study showing that FTSST times correlated with TUG times in older adults ($r = 0.64$; $p < 0.001$) [16]. For a Pearson’s correlation coefficient of $r = 0.60$ and an alpha of 0.05, 19 people had to be examined to achieve 80% power.

Procedures

Data collection was conducted by two licensed physiotherapists who were trained in the testing procedures by the senior author before data collection began. Participants were asked to perform three tests: the FTSST, the FTSST with a dual task and the TUG test. The testing sequence was randomly assigned to the participants using a simple random sampling technique. During the FTSST, the participants began by sitting in an upright trunk position with their arms across their chests in an armless chair with a seat height of 46 cm from the ground. They were then instructed to achieve a full standing position five successive times as quickly as possible without using their arms. Timing began when the tester spoke the word ‘Go’ and stopped when the participants returned to sitting with their buttocks contacting the chair after the fifth repetition. 6 During the FTSST with a dual task, the participants were asked to hold a cup filled with water on a tray in their dominant hand and achieve a full standing position five consecutive times as quickly as possible without using their arms or spilling water from the cup. The tester informed the participants, ‘You must not choose to prioritise either the FTSST or the second task, and please perform both tasks as well as possible’. During the TUG test, the participants were asked to sit in the chair in the starting position, stand, walk forward 3 m as quickly and safely as possible, turn at the traffic cone, walk back and sit down at the starting position. The participants were evaluated by one assessor (assessor A) twice, on the first day and seven days later, to assess intra-rater reliability. Two assessors (assessors A and B) evaluated the participants on the same day to determine inter-rater reliability. Both assessors were unaware of the other’s findings. The participants were allowed to rest for five minutes between the tests to prevent physical fatigue. Each participant was permitted to practice each test one time prior to data collection. The average values of the two trials from the first and second sessions were used for analysis.

Statistical analysis

Data were analysed using SPSS version 28.0 (SPSS Inc., 233 S Wacker Dr, 11th Fl, Chicago, IL 60606). Pearson's correlation coefficient (r) was computed to test the concurrent validity of the FTSST and FTSST with a dual task relative to the TUG test. Correlation strength was determined as follows: little-none ($r < 0.25$), poor ($r = 0.25–0.50$), moderate ($r = 0.50–0.75$) and good-excellent ($r > 0.75$) [23]. 7 Intraclass correlation coefficient (ICC) with a 95% confidence interval was applied to examine the intra-rater (ICC 3,2) and inter-rater (ICC 2,2) reliability of time to complete the FTSST and FTSST with a dual task. The ICC was interpreted as follows: an ICC > 0.75 indicated good reliability and an ICC of 0.5–0.75 indicated moderate reliability [23]. In addition, the standard error of measurement (SEM) and minimal detectable change (MDC), which determine absolute reliability, were calculated using the equations $SEM = \text{Standard deviation (SD)} \times \sqrt{(1 - ICC)}$ and $MDC = 1.96 \times \sqrt{2} \times SEM$.

Results

In the concurrent validity analysis, both the FTSST and the FTSST with a dual task were significantly correlated with the TUG test. Analysis using Pearson's correlation coefficient revealed a moderate relationship between the FTSST and the TUG test ($r = 0.51$, $p < 0.001$) and between the FTSST with a dual task and the TUG test ($r = 0.59$, $p < 0.001$). The means and standard deviations of the time to complete the FTSST and FTSST with a dual task, which were used to determine reliability, are reported in Table 2. The time to complete both the FTSST and the FTSST with a dual task exhibited good intra- and inter-rater reliability. The SEM and MDC of the FTSST's intra- and inter-rater reliability were 0.14 and 0.00 seconds, respectively. In addition, the SEM and MDC of the FTSST with a dual task's intra- and inter-rater reliability were 0.22 and 0.18 seconds, respectively (Table 2).

Discussion

This study aimed to investigate the validity, intra- and inter-rater reliability, SEM, and MDC of the FTSST with a dual task in older adults with MCI. To our knowledge, our study was the first to investigate the FTSST with a dual task in this population. The results indicated that the FTSST with a dual task had a moderate correlation with the TUG test, good intra- and inter-rater reliability, and low SEM and MDC values when used in older adults with MCI. The FTSST and FTSST with a dual task were moderately correlated with the TUG test when employed in older adults with MCI, indicating that adding the secondary task during the FTSST did not change the FTSST's correlation to the TUG. This might be attributed to the type of secondary task employed, as different types of dual tasks have been shown to have varying effects on performance in older adults with MCI [24]. However, the results in this study were consistent with previous studies investigating the validity of the FTSST against the TUG test [16, 25-28]. Therefore, it can be inferred that the FTSST with a dual task is a valid measure for assessing functional mobility in older adults with MCI. This study found good intra- and inter-rater reliability of the FTSST and FTSST with a dual task in older adults with MCI. These results support findings in the literature regarding the reliability of the FTSST in various populations [13-17].

Providing the assessors with practice sessions using the laboratory procedures before data collection began may have contributed to the positive reliability results in the present study. In addition, clear and standardised instructions from the assessor may enable the participants to perform the task effectively. Knowledge of the error in the measurement tool is critical to deciding whether a measurement is reliable enough for therapeutic choices. In previous studies on the FTSST in older adults [16] and older adults with early cognitive loss [17], it was reported that an error of 0.9 9 seconds and 1.20 seconds were highly likely to be considered widely acceptable. In the current study, the SEM values of the FTSST and FTSST with a dual task were less than 0.9 seconds for both inter- and intra-rater reliability; the variability in performance that occurred in this study were thus likely too small. In addition, our study provided MDC values for the FTSST and FTSST with a dual task, which are simple tests that can be easily performed. MDC values can provide a reference point when interpreting data from other population groups. In addition, these values can be used to understand the minimum amount of change that must be observed to indicate a therapeutic change post-intervention in older adults with MCI. There were some limitations in our study. First, the participants in this study were a convenience sample of older adults in one community, which does not reflect the overall population. Second, the secondary task employed in this study was only a motor task, holding a tray with a cup of water. Future research may evaluate other types of motor or cognitive tasks. It may present different results with the secondary task used in this study. Additionally, future studies should include an investigation of the other psychometric properties of the FTSST with a dual task, such as its accuracy in detecting falls in older adults with MCI.

Conclusions

This study demonstrated that the FTSST with a dual task has good intra- and inter-rater reliability and is valid in older adults with MCI. The MDC and SEM for the FTSST with a dual task were small. The findings support the use of the FTSST with a dual task to evaluate performance in this population. 10

Conflict of interest

The authors state no conflict of interest.

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Table 1. Characteristics of study participants (n = 28)

Characteristics	**Mean (SD)/ N (%)**
Age (year); Mean (SD)	67.67 (5.56)
Gender; n (%)	
- **Male**	19 (67.86)
- **Female**	9 (32.14)
Weight (kg); mean (SD)	62.88 (8.96)
Height (cm); mean (SD)	159.61 (8.08)
Education level; n (%)	

- **No education**	1 (3.57)
- **Primary school/elementary school**	
Lower-secondary	1 (3.57)
Upper-secondary	8 (28.57)
- **Secondary school/high school**	
Lower-secondary	6 (21.43)
Upper-secondary	5 (17.86)
- **Bachelor's degree or higher**	7 (25.00)
MoCA (score); mean (SD)	20.68 (2.16)

Note: Montreal Cognitive Assessment score (MoCA), Standard deviation (SD)

Table 2. Intra- and inter-rater reliability of the five-times-sit-to-stand test with and without a dual task.

Intra-rater reliability							
Variables	Time (s)		$ICC_{3,2}$	95% CI	p-value	MDC	SEM
	1st sessions	2nd sessions					
FTSTS	10.71 (3.00)	10.68 (3.06)	0.99	0.99–1.00	< 0.001	0.38	0.14
FTSTS with dual task	11.87 (3.95)	11.84 (3.86)	0.99	0.99–1.00	< 0.001	0.59	0.22
Inter-rater reliability							
Variables	Time (s)		$ICC_{3,2}$	95% CI	p-value	MDC	SEM
	1st sessions	2nd sessions					
FTSTS	10.71 (3.00)	10.72 (2.99)	1.00	1.00–1.00	< 0.001	0.00	0.00

FTSTS with dual task	11.88 (3.95)	11.78 (3.88)	0.99	0.99–1.00	< 0.001	0.48	0.18

Note: Intraclass correlation coefficient (ICC), standard error of measurement (SEM), minimal detectable change (MDC), and confidence interval (CI)

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