IDENTIFICATION OF POSTURAL CONTROL SYSTEM IMPAIRMENTS IN OLDER ADULTS WITH CHRONIC NECK PAIN

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IDENTIFICATION OF POSTURAL CONTROL SYSTEM IMPAIRMENTS IN OLDER ADULTS WITH CHRONIC NECK PAIN

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IDENTIFICATION OF POSTURAL CONTROL SYSTEM IMPAIRMENTS IN OLDER ADULTS WITH CHRONIC NECK PAIN

BY

THANYA MADSALAE

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Chronic neck pain (CNP) can affect postural control among older adults. Gait performance, in terms of gait speed and symmetry, is an indicator of dynamic postural control. The Balance Evaluation Systems Test (BESTest) is used to assess the systems of postural control. This study aims to determine which gait variables were more sensitive to dynamic postural control among older adults with CNP and assessed that BESTest could identify postural control impairments in CNP and item difficulty by Rasch analysis. This cross-sectional study recruited 30 young adults (YOUNG), aged 20-40 years, and 80 older adults, aged 60 years or older [without neck pain (OLD) = 60, with chronic neck pain (CNP) = 20]. Questionnaires were used to collect demographic data, neck pain intensity, self-rated neck pain and disability, and balance confidence. The 10-Meter Walk test was used to assess gait performance with three different conditions: no head movement (NM), horizontal head movement (HM), and vertical head movement (VM). BESTest was used to assess postural control. The Inertial Measurement Unit was used to capture and analyze gait parameters. The CNP group reported moderate pain and zero to mild disability in daily activities. Balance confidence was moderately correlated with gait speed ($r=0.62$) and moderately inversely correlated with gait asymmetry during HM and VM (-0.56 and -0.69, respectively). The CNP group showed slower gait speed during HM and VM ($p<0.05$), lower stride length and cadence. The gait asymmetry index in the CNP group was higher than the OLD group in VM ($p<0.05$). Thus, gait speed with a head movement was more sensitive. Compared to the YOUNG group, the BESTest score was lower in the OLD group, the CNP group had the lowest score, in biomechanical constraints, transitions-anticipatory postural adjustment and reactive postural response ($p< 0.05$). The BESTest was the most accurate of the three was 48.5 of 51 for older adults whose daily life were affected by neck problems with a high AUC (0.79), sensitivity (72%), and specificity (69%). The Timed Up and Go was the most difficult BESTest item for all groups, while 14 items had more difficulty for the CNP group. BESTest can identify postural control impairments in older adults affected by CNP and help clinicians consider management to prevent falls in CNP.

Keyword : head motion, gait variability, balance test, elderly, fall

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THANYA MADSALAE

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LIST OF ABBREVIATIONS

10MWT	10-Meter Walk Test
aBoS	Altered Base of Support
BESTest	Balance Evaluation Systems Test
CNP	Chronic Neck Pain
CNS	Central Nervous System
HM	Horizontal Head Movement
mCTSIB	Modified Clinical Test of Sensory Integration on Balance
NDI	Neck Disability Index
NM	No Head Movement
OLD	Older Adults without Chronic Neck Pain
VM	Vertical Head Movement
YOUNG	Young Adults

CHAPTER 1

INTRODUCTION

1. Background

Chronic musculoskeletal pain is one of the most common reasons that people seek healthcare. It has been shown that chronic pain has a negative effect on lifespans[1, 2, 3, 4, 5] and has been associated with a reduction of perceived health and increased utilization of healthcare services in older adults[6]. Among chronic musculoskeletal conditions, neck pain is one of the most common complaints in older adults. The prevalence of activity-limiting neck pain for at least 1 day, was 4.9% for the global age-standardized point and this increased to 7.3-8.0% in individuals above 65 years old[7]. Furthermore, chronic neck pain (CNP) is ranked in the fourth leading cause of disability worldwide[8].

In addition to decreased mobility of cervical joint[9, 10, 11] and muscle strength[11, 12, 13, 14], older adults with CNP also demonstrated impaired postural control more than healthy older adults. A lot of evidence confirmed that older adults with CNP demonstrated fear of falling and decreased physical performance, that are known risk factors of falling[15, 16, 17, 18, 19]. Older adults with CNP have been observed to have poor sensory orientation and loss of gait stability. They demonstrated sensorimotor disturbances, caused by altered cervical afferent inputs, in term of greater deficits in eye movement control, vertical perception and postural control[19].These alterations can be caused by pain induced change in nociceptor and mechanoreceptor activity at the spinal cord and within the central nervous system (CNS)[20, 21] or chemical changes from inflammatory events that affected sensitivity of the receptors[22]. Other factors involved awkward postures, static and repetitive work, or trauma that disturbed sensitivity of the cervical joint and muscle receptors[23, 24].

Altered cervical somatosensory input in individuals with CNP can cause a mismatch between three major sensory inputs, namely visual, somatosensory and vestibular inputs, that are integrated in the CNS to control static and dynamic postural control[25]. As a result, impairments of sensorimotor integration caused by CNP may lead to poor static and dynamic postural control performance. It is demonstrated by recent studies which found decreased sensorimotor integration in older adults with CNP presented with reduced gait speed, impaired postural control and cervical position sense more than healthy individuals[16, 19]. It is hypothesized that in healthy individuals, the preferred source of sensory inputs is somatosensory from the feet in contact with the supporting surface[26, 27, 28]. In contrast, older adults with CNP rely more on vision and other somatosensory inputs for postural control and thus deficits will be greatest when these inputs are reduced[16, 17, 18, 19]. The modified Clinical Test of Sensory Integration on Balance (mCTSIB) is one of the most common clinical tools used in patients with postural control impairment to determine how well a patient uses the input from three sensory balance systems (somatosensory system, visual system, and vestibular system) during different balance activities. These activities include standing with eyes open/firm surface, eyes closed/firm surface, eyes open/soft surface, and eyes closed/soft surface[16, 19]. However, mCTSIB with altered base of support (mCTSIB-aBoS), including comfortable and narrow stance, has been used in previous studies to challenge the postural control system in older adults with CNP[16, 29]. The tandem stance was excluded due to difficulty even in healthy older adults[30]. The results showed that older adults with CNP demonstrated poorer postural control than healthy controls across sensorimotor integration tasks by increasing postural sway in the anteroposterior direction during the comfortable stance with eyes closed on a firm surface and eyes open on a soft surface and increasing postural sway in the mediolateral direction during the narrow stance with eyes open on a firm surface[16]. Poor static postural control during walking is related to a shortened single support phase as well as weight-bearing asymmetry of the lower extremities, which leads to an abnormal gait pattern[31].

Assessment of gait performance, namely, the spatiotemporal variables and variability of gait, is used to investigate changes in dynamic postural control with age and movement disorders[32]. Gait analysis is frequently used to assess fall risk by clinicians and researchers in the context of clinical practice and health research since gait performance can be easily quantified using portable inertial wearable sensors[33]. In addition, gait performance has been determined to be a significant indicator of both one's functional capacity and their physical condition in clinical and home settings[34, 35].

The strongest evidence indicates that gait speed is an effective predictor of fall risk, and it should be taken into consideration as part of a comprehensive assessment of the risk of falling in older adults(36). It has been demonstrated that an individual's preferred walking speed and stride length decreased with age(37). Moreover, CNP further decreases gait performance in older adults, as demonstrated by increasing gait cycle duration when performing the 10-Meter Walk test (10MWT)(16) and worse functional performance in the Timed Up-and-Go (TUG) test and the dynamic gait index (DGI) than healthy controls(17, 18). Additionally, the studies also revealed that older adults with CNP performed worse when their walking was combined with head movement. Head movements during walking aggravated sudden changes or distinct changes in cervical/vestibular inputs, as demonstrated by significantly longer gait cycle durations, slower self-selected gait speeds, and lower cadence during the 10MWT with head turn conditions(16, 38).

During walking, the cyclic motions of the lower extremities have been considered to be symmetrical naturally(39). One of the key factors influencing gait performance and a predictor of fall risk is gait symmetry(40), which emphasizes the bilateral coordination of swing durations during regular walking(41, 42). Gait asymmetry has been hypothesized to be a greater contributor to the compensatory mechanisms utilized for recovering balance during locomotion than the gait variables themselves; hence, gait symmetry serves as an index of the quality of gait control(43). Previous studies have reported that young adults with CNP walked with a stiffer spine, more asymmetric hip mobility, and more asymmetric gait than those without CNP during preferred walking without head movement[44, 45, 46]. These results indicate that walking may be affected by neck pain, which may subsequently affect the trunk and lower extremities[47]. Both gait speed and gait symmetry are frequently utilized to predict the risk of falls in older adults. Only a stopwatch and a 10-meter walkway are required to determine the gait speed in a clinical setting, whereas gait symmetry assessments require more complicated equipment and calculations. Nevertheless, there is limited information on which of the two variables is more sensitive to dynamic balance impairment during walking in older adults with CNP. This information could help clinicians to select appropriate measurement tools that are sensitive enough to apply in the clinical setting and can identify balance impairments in older adults with CNP, facilitating early implementation of specific interventions designed to reduce the risk of falls.

Musculoskeletal system, internal representations, adaptive processes, anticipatory mechanisms, sensory strategies, individual sensory systems, and neuromuscular synergies are all involved in maintaining balance. Despite the fact that older adults with CNP have impaired sensory orientation and decreased gait stability, no study has been conducted on other postural control systems[48]. Impairment of each postural control system will lead to different characteristics of balance disorders that required different method of management. To be able to design effective balance training for older adults with CNP, assessment of all postural control systems is required. At present, there is still lack of information regarding other postural control systems such as internal representation, adaptive and anticipatory mechanisms that may be impaired in older adults with CNP.

The Balance Evaluation Systems Test (BESTest) was developed based on the postural control system and was constructed to be a comprehensive balance measure in clinical settings for mixed populations[(49)]. Six domains underlying the postural control system, biomechanical constraints, stability limits, transitions–anticipatory postural adjustment, reactive postural response, sensory orientation, and stability in gait, are included in the BESTest[(49)]. The advantage of the BESTest is that it covers almost all systems underlying postural control so that clinicians can determine the types of balance training that are specific to the causes of postural control problems. The BESTest has been shown to be a reliable and valid measure of balance components in individuals with neurological disease (e.g., Parkinson's disease, multiple sclerosis, and stroke). The BESTest can also be used to detect the function of the postural system in healthy individuals, which starts to decline as early as in the middle age group (41-60 years)[(50)]. Furthermore, the BESTest can be used to discriminate between high versus low risk of falls in adults aged 50 years and older[(51)]. However, evidence of its use in older adults with CNP has not been reported. Assessment of all postural control domains, as in the BESTest, could lead to early detection of balance impairment in older adults with CNP, so the specific intervention for improving balance can be promptly implemented.

Therefore, the purpose of this study was to determine which gait variables, gait speed or gait symmetry, were more sensitive to dynamic balance impairment during walking in older adults with CNP. Head movement in the vertical and horizontal planes was used in this study to trigger sudden changes in cervico-vestibular inputs, which led to a perturbation of dynamic balance during walking. Balance impairments in older adults with chronic neck pain (the CNP group) were demonstrated by comparing the gait parameters with those in older adults without chronic neck pain (the OLD group). We hypothesized that gait speed would be more sensitive than gait asymmetry to balance impairment during walking and that this difference would be more apparent during head movement. Furthermore, this study aimed to investigate the use of the BESTest in older adults with CNP compared to older adults without CNP using young adults as the reference. We hypothesized that the BESTest would be able to identify system-specific postural control impairments in older adults with CNP. Rasch analysis (partial credit model) could provide valuable information related to item difficulty to determine the progression of balance exercises from easy to more difficult stages[52]. In addition, this study revealed the level of BESTest item difficulty for older adults with and without CNP for further use in balance rehabilitation and fall prevention purposes.

2. Research question

- Question I: Which gait variables, gait speed or gait symmetry, were more sensitive to dynamic balance impairment during walking in older adults with CNP?
- Question II: Is the BESTest able to identify system-specific postural control impairments in older adults with CNP?

3. Objectives

The main purpose of this study is to determine which gait variables, gait speed or gait symmetry, were more sensitive to dynamic balance impairment during walking and investigate the use of the BESTest in older adults with CNP.

- Objective I: To determine the gait variables, gait speed or gait symmetry, that are sensitive and practical for detecting dynamic balance impairment in walking in older adults with CNP.
- Objective II: To investigate the ability of the BESTest to identify postural control impairment in older adults with CNP.

4. Hypotheses of the study

- Hypothesis I: Gait speed and gait asymmetry would be equally sensitive to detect dynamic balance impairments in older adults with CNP.

- Hypothesis II: The BESTest would be able to identify system-specific postural control impairments in older adults with CNP.

5. Advantages of the study

This study will provide clinicians, researchers and patients with useful and in-depth knowledge on the impairment of each postural control system in older adults with CNP. Moreover, it also provides accurate clinical tools to identify postural control impairment both static and dynamic control in older adults with CNP which could lead to early detection of balance impairment in older adults with CNP. So, the specific intervention for improving balance can be promptly implemented for further use in balance rehabilitation and fall prevention purposes.

6. Key words

head motion, gait variability, balance test, elderly, fall, clinical scale

7. Conceptual framework

as shown in Figure 1.

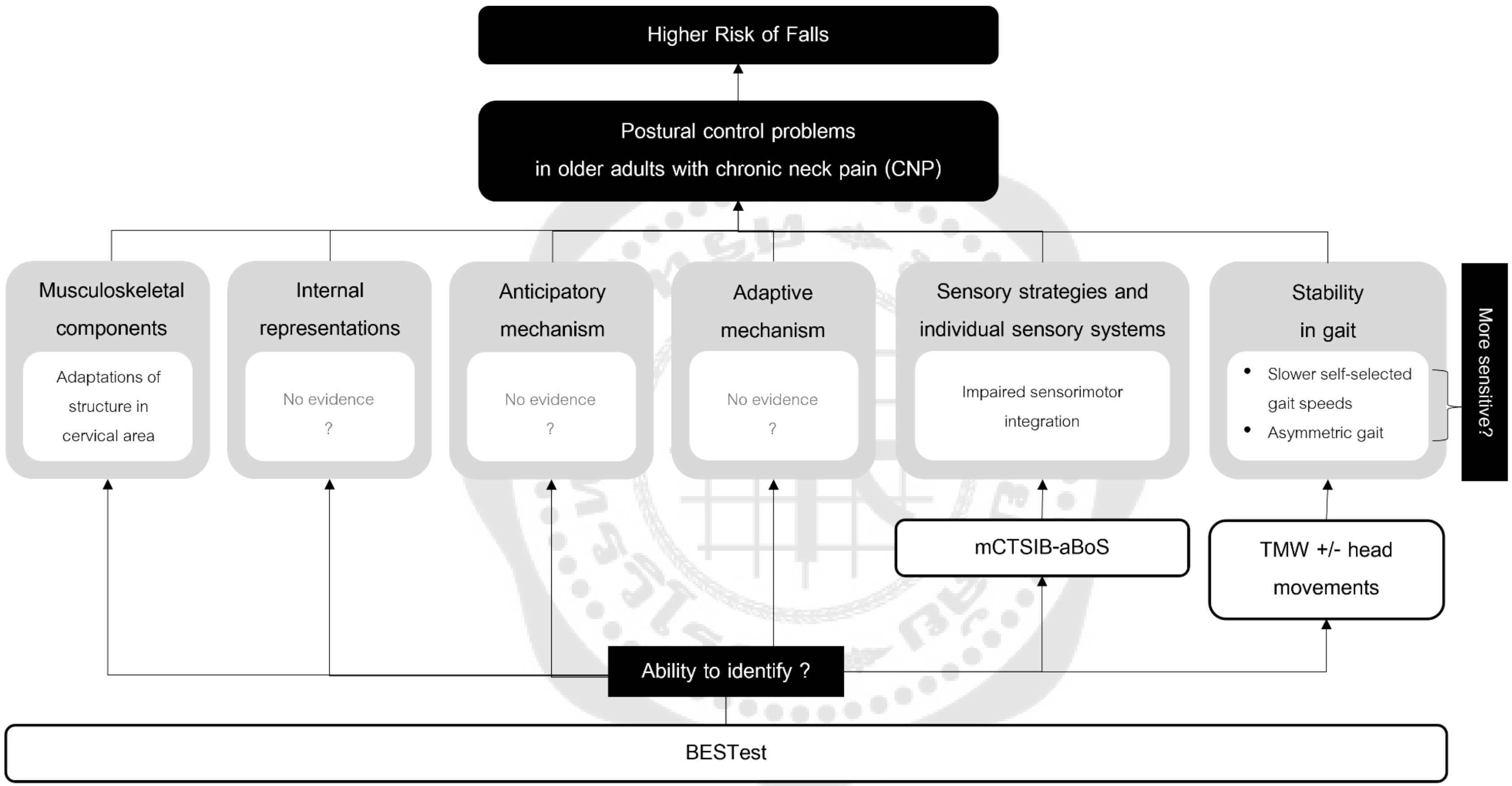

Figure 1: Conceptual Framework

CHAPTER 2

LITERATURE REVIEW

1. Chronic neck pain: an overview

The perception of pain localized to the cervical region is commonly referred to neck pain. This region is physically defined by the superior nuchal line superiorly, the lateral margins of the neck laterally, and an imaginary transverse line through the T1 spinous process inferiorly[53] *(Figure 2)*. Neck pain that can be attributed to a specific cause (such as a herniated disc or compressed nerve) as well as pain with an unknown cause (idiopathic, nontraumatic, or whiplash-associated pain). Typically, it is impossible to establish that a structural abnormality exists[54, 55] and the correlation between radiological results and patient complaints is weak[55, 56].

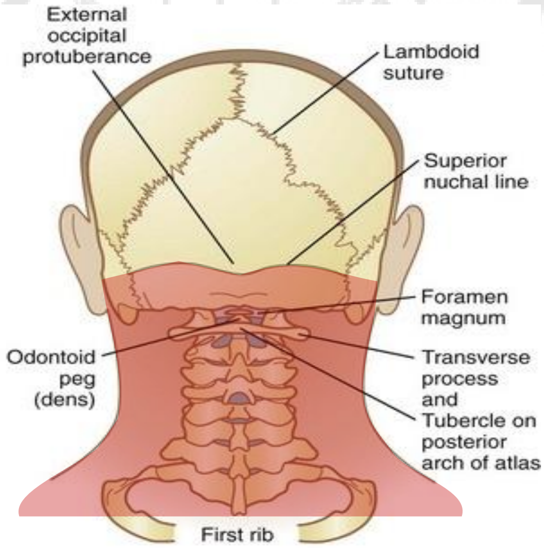

Figure 2: Neck Pain Region

Source: Adapted from https://musculoskeletalkey.com/neck-pain/

Regarding to ''Neck Pain: Clinical Practice Guidelines Revision 2017'', It is suggested that a patient's history of trauma, the existence of cervicogenic headache, and the presence of referred or radiating pain into an upper extremity all serve as useful clinical evidence for classifying neck pain patients, and that clinicians should take these into account. Within one to five years after their initial complaint, fifty to eighty-five percent of the general population will experience neck pain again[57]. This suggests that people with neck pain do not usually complete a full recovery. Pain in the neck that persists for more than three months is considered chronic neck pain. A decrease in cervical mobility in one or more directions is only one of the numerous symptoms reported by those with CNP; others include headaches, aching, and discomfort that travels down the arms and shoulders. Some individuals have weakness, numbness, and tingling in their upper limbs. In some instances, neck pain is accompanied by additional symptoms such as dizziness, nausea, and equilibrium issues[58]. In either case, idiopathic or trauma-induced pain, the occurrence of these symptoms is common[59]. Whiplash-associated persistent neck pain has been related to a high prevalence of dizziness and other balance problems (40%-90%), with 21% of those affected also experiencing a fall[60, 61, 62]. Additionally, unsteadiness or dizziness symptoms may not accompany poor standing balance, thus patients with neck pain may not be aware of it[25, 29, 63, 64].

Furthermore, age is associated with a loss in balance and postural control. [30, 65, 66]. Musculoskeletal conditions, and specifically neck pain which is one of the most common complaints in the elderly population[7], also contributes to balance deficits in the elders[16, 17, 18, 19]. In addition, CNP in the elderly is related to risk factors for falls that consist of concerns of falling and reduced physical performance. [15]. Thus, in addition to the musculoskeletal system examination, rehabilitation of CNP, particularly in elderly patients, should include postural control testing.

2. Postural Control in Older Adults with Chronic Neck Pain

Maintaining good posture while doing regular tasks is crucial. It allows people to maintain their balance whether standing or sitting. Joint range of motion, muscle properties, internal representations, adaptive mechanisms, anticipatory mechanisms, sensory strategies, individual sensory systems, and neuromuscular synergies are all parts of the postural system, as described by Shumway-Cook's system of postural control.[48]

Multiple aspects of postural control deteriorate with ageing. [67]. Postural stability is maintained through the integration of afferent information from the vestibular system, the visual system, and the somatosensory system throughout the central nervous system (CNS). The appropriate reweighting of sensory inputs, which is controlled by the CNS, might be a role in selecting an effective postural control strategy for the currently existing postural circumstances[68]. The most commonly symptom associated with postural control impairment that many older adults complaint is "dizziness"[69]. Furthermore, recent study found that older adults who experienced neck pain also had worse postural control, which also associated with fall efficacy and levels of dizziness handicap[18].

Changes in individual postural control system in older adults with CNP are described below.

2.1. Musculoskeletal components

Age-related decline in the musculoskeletal system is a well-established condition. Changes in connective tissue stiffness and muscular stretch weakness are also associated with aging. Other impacts include forward head posture and thoracic kyphosis[70]. Older adults with weak ankles or hips and a flexed postural alignment might not utilize ankle strategies or compensatory movements for postural recovery[71].

The alterations of muscle structure in CNP patients might be a result of pain, inactivity, or damage to the affected area[72, 73]. Multiple investigations revealed a shift from type I to type II muscle fibers, altered synchronization of motor units, and sustained activation of muscle spindles in the cervical region[73, 74, 75] which enhance sensitivity and motion perception, resulting in an excess of afferent inputs [76].

A maladaptive shift in motor control can also result from alterations at the local level. Pain avoidance causes a complicated reorganization of the motor pattern due to the constriction of the muscles involved in a movement[77, 78]. Individuals with whiplash, for instance, frequently struggle to maintain their balance due to diminished synergistic activity between the longus colli and capitis and increased activation of the sternocleidomastoid muscle[79] which can interfere with proprioception[76]. It has been demonstrated that those with idiopathic neck pain also experience this. Muscle fatigue in the neck (which has been directly linked to altered sensory inputs) has also been shown to impair the ability to maintain correct postural alignment[80, 81].

2.2. Internal representations

Measurement of maximal balance range, which entails leaning forward and backward from the ankles, can predict falls in older adults[82]. According to prior research, functional reach significantly decreases with age[83, 84]. Nonetheless, CNP's internal representation and stability limits remain unproven.

2.3. Adaptive mechanisms

Maintaining postural stability is especially important when unexpected disturbances occur. The capacity to respond rapidly and effectively to postural challenges is crucial for maintaining the balance and avoiding falls. Older adults are less capable of maintaining their balance after platform perturbations, as evidenced by higher postural sway and the increased number of steps needed to recover from the disturbances[85, 86, 87]. Inadequate step length and a foot placement that is more laterally oriented both contribute to the decreased efficiency of protective stepping in older adults in avoiding perturbation-induced momentum[87, 88]. In addition, the response time of older adults to an unanticipated disturbance is less than that of younger adults[88], indicating that they are less capable of integrating sensory integration to determine the appropriate step length and direction.

The effect of unexpected perturbation on postural control of older adults with CNP is not yet reported. However, a study of young adults with CNP demonstrated impaired function of neck muscles during postural adjustments. Alterations in neural regulation of the neck musculature were detected in response to quick and unexpected full-body postural perturbations, particularly during forward sliding, although all individuals were able to restore balance after the unexpected postural perturbations. The findings revealed diminished amplitudes and a delayed onset of muscle activation in the neck. For unexpected anterior-posterior postural disturbances, the neck muscles also co-activate simultaneousl.[89].

2.4. Anticipatory mechanisms

It is estimated that approximately 15% of community-dwelling adults aged 70 to 79 suffer from some kind of mobility impairment[90]. Even if there is no study in older adults with CNP, but previous studies in adults with CNP has revealed a severe deficiency in the automatic feedforward regulation of the cervical spine during arm movement[91, 92].

2.5. Sensory strategies and individual sensory system

Spatial orientation relies largely on sensory integration, which plays a role in both locomotion and postural stability[93, 94, 95]. The majority of older adults were able to maintain their balance, according to a previous study, even when incorrect sensory information was presented[96]. As long as two of three inputs are present, the body may adjust to using that system instead[96, 97]. Consequently, when sensory input from one source is reduced or eliminated, reliance switches to the remaining inputs.

In response to linear acceleration and gravitational tilt, The vestibular system relays information about head movement and position to the CNS. Visual fixation and head stability are preserved by the vestibulo-ocular and vestibulospinal reflexes, respectively, during trunk and limb movements[98]. Research into vestibular function has shown that after age 70, the number of sensory cells in the vestibular system starts to decline[99]. As with vestibular function, vision naturally declines with age. The prevalence of most ocular disorders is greatest among the elderly[100]. In addition, diabetic or hypertensive older adults have a higher risk of developing retinopathies. Around the age of 50, numerous visual processes, including visual acuity[101, 102], contrast sensitivity[103, 104], perception of depth, glare sensitivity, dark adaption, and accommodation[105] , begin to progressively decline. It has been demonstrated that older adults' capacity to recognize low-frequency spatial information considerably decreases[106]. The use of afferent input from the visual system obviously plays an an important role in the creation of the internal representation of the external environment that includes information about location, velocity, and direction. Due to a lack of edge contrast sensitivity, falls among older adults may be exacerbated by obstacles including steps, curbs, tree roots, sidewalk cracks, and uneven surfaces[107].

It is well-known that somatosensory inputs from the cervical spine play a crucial role in maintaining both oculomotor and postural control[108]. The afferent input from somatosensory, ocular, and vestibular systems is strongly relied on the cervical spine[28, 64, 109]. In addition, the superior colliculus and vestibular nuclear complex, two important relay centers for coordinating gaze and postural stability, are connected to the central nervous system via the cervical region[110, 111]. The CNS receives information regarding head movement and position in relation to the trunk by cervical proprioceptors. Mechanoreceptors are highly concentrated in the facet joints of the cervical spine, especially in the upper neck, and there are up to 200 muscle spindles per gram of muscle in the suboccipital region, which is an extremely high ratio when compared to the number of muscle spindles per gram in the first lumbrical of the thumb[25, 112, 113, 114] *(Figure 3)*.

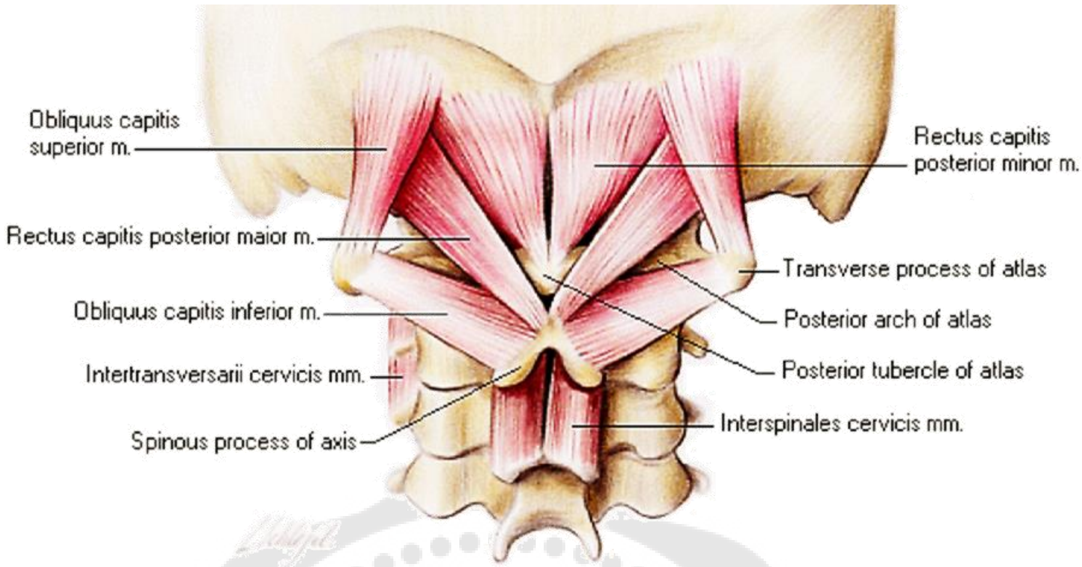

Figure 3: Suboccipital Muscles

Source: www.scapcentre.ca

In addition to transmitting and receiving information from the CNS, the cervical receptors, especially the suboccipital muscles, have specific connections to the visual and vestibular apparatus and the autonomic nervous system[115, 116, 117, 118, 119, 120]. Information concerning head movement and position in space is provided by the cervical proprioceptors, which are involved with the cervico-collic reflex, the cervico-occular reflex, and the tonic neck reflex[25]. This demonstrates the importance of accurate proprioceptive information from the cervical region for efficient posture control and cervical movement. Previous study has artificially perturbed the cervical afferents in asymptomatic patients in order to determine the relevance of the cervical central and reflex connections. Multiple studies have demonstrated that cervical muscular vibration[121, 122, 123], experimental pain[124, 125], and neck fatigue[80, 126, 127] result in altered postural sway. This implies that it is necessary for accurate interpretations of visual and vestibular data. Disturbances in the posture control system may be caused by a sensory mismatch between abnormal information from the cervical spine and normal information from the vestibular and visual systems.

Sensorimotor integration deficits have been observed in older adults with CNP presented with reduced gait speed, impaired balance, eye movement control, and vertical perception more than healthy older adults[16, 17, 19], the particular data are shown in *Table 1*.

Table 1: Characteristics and Outcome Measurements Related with Postural Control in Older Adults with CNP

Study details	Subjects			Outcome measurement			Noted
Author, year	Sample size	Age (years)	CNP duration onset (years)	Variable	Control group	CNP group	
E. Poole et al., 2008	CON: 20	71.4±1.1	healthy	VAS (0-10)	: -	-	
	CNP: 20	70.3±0.88	≥ 3 months	NDI* (0-100)	: 3.00±0.78	23.95±2.3	
				modified CTSIB with CDP*			
				• Comfortable stance-eyes closed on a firm surface	postural sway in AP (CNP > CON)		Reported with diagram.
				• Comfortable stance-eyes open on a soft surface	postural sway in AP (CNP > CON)		ML = Mediolateral direction
				• Narrow stance-eyes open on a firm surface	postural sway in ML (CNP > CON)		AP = Anteroposterior direction
				10MWT*			
				• Time with head turn	: 7.81±0.31	8.93±0.30	
				• Cadence with head turn	: 21.64±3.9	108.97±3.9	
				• Gait cycle duration without head turn	: 1.00±0.02	1.07±0.02	
				• Gait cycle duration with head turn	: 1.01±0.02	1.11±0.02	

** = statistical significant difference, NS = Non-significant difference; Values represented in mean±SD; CON = Control group (i.e. no exercise intervention or comparative group), CNP = Chronic neck pain; VAS = Visual analogue scale; NDI = The Neck Disability Index; CTSIB = Clinical Test of Sensory Integration and Balance; CDP = Computerized dynamic posturography; 10MWT = 10-Meter walk test*

Table 1: Characteristics and Outcome Measurements Related with Postural Control in Older Adults with CNP (Continued)

Study details	Subjects			Outcome measurement			Noted
Author, year	Sample size	Age (years)	CNP duration onset (years)	Variable	Control group	CNP group	
S. Uthaikhup et al., 2012	CON: 20 CNP: 20	69.55±4.2 73.2±6.2	healthy 13.0±12.4	VAS (0-10)	: -	4.3±1.7	
				NDI (0-100)	: -	21.1±9.6	
				SPNT*	: 0.01±0.02	0.03±0.02	CNP had greater deficits in eye-movement control
				JPE	NS		
				RFT*	CNP had the difficulty in perceiving the vertical at 10° and 15° anticlockwise of the frame's angle and at 30° clockwise and anticlockwise of the rod positioned.		
				Standing balance* • Eyes open on a firm surface condition • Eyes close on a firm surface condition	postural sway in ML+AP (CNP > CON) postural sway in AP (CNP > CON)		Reported with diagram. ML = Mediolateral direction AP = Anteroposterior direction
				Step test* Left Right	 : 17.5±3.6 : 17.5±2.9	 12.7±1.7 12.3±2.0	CNP has lower number of steps in 15 s than CON
				10MWT without and with head movement	NS		

** = statistical significant difference, NS = Non-significant difference; Values represented in mean±SD; CON = Control group (i.e. no exercise intervention or comparative group), CNP = Chronic neck pain; VAS = Visual analogue scale; NDI = The Neck Disability Index; SPNT = smooth pursuit neck torsion test (Eye-movement control); JPE = Joint position error (cervical proprioceptive); RFT = Computerized rod-and-frame test, 10MWT = 10-Meter walk test*

Table 1: Characteristics and Outcome Measurements Related with Postural Control in Older Adults with CNP (Continued)

Study details	Subjects			Outcome measurement			Noted
Author, year	Sample size	Age (years)	CNP duration onset (years)	Variable	Control group	CNP group	
J. Quek et al., 2014	CON: 20 CNP: 20	71.40±5.1 70.80±4.1	healthy ≥ 3 months	VAS (0-10)	: -	-	
				NDI* (0-100)	: 3.00±3.5	23.6±10.2	
				Standing balance in AP with four distinct bandwidths *			There is indirect evidence to indicate that the very-low (0.10–0.39 Hz) and moderate frequency (1.56–6.25 Hz) bands may be associated with the vestibular and muscular proprioceptive systems respectively.
				• Eyes closed			
				0.10–0.39 Hz (%)	: 13.61±3.4	20.95±7.1	
				1.56–6.25 Hz (%)	: 44.25±8.2	36.51±6.6	
				• Eyes open			
				0.10–0.39 Hz (%)	: 16.98±4.5	21.48±5.3	
				1.56–6.25 Hz (%)	: 41.75±5.8	38.79±7.3	
				TUG*	: 7.70±1.1	8.74±1.5	
				DGI*	: 21.35±2.0	18.70±1.7	

** = statistical significant difference, NS = Non-significant difference; Values represented in mean±SD; CON = Control group (i.e. no exercise intervention or comparative group), CNP = Chronic neck pain; VAS = Visual analogue scale; NDI = The Neck Disability Index; TUG = Time-up and go test; DGI = Dynamic gait index; AP = Anteroposterior direction*

Table 1: Characteristics and Outcome Measurements Related with Postural Control in Older Adults with CNP (Continued)

Study details	Subjects			Outcome measurement			Noted
Author, year	Sample size	Age (years)	CNP duration onset (years)	Variable	Control group	CNP group	
J. Quek et al., 2018	CON: 49	69.40±4.7	healthy	VAS (0-10)	: -	4.03±2.0	
	CNP: 35	69.60±6.3	≥ 3 months	NDI* (0-100)	: 1.18 ±1.63	20.82±7.14	
				Standing balance in AP with four distinct bandwidths *			There is indirect evidence to indicate that sensory reweighting was in place to engage lower limb proprioception to compensate for deficits in neck proprioception.
				• Eyes closed			
				0.39–1.56 Hz (%)	: 0.67±0.20	0.80±0.38	
				1.56–6.25 Hz (%)	: 0.62±0.22	0.82±0.48	
				• Eyes open			
				0.39–1.56 Hz (%)	: 0.45±0.13	0.55±0.24	
				1.56–6.25 Hz (%)	: 0.40±0.13	0.54±0.28	
				DGI*	: 21.49±1.98	20.26±2.98	

** = statistical significant difference, NS = Non-significant difference; Values represented in mean±SD; CON = Control group (i.e. no exercise intervention or comparative group), CNP = Chronic neck pain; VAS = Visual analogue scale; NDI = The Neck Disability Index; DGI = Dynamic gait index; AP = Anteroposterior direction*

Multiple systems are employed to maintain balance, so that if one system fails, backup systems may compensate. In healthy individuals, the preferred source of inputs is somatosensory from the feet in contact with the supporting surface[26, 27, 28]. On the contrary, older adults with CNP rely more on vision and other somatosensory inputs for balance and thus deficits will be greatest when these inputs are reduced[16, 17, 18, 19]. For example, older adults with CNP demonstrated poorer balance than the healthy controls across the sensorimotor integration tasks, as shown by increasing postural sway in anteroposterior direction during the comfortable stance with eyes closed on a firm surface and eyes open on a soft surface; and increasing postural sway in mediolateral direction during narrow stance with eyes open on a firm surface[16].

Previous studies in older adults with CNP have found a slower self-selected gait speed a slower self-selected gait speed and cadence during assessing TUG and 10MWT with head movement as well as 10MWT with and without head movements that were associated with longer gait cycle durations. [16, 17]. Furthermore, they demonstrated worse scores on DGI than the controls[17, 18]. These problems may alter their functional balance, leading to restriction of walking or social participation and falls[16, 17, 18, 19].

Changes in postural stability and other sensorimotor disturbances may be caused by an excess or deficiency of sensory inputs, a change in the system used for a particular task, or mismatched sensory inputs[124, 128]. This occurs via several mechanisms *(Figure 4)*.

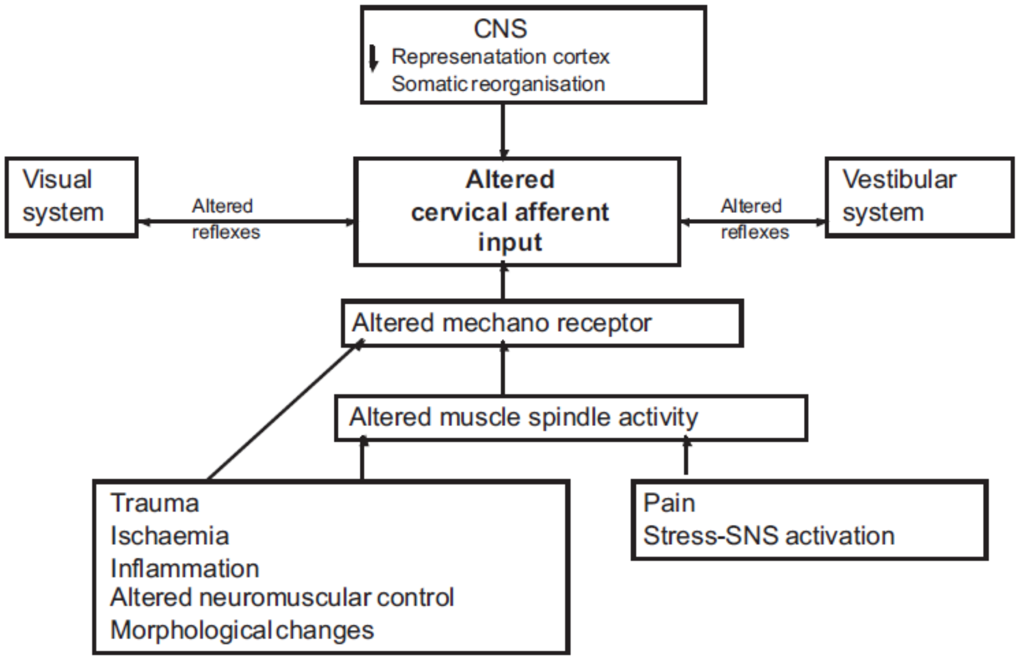

Figure 4: Mechanisms of Postural Disturbances in Chronic Neck Pain

Source: Treleaven J. (2008)

Awkward postures, static and repetitive work, and direct trauma to mechanoreceptors[23, 24] as well as chemical changes from inflammatory events that altered receptor sensitivity[22], muscle dysfunctions such as fatigue[129], and muscular degeneration such as alterations in fiber structure, infiltration of adipose tissue, and muscular atrophy[72, 73, 130, 131] can all alter cervical mechanoreceptor function.

Changes in nociceptor and mechanoreceptor activity in the CNS (both locally and at the spinal cord) were also found in response to pain[20, 21]. The hypothalamic-pituitary-adrenal axis may be activated in response to psychological stress, hence facilitating muscle spindle activity and maintaining internal homeostasis[78, 132]. As a result, both traumatic and idiopathic forms of chronic pain are easier to develop[118, 132]. Integration of information within sensorimotor control may be affected by a variety of processes that originate in the cervical spine and cause immediate and long-lasting alterations in somatosensory function. These deficits may have a common underlying cause, but the symptoms will vary considerably between patients[25, 76, 79].

Aside from processes that work locally to influence balance control, maintaining proper postural control requires both supraspinal processing and local reflexes. Modifications in reflexes and central processes can be perturbed by alterations in cervical motor control, causing postural instability[76, 78, 81]. The CNS uses somatosensory input from cervical regions to build an internal reference frame, or body schema[133, 134]. The frontal and parietal lobes have been linked to balance regulation[109, 135]. These regions, which have been found to deteriorate during chronic pain processing, can exhibit significant increases in grey matter volume in response to whole-body balancing tasks[136, 137]. Furthermore, chronic pain is related with the primary somatosensory cortex, which increases cortical responsiveness, shifts cortex representation, and resizes the affected body part on the homunculus[138].

2.6. Stability in Gait

Alterations in cervical afferent input resulting from chronic neck pain affect the integration of sensorimotor information for postural control, leading to postural instability. Poor static postural control during walking is related to a shorter single support phase and weight-bearing asymmetry of the lower limbs, leading to poor dynamic postural control and asymmetrical gait pattern[31].

Analyzing gait performance, especially the spatiotemporal features and variability of gait, could identify age-related changes in dynamic postural control and movement disorders[32]. Gait analysis is frequently used to assess fall risk by clinicians and researchers in the context of clinical practice and health research since gait performance can be easily quantified using portable inertial wearable sensors[33]. In addition, gait performance has been determined to be a significant indicator of both one's functional capacity and their physical condition in clinical and home settings[34, 35]. Gait speed should be considered as part of a comprehensive assessment of the risk of falling in older adults, as it is an effective predictor of fall risk, according to the strongest evidence[36]. It has been demonstrated that an individual's preferred walking speed and stride length decreased with age[37]. Moreover, CNP further decreases gait performance in older adults, as demonstrated by increasing gait cycle duration when performing the 10-Meter Walk test (10MWT)[16] and worse functional performance in the Timed Up-and-Go (TUG) test and the dynamic gait index (DGI) than healthy controls[17, 18]. Additionally, the studies also revealed that older adults with CNP performed worse when their walking was combined with head movement. Head movements during walking aggravated sudden changes or distinct changes in cervical/vestibular inputs, as demonstrated by significantly longer gait cycle durations, slower self-selected gait speeds, and lower cadence during the 10MWT with head turn conditions[16, 38].

During walking, the cyclic motions of the lower extremities have been considered to be symmetrical naturally[39]. One of the key factors influencing gait performance and a predictor of fall risk is gait symmetry[40], which emphasizes the bilateral coordination of swing durations during regular walking[41, 42]. Gait asymmetry has been hypothesized to be a greater contributor to the compensatory mechanisms utilized for recovering balance during locomotion than the gait variables themselves; hence, gait symmetry serves as an index of the quality of gait control[43]. Gait asymmetry was calculated using the proportion of a gait cycle's swing phase when each foot was off the ground. The term "short swing phase" (SSW) refers to the average percentage that is smaller than that of the "long swing phase" (LSW). The gait asymmetry was calculated by taking the natural logarithm of the number obtained by dividing the short swing phase by the long swing phase and then multiplying the resulting number by 100. When the value increases, it reflects the degree of gait asymmetry. A value of zero denotes complete symmetry[46].

$$\text{Gait Asymmetry Index} = 100 \times \left| \ln\left({}^{SSW}/_{LSW} \right) \right|$$

Previous studies have reported that young adults with CNP walked with a stiffer spine, more asymmetric hip mobility, and more asymmetric gait than those without

CNP during preferred walking without head movement These results suggest that pain in the neck may impact the trunk and lower limbs when walking[47].

3. Measurement tools

3.1. Questionnaire

- Pain

The respondents draw a point on a 10 cm straight horizontal line, with the left and right borders designated "No pain" and "Worst possible pain," to indicate the level of present pain as measured by Visual Analogue Scale (VAS). It has been suggested that this scale is one of the most precise methods for measuring clinical pain[139]. Mild pain was defined as a VAS score of 3 cm or less, severe pain as a score of 7 cm or more, and moderate pain as a score of 3.1 cm to 6.9 cm or more[140]. On the pain intensity scale, a minimum clinically important difference of at least 1.4 cm is considered clinically significant [141].

- Neck disability

The Neck Disability Index (*NDI; APPENDIX I*) is a self-report questionnaire comprised of ten questions regarding daily activities, pain, and concentration[142]. Disability levels range from 0 (no disabilities) to 5 (severe disabilities). Both the minimal detectable change and a minimum clinically important difference is at least 5 points out of a total score of 50, or ten percent[142, 143]. It has been shown that the NDI score is associated with pain ratings on the VAS and the McGill Pain

Questionnaire[144]. It has been demonstrated that the NDI has an excellent level of both test-retest reliability as well as internal consistency[142].

- **Balance Confidence**

Fear of falling is typical among older adults, even non-fallers. It leads to restrictions on physical activity, which increases the risk of physical deterioration and the risk of falls. Recent research shown that older persons with CNP limit their levels of physical or social activities[16, 17, 18, 19]. The Activities-specific Balance Confidence scale (*ABC scale; APPENDIX II*) measures the individuals' perception of their own ability to perform 16 tasks without becoming unstable or falling[145]. It was determined that the ABC scale was more effective than the Falls Efficacy measure in differentiating between older adults with low and high mobility confidence. It is suitable for high-functioning, community-dwelling elders due to the item's exceptional responsiveness[145]. The ABC scale has excellent test-retest reliability, internal consistency, and the ability to predict falls in older individuals living independently[146, 147].

- **Self-perceived handicap associated with dizziness**

The term "dizziness" is frequently used to characterize the uncomfortable sensations associated with a change in three-dimensional spatial orientation. There have been identified four different kinds of dizziness[148];

Type 1 (vertigo) is a movement illusion caused by diseases of the peripheral vestibular system.

Type 2 (presyncope) is a feeling of imminent loss of consciousness caused by cerebral hypoperfusion.

Type 3 (dizziness, disequilibrium) might be sensory or motor. Except in situations of visuo-vestibular mismatch, sensory disequilibrium, unlike its motor counterpart, is aggravated by low ambient light.

Type 4 (psychogenic dizziness), compared to the others, is the form of vertigo that is least commonly recognized and most rapidly evolving. Patients with this condition may experience presyncope when hyperventilating, but they do not exhibit pallor of the face, and the condition persists even after lying down.

The Dizziness Handicap Inventory (DHI; *APPENDIX III*) is a 25-item measure that assesses physical, functional, and emotional impairments associated with dizziness(149). Consequently, it evaluates how patients' dizziness impacts their daily lives in a variety of contexts and provides therapeutic guidance. Excellent test-retest reliability makes it a valuable tool for monitoring progress.

3.2. Postural control assessment

A postural control assessment is a form of motor control assessment. It is related to static and dynamic balance, but not to the system or a disease/condition. There are no methods or devices available that can measure the postural control in CNP. Previous studies in CNP has utilized outcome measurements established for other conditions, such as neurological diseases, vestibular problems and the risk of falls in the elderly.

- **Standard measurement**

  - Computerized dynamic posturography

In the field of older adults with CNP studies, the standard balance measures which have been used to detect postural control impairments include force platform[16, 17, 19, 150] and the Nintendo Wii Balance Board (Kyoto, Japan) was validate the device against the laboratory force platform[150]. The static standing balance was measured with and without altered sensory conditions. Both mediolateral (ML) and anteroposterior (AP) sway in standing balance were observed.

Wavelet analysis[17, 18, 151] was utilized to separate postural sway signals into multiple bandwidths corresponding to visual (< 0.10 Hz)[151], vestibular(0.1-0.9 Hz)[152], cerebellar(0.39-1.56 Hz)[153], and muscular proprioception (1.56-6.25 Hz)[153] systems to better understand the underlying postural control impairments in CNP.

  - Wearable inertial sensor

The usage of WIS technology *(Figure 5)* has recently emerged for the investigation of human movement. In both the clinic and the home, Wearable inertial sensors are able to be used to evaluate a person's movement quality[154, 155]. It is a convenient and inexpensive option for clinicians and researchers to objectively evaluate the movement and fall risk of patients in the clinical setting. Multiple inertial sensors (accelerometers: linear acceleration, gyroscopes: angular velocity, and magnetometers: heading with respect to the magnetic field) are used to capture data in three dimensions.

Figure 5: Wearable Inertial Sensors (Opal Inertia Sensor)

Source: https://www.apdm.com/media/

Postural control in terms of whole-body joint kinematics and spatial and temporal gait characteristics is able to evaluate precisely by combining multiple signals and synchronized sensors with models of human body motion[154, 155, 156]. These devices may autonomously compute gait characteristics, but they rarely assess the trunk's postural stability during walking. Recently, there have been developed algorithms that can automatically, objectively, and quantitatively evaluate balance and mobility.

In a previous study, the center of pressure (COP) was found to be correlated with WIS measurements, validating the WIS with force platform. Previous studies have shown that other WIS sway metrics, such as the Root Mean Square (RMS) amplitude, JERK, mean velocity, and centroidal frequency, are as sensitive as COP in differentiating untreated PD from control groups[157]. The COP and WIS traces of a control group and untreated PD patients during a quiet stance experiment are shown in *Figure 6*.

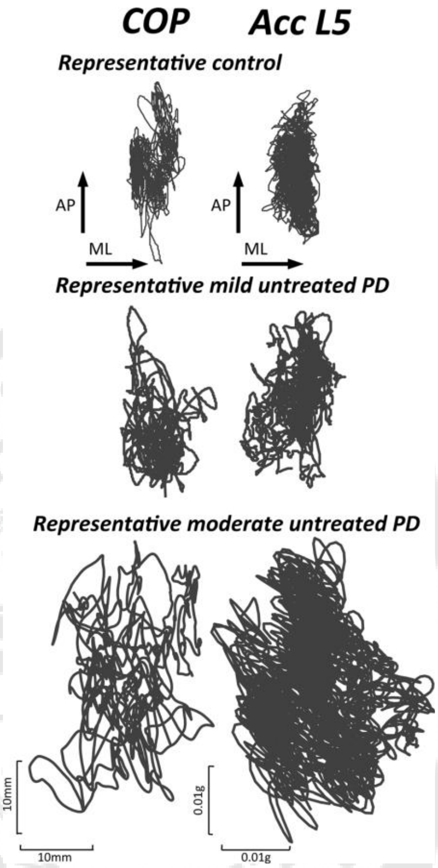

Figure 6: Center of Pressure (Left Panel) and Acceleration (Right Panel) Traces in the Horizontal Plane for Three Representative Subjects.

Source: Mancini, Martina, et al. (2012)

According to a recent study, patients with mild traumatic brain injuries (TBI) who report persistent balance problems can be classified according to the severity of their balance impairment using WIS and the Balance Error Scoring System.

The RMS value of bidirectional sway was calculated in each balance condition of clinical tests since Previous research shows that it has high reliability across a variety of the population[157]. The RMS is an acceleration (acc) output via WIS from the rigid-body motion. A larger RMS value will reflect higher physical error during postural control tasks. The RMS was calculated using the following equation:

$$RMS= \sqrt{APacc^2+MLacc^2}$$

Thus, the WIS is a sensitive measurement to quantify postural control for classifying individual with postural control deficits by calculating RMS value of bidirectional sway.

- **Clinical tools**

The Modified Clinical Test of Sensory Interaction in Balance with an Altered Base of Support (mCTSIB-aBoS) is an assessment tool that is typically administered to older adults with CNP[16, 19] for examining sensory orientation. Postural control impairment in older adults with CNP have been quantified using several mobility scales, including the 10-Meter Walk Test with and without head movement[16, 19, 158] Dynamic Gait Index (DGI) [17, 18, 159]; and Timed Up and Go Test (TUG)[17]. However, the 10-Meter Walk Test (10MWT), on the other hand, may not reliably predict actual functional mobility in real life. The 10MWT, for instance, examines just one aspect of functional mobility despite its importance in daily life.

- Sensory strategies and individual sensory system

The Modified Clinical Test of Sensory Interaction and Balance with an Altered Base of Support (mCTSIB-aBoS) has been used frequently in CNP research. It was designed to differentiate between visual, vestibular, and somatosensory inputs in order to improve the development of a treatment plan for neurological patients with balance problems. It has been demonstrated to have excellent test-retest reliability among older adults(160). The examiner uses a wall grid or plumb line to subjectively measure the amount of sway. The patient must stand in a variety of settings, some with a hard surface and others with a foam one, with or without a conflict dome, and with or without their eyes open. The duration of each test location is 30 seconds. The results obtained from the conflict dome with the eyes closed have unfortunately shown non-significant(160). Thus, the modified version has been developed by reducing the conditions with the conflict dome. The mCTSIB-aBoS demonstrated 90% of sensitivity and 95% of specificity to classify subjects who complained of dizziness and imbalance, as compared to dynamic posturography(161). Standing balance in older adults with and without CNP has been compared using computerized posturography and the mCTSIB-aBoS. Challenges to postural control include the addition of a comfortable stance and a narrow stance to the normal conditions of standing still on a firm or soft surface with eyes open or eyes closed as shown in *Figure 7*. However, no evidence has been reported about mCTSIB-aBoS responsiveness and validity for differentiating postural control impairment in older adults with CNP.

Figure 7: Modified Clinical Test of Sensory Interaction and Balance with Altered Base of Support (mCTSIB-aBoS)

- Dynamic Gait Index (DGI)

The Dynamic Gait Index (DGI; APPENDIX IV) was developed in order to evaluate the functional stability of older adults' gait activities and risk of falls[162]. The reliability and validity of the DGI has been demonstrated with a variety of populations [163, 164, 165, 166]. DGI consists of eight components, including the ability to walk including walking while altering speed, walking with horizontal and vertical head movements, walking with a pivot turn, walking over and around obstacles, and ascend stairsA DGI score of 0 indicates the most severe impairment, while a score of 3 indicates good performance. The highest conceivable result for outstanding performance is 24. If you have a low total DGI score, you have significant functional mobility impairment.

- Timed Up and Go Test

Turning is associated with increased risk of falling and injury among older adults living in the community. In the case of the elderly, it can be much more common than normal walking, especially for those who are limited to small houses. Around eight times more likely for it to occur than while walking in a straight line[167, 168]. This is due to the fact that postural transitions require cognitive and executive function in the frontal lobe, as turning requires more interlimb coordination, increased coupling between posture and locomotion, and variations in locomotor patterns[169, 170]. Older adults might discover it difficult to turn when walking because it requires stopping, rotating head and neck, rotating the body, and taking a stride in a new direction[171]. Fallers frequently stagger while turning, take longer to turn, and require more steps to complete a turn than non-fallers[172]. Due to impairments in head-trunk coordination, older adults with CNP may have difficulty maintaining dynamic balance while turning and completing the task.

For the TUG, an individual stands up from a chair, walks 3 metres while making a 180-degree turn around a cone, and then sits back down. Therefore, this evaluation includes elements (e.g., sitting to standing, walking, and turning) that are crucial for performing daily tasks. Objective assessments of turning mobility have been shown to be more sensitive than gait speed or other clinical measures to identify those with impaired dynamic balance and mobility[173, 174]. Several groups have used it recently; among them is older persons with CNP, who were found to have lower scores on the TUG compared to healthy controls. This finding provides more evidence of the existence of balance deficiencies in this group[17]. However, TUG only uses time as a single measure for evaluating how well the sequence of activities was completed. This method relies entirely on the tester's observable evaluation of balance and is therefore widely used in clinical settings. As a result, it is unable to discriminate between subtle changes in sway patterns that indicate postural sway discrepancies since it does not contain task-specific information[175].

- BESTest

The Balance Evaluation Systems Test1 (BESTest; APPENDIX V) was established to assist physiotherapists treat their patients more effectively by identifying the underlying postural control system that contributes to impaired functional balance[49]. It has been shown to be a reliable and valid measure of balance in individuals with neurological disease (e.g. Parkinson Disease[176, 177, 178, 179], Multiple Sclerosis[178, 180], Stroke[181, 182, 183], and older adults[51, 184]). The BESTest is a test that consists of thirty-six items and provides ordinal scores ranging from 0 to 3, with 0 indicating the lowest level of function and 3 indicating the highest level. The highest possible raw score is 108, which indicates an extremely high level of functioning. You may get your percentage score by dividing your total points by 108 and multiplying the result by 100%. Greater percentages represent greater balance.

The BESTest consists of six sections: biomechanical constraints, stability limits/verticality, anticipatory postural adjustments, postural responses, sensory orientation, and gait stability. Additionally, the percentage ratings for each subsystem are computed.

- <u>10-Meter Walk Test</u>

The 10-Meter Walk test (10MWT) is clinician-administered and measures the time in which participants select a preferred walking speed over 10 meters. It is widely used and recommended as a physical mobility and balance test[185]. The 10MWT is a primary predictor of self-perceived function[186]. Also, it is widely used to assess dynamic balance in participants with CNP both with and without head movements. The participants were given instructions to walk at their preferred speed barefoot under three different movements of the head: no head movement (NM), horizontal head movement (HM), and vertical head movement (VM). While walking 10 meters without assistance, timer starts when the participants cross the 2-meter mark and stops when participants cross the 8-meter mark. The 6-meter in the middle is then divided by the total time taken (in seconds) to complete and recorded in m/s.

4. Summary

The literature indicates that one of the most important problems of CNP, in addition to pain and disability, is postural control deficits, especially in older adults with CNP who have declined balance and increased risk of falls. As of now, a number of impairments observed in CNP patients, such as unsteadiness/dizziness, deficiencies in cervical joint proprioception(62, 187), poor oculomotor control(29, 187, 188, 189), or altered postural stability (25, 79, 190, 191) , have been more precisely classified as originating from a sensorimotor disorder. Therefore, previous studies in older adults with CNP which examined postural control impairments often considered sensory integration or orientation and stability in gait, while other postural control systems have not been thoroughly investigated. Several postural control systems including musculoskeletal system, sensory integration, sensorimotor strategy, internal representation, adaptive and anticipatory mechanism, are responsible for controlling balance. Impairment of each postural control system will lead to different characteristics of balance disorders that required different method of management. To be able to design effective balance training for older adults with CNP, assessment of all postural control systems is required. At present, there is still lack of information regarding other postural control systems such as internal representation, adaptive and anticipatory mechanisms that may be impaired in older adults with CNP. Although various clinical scales were used for determining postural control in older adults with CNP studies including The mCTSIB-aBoS(16, 19), DGI[17], 10MWT with and without head movement[16, 19], and TUG[17]. However, these clinical tools provide insufficient information on postural control and may limit the overall evaluation of a person's ability to control their posture. Furthermore, their sensitivities in detecting older adults with CNP with postural control problem have never been reported.

The BESTest is a comprehensive balance measure targeting the 6 interacting systems underlying postural control[49]. The majority of the items on the BESTest was selected from the following lists of validated balance tests: Single-Leg Stance Test (SLT), TUG, DGI, Functional Reach Test, mCTSIB-aBoS, and Berg Balance Score[49]. Therefore, the BESTest is the interesting clinical tools that have the potential to discriminate postural control impairment in older adults with CNP.

CHAPTER 3

METHODOLOGY

Two objectives have been investigated in this study using cross-sectional study design. The first objective of this study was to determine the gait variables, gait speed or gait symmetry, that are sensitive and practical for detecting dynamic balance impairment in walking in older adults with chronic nick pain (CNP). Since only impaired sensory orientation and loss of stability in gait have been evident in older adults with CNP, other postural control systems have not been thoroughly investigated. Hence, the second objective of this study was to investigate the ability of the Balance Evaluation Systems Test (BESTest) to identify postural control impairment in older adults with CNP.

1. Participants

<u>Setting</u>

- Srinakharinwirot University
- Physical Therapy Clinic
- Community

<u>Participants selection</u>

This study recruited older adults without chronic neck pain (the OLD group), older adults with chronic neck pain (the CNP group), and healthy young adults (the YOUNG group) as the reference. Participants were recruited conveniently and screened for inclusion and exclusion criteria by researcher 1. Those who met the criteria were asked to consent to the study in writing and were provided with a copy of the signed consent form.

Inclusion criteria

For asymptomatic group (the OLD group), this study recruited the participants who have;

- aged ≥ 60 years old
- able to walk independently
- no history of neck pain

For symptomatic group (the CNP group), this study recruited the participants who have;

- aged ≥ 60 years old
- able to walk independently
- suffered neck pain (average intensity ≥ 3 mm on the 10 mm VAS in the last week) for at least 3 months with/without radiating pain[192]

For healthy young adults group (the YOUNG group), this study recruited the participants who have;

- aged 20-40 years old
- able to walk independently
- no history of neck pain

Exclusion criteria

- previous history of neck and head trauma[193]
- recent orthopedic surgery or fracture (within the last six months to lessen the impact of injury's short-term aftereffects)[194, 195, 196]
- recent acute musculoskeletal injury or inflammatory joint disease/arthritis that required active management[194, 197, 198, 199]
- known or suspected vestibular pathology, vertigo or dizziness from ear or brain disorders, neurological conditions such as stroke or parkinson's disease[193, 194, 199, 200]
- systemic conditions such as cancer, diabetes with peripheral neuropathy, etc.[194, 199, 201, 202]
- use of certain medications affected postural control four or more during the assessment date (such as digoxin, opioids, anticonvulsants, psychostimulants, and antidepressants)[194]
- cognitive impairment[203] as measured by Montreal Cognitive Assessment (MoCA) with the total score of less than 24/30[204]

2. Sample size

Objective I

For objective I, the sample size was estimated using data from a previous study[46] that found an effect size of 1.00. A sample size of at least 12 individuals in each group is needed to provide a sufficient power of 0.80 for the Mann-Whitney U test when the alpha level is set at 0.05. However, this study included a larger sample size in the control group for an accurate comparison. Thus, a convenience sampling technique was used to recruit fourteen older adults with CNP (n = 14) and 36 controls (n = 36).

Objective II

For objective II, the effect size of 0.52 was calculated from prior study[17]. A power analysis performed with G*Power version 3.1.9.4 indicated that at least 15 participants in each group would be needed to ensure an adequate power level of 0.80 for the Kruskal–Wallis test at an alpha level of 0.05.

According to Sheskin, D. J. (2003)[205], the sample size calculation of the Kruskal-Wallis Test is the same as with the 1-way ANOVA but with 15-20% more samples. Thus, the minimum sample size of 20 are required for each group (OLD, CNP, YOUNG), resulting in a total of 90 participants for this study. Thus, one hundred and ten participants from three groups of subjects, thirty healthy young participants aged 20-40 years and eighty older adults aged 60 years or older with (n = 20) and without CNP (n = 60), were included in the study

3. Data collections

To investigate the objectives of the study, the primary and secondary variables will be collected as summarized in *Table 2*.

Table 2: The Variables of Interest

Measurement tools	Variables	Unit	Type of scale
Primary variables			
mCTSIB-aBoS	Averaged time	s	Ratio
Gait speed	Averaged speed	m/s	Ratio
Stride length	Averaged length	cm	Ratio
Cadence	Averaged step in a minute	steps/min	Ratio
Gait Asymmetry Index	Proportions of asymmetry	-	Ordinal
BESTest	Total score	%	Ordinal
Secondary variables			
VAS	Averaged pain	cm	Ratio
NDI	Total score	%	Ordinal
ABC scale	Total score	%	Ratio
DHI	Total score	-	Ordinal

mCTSIB-aBoS = Modified Clinical Test of Sensory Integration and Balance with an altered base of support; BESTest = The Balance Evaluation Systems Test; VAS = Visual Analogue Scale; NDI = The Neck Disability Index; DHI = Dizziness Handicap Inventory; ABC scale = Activities-specific Balance Confidence scale

After obtaining informed consent, demographic data and questionnaires were administered by researcher 1. Researcher 2, who was blinded to the participants' group and demographic information conducted the postural control assessments in quiet laboratory settings with verbal instructions. Researcher 2's intrarater reliability on the mCTSIB-aBoS and BESTest were calculated using the intraclass correlation coefficient (ICC) for a sample of 10 older adults. The findings demonstrated that Researcher 2 had a high intrarater reliability of both tests (ICC = 0.98 and 0.96, respectively).

3.1. Questionnaire

The questionnaire including age, gender, body mass index (BMI), medication intake and co-morbidities were obtained via interviewer-assisted questionnaire and medical record of each participant. In order to reach the participants that representative of older adults aged 60 or older, individuals with mild and common conditions were not excluded from the study. Four distinct groups of comorbidities were coded and classified into four categories:

1) musculoskeletal conditions
2) history of orthopedic surgery or fracture
3) common health problems include hypertension, heart disease, osteoporosis, and depression
4) dizziness

For each participant's co-morbidities, the number of 'positive' codes was counted, with the highest number of codes equal to four.

Neck pain intensity was assessed as “pain at the moment” on a blank 10 cm visual analog scale (VAS), on which 0 cm corresponds to "no pain at all" and 10 cm corresponds to "worst imaginable pain".

The Neck Disability Index (NDI) Thai version(206) was administered via an interviewer-assisted questionnaire to assess the degree of self-reported neck pain and disability. It consists of 10 items concerning daily living, pain and concentration. Each item is scored from 0–5, with 0 representing no disability and 5 signifying extreme disability, giving a total score of 50 or 100 percent. The total scores can be interpreted into the following 5 levels of disability in performing activities of daily living: 0-8%, no disability; 10-28%, mild disability; 30-48%, moderate disability; 50-64%, severe disability; and 70-100%, complete disability[207].

The Activities-specific Balance Confidence scale (ABC) was used to assess participants' balance confidence. The ABC requires patients to indicate their confidence in performing 16 activities without losing their balance or becoming unsteady on an 11-point scale (0 to 100%). Each item describes a specific activity that requires progressively increased balance control. Greater scores indicate higher balance confidence.

The Dizziness Handicap Index (DHI) was used to examine the self-perceived handicap associated with dizziness. The DHI consists of 25 items divided into three subscales: physical, functional, and emotional. Higher scores indicate the maximum perceived disability, with a maximal score of 100. The DHI can be used to classify individuals into 3 levels of disability; a total score of 0-30 indicates mild disability, 31-60 indicates moderate disability, and 61-100 indicates severe disability[149].

3.2. Postural Control Assessment

Participants performed each test once and they were given time to familiarize themselves with the testing procedures and instructions prior to data collection. The participants were randomly assigned into each sequence, and the researcher ensured that there was an equal number of participants in each sequence. Participants were encouraged to rest for 5 minutes as needed between each section of the test to avoid fatigue. The total testing time was approximately 2 hours, but if the test could not be completed within 1 day, it was continued the next day. To verify the accuracy of the scoring, the entire testing session of each participant was videotaped for subsequent review.

Objective I

To determine the gait variables that are sensitive and practical for detecting dynamic balance impairment in walking in older adults with CNP, the Modified Clinical Test of Sensory Integration and Balance with adjusted base of support (mCTSIB-aBoS) and the 10-Meter Walk test (10MWT) were used to collect gait variables with the Inertial Measurement Units (IMU).

- Modified Clinical Test of Sensory Integration and Balance with adjusted base of support (mCTSIB-aBoS): The aim of the standing balance test is to objectively evaluate the effects of visual, vestibular, and somatosensory input on the ability to maintain balance[28], is a timed test that have good test-retest reliability in older populations[160]. Participants, similar to those in the previous study of older adults with CNP[29], were given eight conditions and instructed to stand with their arms crossed as steadily as possible for 30 seconds: eyes open while standing comfortably on a firm surface (C1), eyes open while standing narrowly on a firm surface (C2), eyes closed while standing comfortably on a firm surface (C3), eyes closed while standing narrowly on a firm surface (C4), eyes open while standing comfortably on a soft surface (C5), eyes open while standing narrowly on a soft surface (C6), eyes closed while standing comfortably on a soft surface (C7), and eyes closed while standing narrowly on a soft surface (C8). When participants opened their eyes, moved an arm or both, and took a step, the trial ended. The length of time required to complete each condition was recorded. The total score was calculated by averaging the times on all conditions.

- The 10-Meter Walk test (10MWT), in which participants select a preferred walking speed over a distance of 10 meters, is widely used and recommended as a physical mobility and balance test[185]. Participants were instructed to do three different head movements while walking barefoot at their preferred speed. no head movement (NM), horizontal head movement (HM), and vertical head movement (VM).

- Inertial Measurement Units (IMU)

Gait parameters, including gait speed, stride length, and cadence during the walking test, were collected with the Instrumented Long Walk (IWalk) test (APDM, Inc., Portland, USA). Six inertial measurement units (IMUs, Inc., Portland, OR, USA) were worn by all participants at the chest, lumbar region, wrists, and ankles before performing the clinical test, with The sensors, which include a gyroscope and an accelerometer, collect data at a sampling rate of 200 Hz and report angular velocity and acceleration, respectively[208]. The instrument has high to moderate validity when measuring most of the gait metrics tested[209]. The IMUs at both shanks are used to detect and evaluate gait speed, stride length, and cadence. To allow comparison to normative data, the value was averaged for the left and right sides in relation to the subject's body height[210]. Gait asymmetry was calculated using the proportion of a gait cycle's swing phase when each foot was off the ground. The term "short swing phase" (SSW) refers to the average percentage that is smaller than that of the "long swing phase" (LSW). The gait asymmetry was determined by taking the natural logarithm of the number that resulted from the ratio of the short swing phase to the long swing phase and then multiplying that result by 100. When the value increases, it reflects the degree of gait asymmetry. A value of zero denotes complete symmetry[46].

$$\text{Gait Asymmetry Index} = 100 \times \left| \ln\left({}^{SSW}/_{LSW} \right) \right|$$

The testing conditions were organized into 11 sequences that began with different clinical test conditions and continued with the subsequent conditions. The test conditions were organized into 11 sequences that began with different clinical test conditions and continued with the subsequent conditions. For example, the first sequence, C1 of the mCTSIB-aBoS was assigned first, followed by C2, C3, C4, C5, C6, C7, C8, walk with NM, walk with HM, and walk with VM, while in the second sequence, C2 of the mCTSIB-aBoS was assigned first, followed by C3, C4, C5, C6, C7, C8, walk with NM, walk with HM, walk with VM, and C1.

Objective II

To investigate the ability of the Balance Evaluation Systems Test (BESTest) to identify postural control impairment in older adults with CNP, the BESTest was used in this study. The testing items were grouped into 6 sequences, which were initiated with different sections of the BESTest and followed by the subsequent sections. For example, in the 1st sequence, Section I of the BESTest was administered first, followed by Sections II, III, IV, V, and VI, and in the 2nd sequence, Section II was administered first, followed by Sections III, IV, V, VI, and I.

- Balance Evaluation Systems Test: The participants were instructed to perform 6 sections (S1-S6) including 27 tasks. There are a total of 36 items on the BESTest. Each item is scored on a 4-level, ordinal scale from 0 (worst performance) to 3 (best performance). The scores were summed to obtain a total score out of a possible maximum score of 108 points. Scores for the total test, as well as for each section, were expressed as a percentage of total points(49).

4. Statistical analysis

Descriptive statistics were used to describe demographic data. The risk for bias was minimized by coded data during the analyzing process.

Objective I

To determine the first hypothesis, the Mann–Whitney U test was selected to compare the total score of the mCTSIB-aBoS, gait speed, stride length, cadence, and gait asymmetry index between older adults with and without CNP. The Kruskal–Wallis test was chosen to investigate the differences in outcome variables among the three types of walking within the group: walking with no head movement, walking with horizontal head movement, and walking with vertical head movement.

Spearman's correlation coefficient was used to determine the degree of the relationship between fear of falling and gait parameters (gait speed and gait symmetry index) for each walking condition. The direction of the correlation was indicated by the sign of the correlation coefficient, r. If r was negative, then there was an inverse relationship between the variables. Most biologically significant coefficients in clinical and biomedical investigations fall in the range of 0.5 to 0.8 (or -0.5 to -0.8)[211], which is classified as a moderate to strong correlation[212]. All analyses were conducted with a significance level of 0.05.

Objective II

To investigate the second hypothesis, the Kruskal–Wallis test was selected to compare the percentage of the BESTest total and each section score between 3 groups. The pairwise comparison was used to pinpoint the difference between groups. The Mann–Whitney U test was used to compare the BESTest item scores between older adults with and without CNP in the selected BESTest section. The significance level was set to 0.05 for all tests.

Once the BESTest domains that were significantly different between older adults with and without CNP had been identified, receiver operating characteristic (ROC) curve analysis was further conducted on those BESTest domains to differentiate the older adults whose daily life had been affected by neck problems using the NDI scores as a reference: participants with disability (total score ≥ 10%) and without disability (total score < 10%). The area under the curve (AUC) and the specificity, sensitivity, and cutoff points were calculated. An AUC value of 0.7 to 0.9 is generally considered to be acceptable for differentiation[213]. The largest Youden index (sensitivity + [1-specificity]) was chosen as the cutoff score. Positive likelihood ratios (+LR) were calculated as sensitivity/(1-specificity). Negative likelihood ratios (-LR) were calculated as (1-sensitivity)/specificity. The greater the +LR is than 1.0, the more valuable the positive test result. The -LR indicates the usefulness of a negative test result: the greater the value is less than 1.0, the more valuable the negative test result[214]. Posttest accuracy was later calculated from the proportion of true positives and true negatives in all tested cases.

The item difficulty measure was estimated from the BESTest item score of each participant group by Rasch analysis (partial credit model)[52] using WINSTEPS software 5.2.2 (Winsteps®, Portland, Oregon). The “simulate data” option was used to strengthen the findings due to the small sample size. The item difficulty was expressed in a logit scale, in which the highest logit represents the most difficult item, and the lowest logit represents the easiest item.

5. Ethical Considerations

Risks and management

1) Fall during postural control assessment

All participants will be screened before participating in the study, and those who have extreme balance loss will not participate in the study. There will also be a padded surface on the floor and the researchers (Researcher 1 or 2) nearby to catch the participants if they should fall off.

2) Discomfort and/or pain during testing

All participants will be screened before participating in the study, and those who have extreme pain will not be allowed to participate in the study. The participants will be allowed to rest for a longer period or stop in between if the testing protocols induce pain.

3) Muscle fatigue and soreness during testing

The participants will be allowed to rest for a longer period of time in between trials if they are too fatigued.

CHAPTER 4

RESULTS

1. Objective I

The first purpose of this study was to identify which gait variables were more sensitive to dynamic balance impairment in older adults with chronic neck pain (CNP). The demographic data of older adults without chronic neck pain (the OLD group) and older adults with chronic neck pain (the CNP group) are shown in Table 3. No significant differences in gender, age or comorbidities between older adults with and without CNP were found. Most of the participants in both groups were female, without significant difference in body mass index between groups. According to the NDI score, participants of the CNP group reported experiencing no to mild disability in activities of daily living due to neck problems, which was significantly greater than the OLD group ($p < 0.05$). The pain level of the CNP group was classified as moderate intensity. Based on the ABC scale, those with CNP were less confident than the OLDs in their ability to carry out daily activities without losing their balance ($p < 0.05$). Additionally, the total scores on the mCTSIB-aBoS, which represent static postural control, were significantly lower in the CNP group ($p < 0.05$).

Table 3: Characteristics of Participants

	OLD (n=36)	CNP (n=14)
Age (years, mean ± SD)	64.44 ± 3.68	63.29 ± 2.76
Gender (female, n (%))	29 (80.56)	11 (78.57)
BMI (kg/m^2, mean ± SD)	23.31 ± 2.05	23.62 ± 4.03
NDI (0-100, mean ± SD)	0.72 ± 1.45	13.57 ± 6.09*
ABC scale (%, mean ± SD)	95.25 ± 5.08	90.53 ± 8.53*
DHI (points, mean ± SD)	N/A	0.64 ± 1.34
VAS (0-10, mean ± SD)	0	4.43 ± 1.45
Duration of neck pain (months, mean ± SD)	N/A	17.89 ± 15.07
Side of neck pain (sides, n (%))		
- Right side	N/A	3 (21.43)
- Left side	N/A	2 (14.29)
- Both side	N/A	9 (64.29)
Comorbidities (conditions, median (SE))	0.00 (0.63)	0.50 (0.65)
mCTSIB-aBoS (% total score, mean ± SD)	100 ± 0.00	99.23 ± 1.21*

NDI = Neck Disability Index; ABC scale = Activities-specific Balance Confidence scale; DHI = Dizziness Handicap Index; VAS = Visual Analog Scale; OLD = Older Adults without Chronic Neck Pain; CNP = Older Adults with Chronic Neck Pain, N/A = not applicable

*$p < 0.05$ comparison of OLD and CNP

The spatiotemporal variables are presented in Table 4 as the mean and standard deviation. There was no difference in gait speed, stride length or cadence between the OLD and CNP groups during walking with no head movement (NM). However, when walking with horizontal head movement (HM) and vertical head movement (VM), the CNP group had lower gait speed, stride length, and cadence than the OLD group. Furthermore, gait speed was significantly different among all walking conditions in the CNP group; it was highest during walking with NM and lowest during walking with VM ($p < 0.05$), as shown in Figure 8.

Table 4: Gait Parameters (Mean ± SD) under Three Different Walking Conditions between Older Adults with and without Chronic Neck Pain

Gait parameter	Walk without head movement		Walk with horizontal head movement		Walk with vertical head movement	
	OLD	CNP	OLD	CNP	OLD	CNP
Gait speed (m/s)	1.14 ± 0.07	1.09 ± 0.09	1.11 ± 0.08	0.97 ± 0.05*	1.11 ± 0.07	0.89 ± 0.06*
Stride length (cm.)	124.19 ± 7.66	120.22 ± 7.23	118.25 ± 6.89	111.50 ± 8.51*	118.91 ± 7.34	112.35 ± 9.06*
Cadence (steps/min)	106.23 ± 5.62	103.15 ± 5.41	102.64 ± 6.26	96.14 ± 5.72*	105.13 ± 6.93	95.83 ± 5.31*

OLD = Older Adults without Chronic Neck Pain; CNP = Older Adults with Chronic Neck Pain

*$p < 0.05$ comparison of OLD and CNP

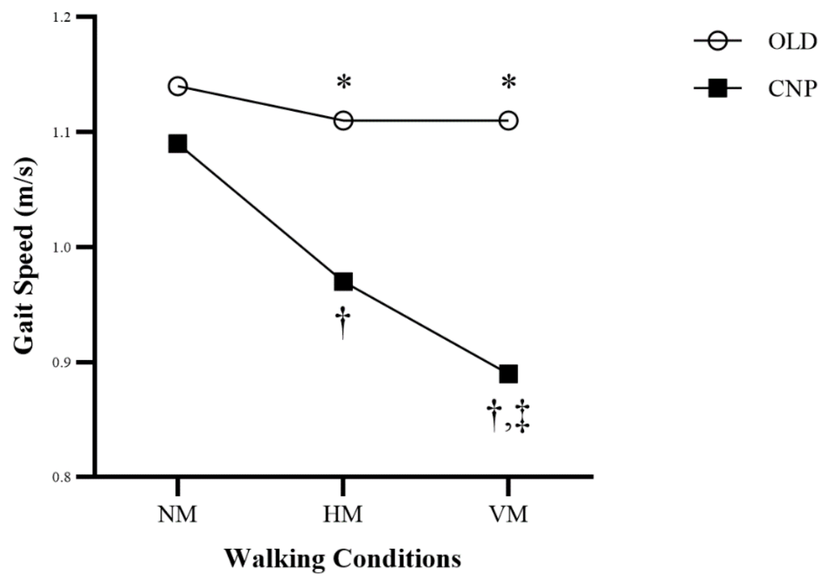

Figure 8: Gait Speed under Three Different Walking Conditions between the Control (OLD) and Neck Pain Groups (CNP);

*There was no difference across walking condition in the OLD group. * Significant difference in gait speed between group were found during walking with Horizontal Head Movement (HM) and Vertical Head Movement (VM); † The pairwise comparison within the CNP group showed significant difference between walking with No Head Movement (NM) and HM, and between walking with NM and VM; ‡ The pairwise comparison within the CNP group showed significant difference between walking with HM and VM.*

Gait asymmetry indices during the 3 walking conditions in the OLD and CNP groups are presented in Table 5. Compared to the OLD group, the CNP group had the largest gait asymmetry index when walking with VM ($p < 0.05$). Further investigation within groups revealed a significant difference in the gait asymmetry index between walking with NM and VM in the CNP group (NM = 3.02 ± 1.76, VM = 6.11 ± 3.07; $p < 0.05$), as shown in Figure 9.

Table 5: Gait Asymmetry Index (Mean ± SD) under Three Different Walking Conditions between Older Adults with and without Chronic Neck Pain

Walking Conditions	OLD (n=36)	CNP (n=14)	p-value
Walk without head movement	3.01 ± 2.18	3.02 ± 1.76	0.730
Walk with horizontal head movement	3.06 ± 1.86	4.44 ± 3.40	0.342
Walk with vertical head movement	3.62 ± 2.06	6.11 ± 3.07	0.006*

OLD = Older Adults without Chronic Neck Pain; CNP = Older Adults with Chronic Neck Pain

*p < 0.05 comparison of OLD and CNP

As shown in Table 6, there were significant correlations ($p < 0.05$) between gait parameters and balance confidence (as measured by the ABC scale) while walking with head movement. In both walking with HM and VM, the correlation between balance confidence and gait speed was determined to be moderate ($r = 0.618$ and $r = 0.620$, respectively), whereas the gait asymmetry index had a moderate inverse correlation ($r = -0.563$, $r = -0.698$, respectively) with balance confidence.

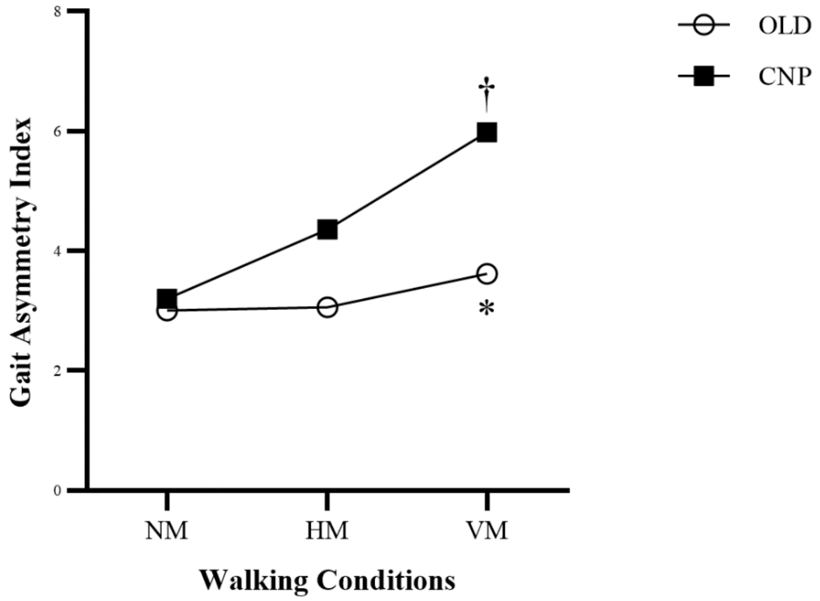

Figure 9: Gait Asymmetry Index under Three Different Walking Conditions between the Control (OLD) and Neck Pain Groups (CNP);

*There was no difference across walking condition in the OLD group. * Significant difference in gait asymmetry index between group was found during walking with Vertical Head Movement (VM); † The pairwise comparison within the CNP group showed significant difference in gait speed between walking with No Head Movement (NM) and VM, while no significant difference was found during walking with Horizontal Head Movement (HM) condition.*

Table 6: Spearman's Rank Correlation Coefficient between Balance Confidence and Gait Parameters in the Chronic Neck Pain Group across Walking Conditions

Parameters	ABC scale; r (p-value)		
	Walk without head movement	Walk with horizontal head movement	Walk with vertical head movement
Gait Speed	0.196 (0.501)	0.618 (0.019)*	0.620 (0.018)*
Gait Asymmetry Index	- 0.481 (0.081)	- 0.563 (0.036)*	-0.698 (0.006)*

ABC scale = Activities-specific Balance Confidence scale

*p < 0.05

2. Objective II

The second purpose of this study was to determine whether the BESTest is able to identify system-specific postural control impairments in older adults with CNP. The demographic data of the young adults (YOUNG), the OLD group and the CNP group are presented in Table 7. As expected, there were significant differences in age between young and older adults ($p < 0.05$), whereas older adults with and without CNP did not significantly differ in age or comorbidities. Most of the participants in all groups were female, without a significant difference in body mass index. The CNP group had moderate pain and none to mild disability of daily living affected by neck problems (from the NDI score) and were significantly worse than the OLD group ($p < 0.05$). Moreover, those with CNP had less balance confidence in performing daily activities than those without CNP ($p < 0.05$).

Table 7: Characteristics of Participants

	YOUNG (n=30)	OLD (n=60)	CNP (n=20)
Age (years, mean ± SD)	24.20 ± 4.13	64.70 ± 3.74†	63.85 ± 3.73‡
Gender (female, n (%))	21 (70.00)	46 (76.67)	16 (80.00)
BMI (kg/m^2, mean ± SD)	22.14 ± 2.25	23.56 ± 2.97	23.65 ± 3.75
NDI (0-100, mean ± SD)	-	0.63 ± 1.35	13.63 ± 6.74*
ABC scale (%, mean ± SD)	-	94.08 ± 5.79	88.78 ± 10.67*
DHI (points, mean ± SD)	-	0.03 ± 0.26	1.45 ± 4.51*
VAS (0-100, mean ± SD)	-	-	4.50 ± 1.47
Duration of neck pain (months, mean ± SD)	-	-	14.63 ± 14.15
Side of neck pain (sides, n (%))			
- Right side	-	-	4 (20.00)
- Left side	-	-	4 (20.00)
- Both side	-	-	12 (60.00)
Comorbidities (conditions, median (SE))	-	1.00 (0.71)	1.00 (0.63)
Taking more than four medications (n (%))	-	5 (8)	2 (10)

NDI = Neck Disability Index; ABC = Activities-specific Balance Confidence scale; DHI = Dizziness Handicap Index; VAS = Visual Analog Scale; OLD = Older Adults without Chronic Neck Pain; YOUNG = Young Adults; CNP = Older Adults with Chronic Neck Pain

†p < 0.05 comparison of YOUNG and OLD

‡p < 0.05 comparison of YOUNG and CNP

*p < 0.05 comparison of OLD and CNP

The BESTest scores from 3 groups of participants, young adults and older adults with and without CNP, are presented in Table 8. Older adults with and without CNP demonstrated significantly lower BESTest total scores than young subjects. The comparison between the two groups of older adults showed that the CNP group had a lower BESTest total score than the OLD group. Regarding the section scores, the OLD group had a significantly lower score than the YOUNG group in all sections, except Section I (Biomechanical Constraints) and Section V (Sensory Integration), while the CNP group had lower scores than the YOUNG group in all sections except Section V. In addition, the CNP group had a significantly lower score than the OLD group in 3 sections: Biomechanical Constraints (Section I), Transitions–Anticipatory Postural Adjustment (Section III), and Reactive Postural Response (Section IV), which is 93.67 ± 5.91, 94.44 ± 6.74, and 89.17 ± 12.29, respectively ($p < 0.05$). Therefore, scores from these 3 sections (I, III, and IV) were selected for the following analyses.

Table 8: Percentage Score in Total and each section of the BESTest

BESTest	YOUNG (n=30)	OLD (n=60)	CNP (n=20)
Total (%)	99.73 ± 0.64	94.26 ± 3.35†	91.58 ± 3.11‡, *
Section I: Biomechanical Constraints (%)	99.33 ± 0.06	97.56 ± 4.42	93.67 ± 5.91‡, *
Section II: Stability Limits/Verticality (%)	100.00 ± 0.00	88.97 ± 6.88†	89.29 ± 8.30‡
Section III: Transitions-Anticipatory Postural Adjustment (%)	100.00 ± 0.00	97.41 ± 4.95†	94.44 ± 6.74‡, *
Section IV: Reactive Postural Response (%)	100.00 ± 0.00	95.56 ± 5.58†	89.17 ± 12.29‡, *
Section V: Sensory Orientation (%)	100.00 ± 0.00	99.56 ± 2.08	99.33 ± 2.05
Section VI: Stability in Gait (%)	99.05 ± 0.48	86.51 ± 7.55†	83.57 ± 4.76‡

OLD = Older Adults without Chronic Neck Pain; YOUNG = Young Adults; CNP = Older Adults with Chronic Neck Pain

†$p < 0.05$ comparison of YOUNG and OLD

‡$p < 0.05$ comparison of YOUNG and CNP

*$p < 0.05$ comparison of OLD and CNP

The frequency distribution of the BESTest scores within Sections I, III and IV between older adults with and without CNP are shown in Table 9. Compared to the OLD group, the CNP group demonstrated a lower percentage of individuals who scored “normal” (3 scores), which differed significantly in the following items: Section I, hip/trunk lateral strength; Section III, stand on nondominant leg; and Section IV, compensatory stepping correction–forward and backward.

Table 9: The Frequency Distribution of the BESTest Scores in each Section

BESTest	Frequency (%)			
	OLD (n=60)		CNP (n=20)	
	Normal	Abnormal	Normal	Abnormal
Section I: Biomechanical Constraints				
- Base of Support	100	0.00	100	0.00
- COM Alignment	100	0.00	100	0.00
- Ankle Strength & Range	78.3	21.7	60.0	40.0
- Hip/Trunk Lateral Strength	88.3*	11.7	60.0*	40.0
- Sit on Floor and Standup	100	0.00	100	0.00
Section II: Stability Limits/Verticality				
- Sitting Verticality and Lateral Lean: Lean (Lt.)	86.7	13.3	85.0	15.0
- Sitting Verticality and Lateral Lean: Lean (Rt.)	90.0	10.0	95.0	5.00
- Sitting Verticality and Lateral Lean: Verticality (Lt.)	83.3	16.7	90.0	10.0
- Sitting Verticality and Lateral Lean: Verticality (Rt.)	90.0	10.0	80.0	20.0
- Functional Reach Forward Distance Reached	55.0	45.0	55.0	45.0
- Functional Reach Lateral Distance Reached (Lt.)	26.7	73.3	45.0	55.0
- Functional Reach Lateral Distance Reached (Rt.)	38.3	61.7	55.0	45.0
Section III: Transitions-Anticipatory Postural Adjustment				
- Sit to Stand	100	0.00	100	0.00
- Rise to Toes	88.3	11.7	90.0	10.0
- Stand on Non-dominant Leg	85.0*	15.0	55.0*	45.0
- Stand on Dominant Leg	88.3	11.7	75.0	25.0
- Alternate Stair Touching	100	0.00	100	0.00
- Standing Arm Raise	100	0.00	100	0.00

OLD = Older Adults without Chronic Neck Pain; CNP = Older Adults with Chronic Neck Pain

Normal = Able to perform the test perfectly and score as 3, Abnormal = Unable to perform the test perfectly and score as 2, 1, or 0

Percentage of frequency was calculated by dividing the amount of participant in each score by the total participants of each group, and then multiplying the result by 100.

*$p < 0.05$ comparison of OLD and CNP

Table 9: The Frequency Distribution of the BESTest Scores in each Section (Continued)

BESTest	Frequency (%)			
	OLD (n=60)		CNP (n=20)	
	Normal	Abnormal	Normal	Abnormal
Section IV: Reactive Postural Response				
- In Place Response: Forward	100	0.00	95.0	5.00
- In Place Response: Backward	93.3	6.70	85.0	15.0
- Compensatory Stepping Correction: Forward	96.7*	3.33	75.0*	25.0
- Compensatory Stepping Correction: Backward	90.0*	10.0	60.0*	40.0
- Compensatory Stepping Correction: Lateral (Nondominant)	73.3	26.7	60.0	40.0
- Compensatory Stepping Correction: Lateral (Dominant)	71.7	28.3	60.0	40.0
Section V: Sensory Orientation				
- Eyes Open, Firm Surface	100	0.00	100	0.00
- Eyes Closed, Firm Surface	100	11.7	100	0.00
- Eyes Open, Soft Surface	100	15.0	100.0	5.00
- Eyes Closed, Soft Surface	95.0	5.00	90.0	10.0
- Inclined - Eyes Closed	100	0.00	100	0.00
Section VI: Stability in Gait				
- Gait – Level Surface	33.3	66.7	15.0	85.0
- Change in Gait Speed	96.7	3.30	95.0	5.00
- Walk with Head Turns - Horizontal	93.3	6.70	85.0	15.0
- Walks with Pivot Turns	100	0.00	100	0.00
- Step over Obstacles Time	95.0	5.00	95.0	5.00
- Timed “Get Up & Go” Get Up & Go	48.3	51.7	25.0	75.0
- Timed “Get Up & Go” with Dual Task Dual Task	15.0	85.0	10.0	90.0

OLD = Older Adults without Chronic Neck Pain; CNP = Older Adults with Chronic Neck Pain

Normal = Able to perform the test perfectly and score as 3, Abnormal = Unable to perform the test perfectly and score as 2, 1, or 0

Percentage of frequency was calculated by dividing the amount of participant in each score by the total participants of each group, and then multiplying the result by 100.

*$p < 0.05$ comparison of OLD and CNP

Findings from the ROC analysis on the summative scores from Sections I, III and IV are shown in Table 10. The AUC was 0.79, indicating good diagnostic accuracy for classifying older adults with mild disability from neck pain, with a cutoff score of 48.5 out of 51. The sensitivity and specificity were high (72% and 69%, respectively), with acceptable LRs and good posttest accuracy (71.25%).

Table 10: Cutoff Points for the Summation Score of Section I, III, and IV from the BESTest with Associated Area Under the Curve of Receiver Operating Characteristic Curve, Sensitivity and Specificity, and Likelihood Ratios in Older Adults with and without Disability

Variables	Total Score of Section I, III, and IV
Area Under the Curve	0.79
Cutoff Score (/51)	48.5
Sensitivity	0.72
Specificity	0.69
Positive Likelihood Ratio	2.32
Negative Likelihood Ratio	0.41
Accuracy (%)	71.25%

Closer examination of each BESTest item difficulty level of older adults with and without CNP is presented in Table 11 and Table 12, respectively. The item order was determined by its difficulty from the easiest to the most difficult. All items of the BESTest were found to be too easy for young adults (item difficulty = -7.54, standard error = 2.04), except one item, the Timed Up and Go with dual task test, which was the most difficult item. Similarly, the Timed Up and Go with dual task item was also found to be the most difficult item for older adults with and without CNP. In contrast, eleven items were found to be the easiest items for both older adults with and without CNP, including base of support, center of mass alignment, sit on floor and standup, sit to stand, alternate stair touching, standing arm raise, sensory integration for balance—eyes open on firm surface, eyes closed on firm surface, eyes open on soft surface, and incline–eyes closed—and walk with pivot turns. Apart from these similarities, hip/trunk lateral strength, stand on nondominant leg, and compensatory stepping correction–forward and backward were found to be harder for the CNP group than for the OLD group.

Table 11: Item Difficulty Measures of the BESTest in Older Adults with Chronic Neck Pain (CNP)

Items	Item Difficulty	Standard Error (SE)	Items	Item Difficulty	Standard Error (SE)
Base of Support	-3.34	1.84	Walk with Head Turns – Horizontal	-0.87	0.63
COM Alignment	-3.34	1.84	In Place Response – Backward	-0.87	0.63
Sit on Floor and Standup	-3.34	1.84	Sitting Lateral Lean to Non-dominant Side	-0.87	0.63
Sit to Stand	-3.34	1.84	Sitting Verticality (Dominant side)	-0.23	0.51
Alternate Stair Touching	-3.34	1.84	Compensatory Stepping Correction - Forward	0.02	0.48
Standing Arm Raise	-3.34	1.84	Stand on Dominant Leg	0.02	0.48
Sensory Integration for Balance - Eyes Open on Firm Surface	-3.34	1.84	Compensatory Stepping Correction - Backward	0.43	0.44
Sensory Integration for Balance - Eyes Closed on Firm Surface	-3.34	1.84	Ankle Strength & Range	0.43	0.44
Sensory Integration for Balance - Eyes Open on Foam Surface	-3.34	1.84	Compensatory Stepping Correction - Lateral (Dominant side)	0.79	0.41
Sensory Integration for Balance - Incline- Eyes Closed	-3.34	1.84	Compensatory Stepping Correction - Lateral (Non-dominant side)	0.96	0.40
Walk with Pivot Turns	-3.34	1.84	Functional Reach Lateral (Dominant side)	0.96	0.40
Step over Obstacles	-2.10	1.03	Functional Reach Forward	0.96	0.40
Change in Gait Speed	-2.10	1.03	Hip/Trunk Lateral Strength	0.96	0.40
In Place Response – Forward	-2.10	1.03	Stand on Non-dominant Leg	1.12	0.39
Sitting Lateral Lean-to Dominant side	-2.10	1.03	Functional Reach Lateral (Non-dominant side)	1.12	0.39
Sensory Integration for Balance - Eyes Closed, Foam Surface	-1.34	0.75	Gait – Level Surface	1.56	0.38
Rise to Toes	-1.34	0.75	Timed “Get Up & Go”	1.84	0.37
Sitting Verticality (Non-dominant Side)	-1.34	0.75	Timed “Get Up & Go” with Dual Task	4.08	0.44

COM = Centre of Mass

Table 12: Item Difficulty Measures of the BESTest in Older Adults without Chronic Neck Pain (OLD)

Items	Item Difficulty	Standard Error (SE)	Items	Item Difficulty	Standard Error (SE)
Base of Support	-4.22	1.84	Sitting Lateral Lean-to Dominant side	-0.95	0.46
COM Alignment	-4.22	1.84	Sitting Verticality (Dominant side)	-0.95	0.46
Sit on Floor and Standup	-4.22	1.84	Compensatory Stepping Correction - Backward	-0.95	0.46
Sit to Stand	-4.22	1.84	Rise to Toes	-0.75	0.43
Alternate Stair Touching	-4.22	1.84	Sitting Lateral Lean to Non-dominant Side	-0.58	0.40
Standing Arm Raise	-4.22	1.84	Hip/Trunk Lateral Strength	-0.42	0.39
Sensory Integration for Balance - Eyes Open on Firm Surface	-4.22	1.84	Sitting Verticality (Non-dominant Side)	-0.28	0.37
Sensory Integration for Balance - Eyes Closed on Firm Surface	-4.22	1.84	Stand on Non-dominant Leg	-0.28	0.37
Sensory Integration for Balance - Eyes Open on Foam Surface	-4.22	1.84	Stand on Dominant Leg	-0.14	0.36
Sensory Integration for Balance - Incline- Eyes Closed	-4.22	1.84	Ankle Strength & Range	0.10	0.34
Walk with Pivot Turns	-4.22	1.84	Compensatory Stepping Correction - Lateral (Non-dominant side)	0.50	0.31
In Place Response – Forward	-4.22	1.84	Compensatory Stepping Correction - Lateral (Dominant side)	0.68	0.29
Compensatory Stepping Correction - Forward	-2.23	0.74	Functional Reach Forward	1.38	0.36
Change in Gait Speed	-2.23	0.74	Gait – Level Surface	1.58	0.26
Step over Obstacles	-1.77	0.62	Functional Reach Lateral (Dominant side)	1.97	0.25
In Place Response – Backward	-1.44	0.54	Timed “Get Up & Go”	2.22	0.25
Sensory Integration for Balance - Eyes Closed, Foam Surface	-1.44	0.54	Functional Reach Lateral (Non-dominant side)	2.40	0.25
Walk with Head Turns – Horizontal	-1.44	0.54	Timed “Get Up & Go” with Dual Task	4.08	0.44

COM = Centre of Mass

CHAPTER 5
DISCUSSION AND CONCLUSION

1. Discussion

1.1. Objective I

In addition to decreased mobility of cervical joint and muscle strength, older adults with chronic neck pain (CNP) also demonstrated impaired postural control more than healthy older adults. Due to sensory integration disturbances, older adults with CNP showed poor static and dynamic balance, leading to altered gait and functional impairments in older adults. Gait speed and gait asymmetry are often used to indicate dynamic balance problems in older adults. The first purpose of this study was to identify which gait variables were more sensitive to dynamic balance impairment in older adults who suffered from chronic neck pain (the CNP group). In comparison to older adults who did not suffer from chronic neck pain (the OLD group), those with CNP had slower gait speed, shorter stride length, and a lower cadence while walking with horizontal head movement (HM) and vertical head movement (VM). However, the asymmetrical gait index significantly differed between groups only when walking with VM. Therefore, gait speed while walking with the head movement seemed more sensitive to dynamic balance problems in older adults with CNP than gait asymmetry.

The findings of slower gait speed and other altered gait parameters in older adults with CNP during walking with head movement were consistent with the findings of previous study[215]. Self-selected or preferred gait speed is a predictor of self-perceived function[186]. Stride length and gait speed were found to be significantly lower in older adults with a history of falls compared to controls[216, 217, 218]. Alterations in gait performance seen in current study could indicate a higher risk of falls in those with CNP compared to the OLDs. Multiple gait parameters are correlated with the strength of multiple lower extremity muscles in older adults, particularly women[219]. Decreased lower extremity muscle strength may explain the altered gait parameters in older adults with CNP. Additionally, older adults with CNP demonstrated significantly reduced hip and trunk lateral strength in the comprehensive balance test (Balance Evaluation Systems Test; BESTest)[220].

Significant alterations in gait speed were seen in the CNP group when walking with HM and VM in the current study. Sustained abnormal afferent input could disturb sensory system integration and lead to subsequent impairment of the vestibular system. Furthermore, abnormalities in the cervical spine, either ischemia of the vertebral arteries or a malfunction in the neck's proprioceptive system, could affect vestibular nuclei[221]. Abnormal afferent inputs from the somatosensory and/or vestibular systems at the neck level might lead to greater gait disturbances while walking with head movement[25]. Stabilizing the trunk in space and facilitating intersegmental movements is the primary function of vestibulospinal control. Changes in vestibular signals could lead to higher trunk variability and disrupt the trunk-leg phase[222]. In addition, visual, vestibular, proprioceptive, and somatosensory input all play a key role in walking ability[48]. Abnormal afferent inputs from the cervical spine have been proposed to affect the signal integration of the sensorimotor control system[25, 110]. According to numerous studies, neck pain can affect proprioceptive function, posture, oculomotor control, and hand-eye coordination[25, 223, 224]. Cervical spine functional and structural abnormalities may change proprioceptive functions, joint mechanics, and muscle spindle sensitivity, resulting in postural instability and reduced gait speed[25, 110]. Thus, the abnormal gait performance in older adults with CNP may be caused by sudden or distinct changes in cervical/vestibular inputs from head movements combined with the malfunction of one or more sensorimotor control system components, as partly observed in the lower total scores on the mCTSIB-aBoS.

The CNP group exhibited gait asymmetry when walking with vertical head movement compared to walking with no head movement (NM) and compared to the OLD group. The asymmetrical gait pattern may be a compensatory strategy for the instability assumed by those with CNP when stability is challenged. It has been hypothesized that abnormal cervical afferent inputs could lead to the asymmetric gait seen in older adults with CNP. Neck pain is usually unilateral or worse on one side[225], which may lead to asymmetrical afferent inputs from receptors and have a substantial effect on postural control, orientation, and body schema perception[226, 227, 228]. In a recent study[229], the CNP group showed a distorted body schema. During walking, neural circuits in the spinal cord receive input from the lower extremities[41]. Modulation of sensory feedback as a result of distorted body schema caused by CNP may result in an asymmetrical gait pattern by altering motor responses in lower extremities. In contrast, no asymmetrical gait pattern was observed in the CNP group during walking with HM. A possible explanation could be that bilateral gait compensation occurred due to turning the head right and left; thus, an asymmetrical pattern was not observed. The majority of the head movements related to maintaining balance during normal daily activities occur when the head is moved horizontally, rather than vertically, since this kind of movement is more relevant to typical daily tasks[230]. Moreover, normal field of the vision is typically 180º horizontally (160º for monocular vision) and 135º vertically [231]; thus, a person may better compensate for horizontal head movement than vertical head movements.

Walking with head movement can be classified as performing a dual motor task. The findings may also imply that it is difficult for older adults with CNP to perform two tasks simultaneously. Lots of evidence has shown that gait disturbances during a complex gait task have been associated with CNP. [16, 38, 46, 224, 232]. Dual task performance evaluation might be utilized to differentiate fallers from non-fallers. There were no variations in gait parameters during a single-task condition between fallers and non-fallers; however, there were significant differences while performing an additional task while walking[233]. These findings are in agreement with our findings that a challenging condition, such as head movement while walking, was required to observe the gait disturbances caused by the alteration of afferent inputs from the cervical region in older adults with CNP. It is possible that individuals with CNP who have gait disturbances also have a fear of movement since we found moderate correlations of balance confidence with both gait speed and the gait asymmetry index. Additionally, pain or fear of pain[234] caused by turning the neck might alter the cervical somatosensory input that affects the postural control system, which could worsen the balance and gait

According to the findings of this study, gait speed is a more sensitive and practical measure to evaluate dynamic balance problems in individuals with CNP in a clinical setting than the gait asymmetry index, as evidenced by slower gait speed during both horizontal and vertical head movement. In older adults with CNP, gait speed (i.e., walking at a preferred speed) was slower while walking with head movement compared to walking without head movement. This implies that older adults with CNP are at a higher risk of falling. Nevertheless, the current study was unable to clarify whether gait disturbances are caused by sustained abnormal afferent inputs from cervical or an additional vestibular disturbance. Therefore, additional research is required in order to better understand the mechanisms that contribute to gait disturbances during walking with head movement in individuals with CNP.

The limitations of the study should be taken into account while interpreting its findings. Most participants in the CNP group experienced moderate pain with no or mild disability during normal daily activities. The severity of the condition may differ across patients with varying degrees of pain and disability. To account for the effects of age-related decline, older adults with CNP who had other health problems associated with postural control were considered ineligible. It is widely known that older adults have several comorbidities in general. Therefore, dynamic balance impairments are expected to be worse in a broader sample of older adults with CNP. Nonetheless, future research should include older adults with CNP and other comorbidities in order to endorse this hypothesis.

1.2. Objective II

Impaired sensory integration and loss of stability in gait are evident in older adults with CNP, other systems for postural control have not been thoroughly investigated. The BESTest is a comprehensive clinical tool for balance measurement in which 6 different systems contribute to the control of balance and posture, but its use in CNP has not been reported. This study is the first to investigate the use of the BESTest in older adults with CNP to identify which system of balance control would be impaired as a result of CNP. The OLD and YOUNG groups were also investigated in this study to control the effect of confounding age factors. Corresponding to the study's hypothesis, our results demonstrated that the BESTest can be used to identify system-specific postural control impairments in CNP. The BESTest scores showed that balance control was deteriorated from the normal aging process and further declined in the CNP group, such that CNP affected three balance control systems, biomechanical constraints, transitions–anticipatory postural adjustment, and reactive postural response, when compared with the OLD group.

Biomechanical constraints correspond to the musculoskeletal system, including muscle strength, range of motion and body alignment. In contrast to a previous study[235], this study demonstrated no significant differences between the OLD and YOUNG groups. This disagreement could be due to different participant characteristics; those in our OLD group were younger and a high level of physical functioning, as indicated by an ABC score of more than 80[146]. However, the problem with biomechanical constraints was found to be declining in the CNP group. Closer examination (Table 11) showed that decreased hip/trunk lateral strength in the CNP group is a major problem. According to previous studies, CNP was found to increase concerns about falling and decrease physical performance[15], whereas hip muscle strength was reported to be an important indicator of physical performance, especially in elderly women[236]. This finding was associated with the results of transitions–anticipatory postural adjustment (Section III), which was found to decline from the aging process and further declined when an individual experienced CNP.

Standing on the nondominant leg was the item from Section III that showed a significant difference between the OLD and CNP groups. A previous study[237] showed that vibratory stimulation directed to the dorsal neck muscles in human perturbed proprioceptive information and led to postural control instability during standing, suggesting that cervical afferent inputs play a dominant role in postural control in an upright stance. Altered cervical afferent inputs can be caused by CNP from a pain-induced change in nociceptor and mechanoreceptor activity at the spinal cord and within the central nervous system (CNS)[21] or from chemical changes caused by inflammatory events that affect the sensitivity of the receptors[22]. Other factors involve awkward postures, static and repetitive work, or trauma that disturbs the sensitivity of the cervical joint and muscle receptors[24]. Thus, disturbed lower extremity muscle activity by altered cervical afferent inputs combined with decreased hip/trunk lateral strength from declining physical performance in individuals with CNP can affect their balance control.

There was a greater deficit in the reactive postural response in older adults with CNP than in those with normal aging, suggesting that most of them had failed to preserve postural stability by activating the stepping strategy. Compared to the OLD group, a higher number of older adults with CNP had significant problems with compensatory stepping correction in both forward (25%) and backward directions (40%), where participants were asked to stand with feet shoulder width apart, arms at their sides and lean forward/backward against the researcher’s hands until their shoulders and hips were out of line with their toes and the researcher suddenly released the support to elicit the step. The CNS is responsible for integrating afferent inputs and sending postural adjustments to maintain the center of gravity over the base of support.

If somatosensory inputs are impaired, the CNS will be unable to select the correct strategies in time[238]. The cervical spine has an important role in providing afferent inputs for the internal reference frame to maintain postural stability, since the main input comes from at least three sources, including somatosensory (local and distal), visual, and vestibular systems[28]. Furthermore, cervical proprioceptors provide the CNS with information about the movement and location of the head in relation to the trunk. The cervical muscles, which have a high concentration of muscle spindles, relay information to and receive information from the CNS, and there are specific connections between the cervical receptors, the visual and vestibular apparatus and the autonomic nervous system[120]. Cervical proprioceptors are involved in the cervico-collic reflex, the cervico-occular reflex and the tonic neck reflex, which provide information about the movement and position of the head in space[25]. Older adults with CNP demonstrated sensorimotor disturbances caused by altered cervical afferent inputs in terms of greater deficits in eye movement control, vertical perception and postural control[16, 17, 18, 19]. Therefore, impairments in sensorimotor integration caused by CNP may lead to impaired reactive postural responses. In addition, our study demonstrated a trend for those with CNP to have problems with the compensatory stepping correction in backward directions more than forward directions when compared to the OLD group. Backward stepping requires more effort than forward stepping since the margin of stability is smaller and there is greater instability in the backward direction[239]. Furthermore, aging was found to affect the recruitment of proper muscle synergies during reactive backward stepping. Changes in the contribution of tibialis anterior, biceps femoris (long head) and gastrocnemius muscles in the stance limb of older adults may contribute to decrease in step length during reactive backward stepping when compared to young adults[240]. Although no differences between the OLD and CNP groups were found during the compensatory stepping correction on either lateral side, both groups demonstrated lower scores than the YOUNG group. Thus, compensatory stepping correction in all directions needs to be considered in CNP.

This study demonstrates that aging has a deteriorating effect on multiple aspects of postural control, except sensory orientation. Our result was not in accordance with the result of mCTSIB-aBoS from the objective I and previous studies that reported a significant difference in the sensory integration declined by both aging and CNP[16, 17, 18, 19, 241]. The discrepancy of findings may be because the tasks and measurement tools are not entirely comparable. In this study, the participants were examined by a clinical tool (BESTest) that included the mCTSIB without altered base of support and standing balance test with eyes closed on an inclined surface to determine sensory integration without using laboratory tools, whereas in previous studies[16, 17, 18, 19, 241], the participants were examined by various tests using laboratory tools. Furthermore, Rasch analysis showed that all items in Section V (Sensory Orientation) of the BESTest were the easiest items. Thus, altering the base of support might be required for clinically assessing sensory integration in older adults with and without CNP who have a high level of physical functioning.

In this study, stability in gait scores (Section VI) in both older adult groups were significantly lower than those in the YOUNG group, but we did not find a section score difference between the OLD and CNP groups, which contradicted the results from objective I. This could be due to types of measurement scale used in each objective which were different. Our findings from the objective II also did not agree with those of previous studies[16, 17, 19], which found slower walking speed during the Timed Up and Go (TUG) test, poorer scores on the Dynamic Gait Index (DGI), and gait parameter disturbance during the Timed 10-Meter Walk test with and without head movement in CNP. This may be caused by the differences in age and disability level caused by neck problems, where participants in the previous study were older and had moderate disability. However, according to the results of the Rasch analysis of the BESTest, gait assessment was more challenging for the CNP group than for the OLD group. The Timed Up and Go with dual task test was found to be the most difficult item for the CNP group, followed by the TUG and gait–level surface tests, which may be attributed to both cognitive decline of normal aging and impaired balance control from CNP. Most participants in the OLD and CNP groups were unable to walk 20 feet on an even surface within 5.5 sec (OLD = 66.7%, CNP = 85%) and unable to complete TUG with Dual Tasks without changing in gait speed (OLD = 85%, CNP = 90%). Gait speed is an essential component for identifying a history of falls[242], and the TUG test alone is a sensitive and specific test for identifying risk factors for falls in older adults[243]. The dual task used in the BESTest is a cognitive task (counting backward by threes from 100); when combined with the TUG test, it can be used to detect the risk of falls and mild cognitive impairment-related changes in older adults[244]. Impairments in stability in gait combined with lower extremity muscle weakness and impaired balance should be a concern, since all are considered risk factors for falls[245].

Additionally, the results demonstrated that the BESTest was an accurate tool for differentiating older adults whose daily life had been affected by neck problems with a high AUC (0.79), sensitivity (72%), and specificity (69%). The BESTest also has a good posttest accuracy (71.25%) using the suggested cutoff score of 48.5 out of 51. The participants in the CNP group were presented with relatively moderate levels of neck pain intensity (average pain intensity = 4.50/10) and mild neck disability (average NDI score = 13.63/100). Although the average ABC scale, which represented the fear of falling, was significantly lower in the CNP group than in the OLD group, the scores of the CNP group were relatively good and they were considered to have a high level of physical functioning[146] (average ABC scale = 88.78/100). This is relevant, as it highlights that decreased postural control as measured by the BESTest can be found in the CNP, even with relatively moderate pain, mild disability and a high level of physical functioning.

Our study has several implications. First, the results revealed that the BESTest can be used in the detection of system-specific postural control impairments in older adults with CNP by using the total score of Sections I, III, and IV as a screening tool. Second, the results suggested that older adults with CNP who have moderate pain and mild disability may have lower extremity muscle imbalance and a reduced ability to compensate for stepping correction, especially in the forward and backward directions. However, other balance problems can also be found, since significant differences were reported in almost all subsystems except sensory integration when compared to young adults. Impairments in stability in gait combined with lower extremity muscle weakness and impaired balance are considered risk factors for falls[(245)]. Therapists need to be mindful of the balance problem caused by normal aging and CNP. When assessing the patient with CNP and obtain the Neck Disability Index (NDI) scores of more than 10%, therapists should administer Sections I, III, and IV of the BESTest. If the total score of three sections is greater than 48.5/51, the rest of the BESTest sections should be utilized to identify postural control impairments in other systems. Third, the hierarchical order of the item difficulty suggested that 11 out of 36 items of the BESTest do not challenge older adults with CNP who have moderate pain and mild disability. However, the remaining items can provide valuable information for therapists to implement specific training and determine the progression of balance training from easy to more difficult stages. For example, if a patient is unable to complete hip/trunk lateral strength and stand on one leg, it is recommended to start with hip/trunk muscle strengthening before progressing to standing on one leg.

The results of this study should be interpreted in light of its limitations. First, to control the effects of the aging process in the CNP group, older adults with any kind of pathology related to balance control were excluded from this study, resulting in the small sample size of individual with CNP. It is well known that older adults with CNP in general have multiple health problems and complications; thus, a higher severity of balance problems could be expected. Nevertheless, individuals with CNP with other comorbidities typically found in older adults should be recruited in future studies to confirm this speculation. Second, most participants in the CNP group had moderate pain and mild disability. It is necessary to be concerned that the severity of the problem may vary with patients who have different levels of pain and disability. Third, the muscle strength and endurance of the lower extremities, which may have contributed to their ability to maintain equilibrium, were not measured. Future studies are warranted to determine this limitation.

2. Conclusion

Recording the gait speed during 10-Meter Walk Test with head movement is more suitable and practical to identify stability in gait in clinical setting, while gait speed itself was more sensitive to dynamic postural problem than the gait asymmetrical index in older adult with chronic neck pain (CNP) who has mild disability and high physical functioning.

The BESTest can be used to identify system-specific postural control impairments in older adults with CNP, since the scores showed that balance control deteriorated from the normal aging process and further declined in CNP. Three sections of the BESTest, biomechanical constraints, transitions–anticipatory postural adjustment, and reactive postural response, are suggested for the detection of system-specific postural control impairments in older adults whose daily life was affected by neck problems at least 10% of the Neck Disability Index scores. The other sections of the BESTest should be utilized to identify the impairment of other postural control systems, if the total score of the three suggested sections is more than 48.5/51. Altering the base of support during the sensory integration test (Section V of the BESTest) and recording the gait speed during the 10MWT with head movements are recommended for patients with mild disability caused by neck problem. The Rasch analysis revealed 14 items of the BESTest that could be further used for balance rehabilitation and fall prevention for older adults.

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APPENDIX

APPENDIX I

ดัชนีวัดความบกพร่องความสามารถของคอ

(Neck Disability Index)

แบบสอบถามนี้ใช้ในการประเมินผลกระทบของอาการปวดคอที่มีต่อความสามารถในการจัดการชีวิตประจำวันของท่าน โปรดเลือกข้อที่ตรงกับอาการและความสามารถของท่านมากที่สุดเพียงข้อเดียว และกรุณาให้ข้อมูลในทุกข้อ

ข้อที่ 1 ความรุนแรงของอาการปวด

- ☐ ในขณะนี้ไม่มีอาการปวด
- ☐ ในขณะนี้มีอาการปวดเพียงเล็กน้อย
- ☐ ในขณะนี้มีอาการปวดปานกลาง
- ☐ ในขณะนี้มีอาการปวดค่อนข้างมาก
- ☐ ในขณะนี้มีอาการปวดมาก
- ☐ ในขณะนี้มีอาการปวดมากที่สุดเท่าที่จะจินตนาการได้

ข้อที่ 2 การดูแลตนเอง (เช่น อาบน้ำ/ชำระล้างร่างกาย แต่งตัว เป็นต้น)

- ☐ สามารถทำเองได้ตามปกติ โดยไม่ทำให้อาการปวดเพิ่มขึ้น
- ☐ สามารถทำเองได้ตามปกติ แต่มีอาการปวดเพิ่มขึ้น
- ☐ การทำเองทำให้มีอาการปวด จึงทำให้ต้องทำอย่างช้า ๆ และระมัดระวัง
- ☐ ทำเองได้เป็นส่วนใหญ่ แต่จะต้องการความช่วยเหลืออยู่บ้าง
- ☐ ต้องการการช่วยเหลือในการดูแลตนเองเกือบทั้งหมด ทุกวัน
- ☐ ไม่สามารถแต่งตัวได้เอง อาบน้ำ/ชำระล้างร่างกายเองได้ด้วยความยากลำบาก และต้องอยู่บนเตียง

ข้อที่ 3 การยกของ

- ☐ สามารถยกของหนักได้ โดยไม่มีอาการปวดเพิ่มขึ้น
- ☐ สามารถยกของหนักได้ แต่มีอาการปวดเพิ่มขึ้น
- ☐ อาการปวดทำให้ไม่สามารถยกของหนักขึ้นจากพื้นได้ แต่สามารถยกได้หากของนั้นอยู่ในที่ที่เหมาะสม เช่น บนโต๊ะ
- ☐ อาการปวดทำให้ไม่สามารถยกของหนักขึ้นจากพื้นได้ แต่สามารถยกได้หากของนั้นมีน้ำหนักเบาถึงปานกลาง และจัดวางอยู่ในที่ที่เหมาะสม
- ☐ สามารถยกของที่มีน้ำหนักเบามาก ๆ ได้
- ☐ ไม่สามารถยก/ถือ/หิ้ว/แบก/อุ้ม หรือสะพายสิ่งของใด ๆ ได้เลย

ข้อที่ 4 การอ่าน

- ☐ สามารถอ่านได้มากตามที่ต้องการ โดยไม่มีอาการปวดคอ
- ☐ สามารถอ่านได้มากตามที่ต้องการ โดยมีอาการปวดคอเพียงเล็กน้อย
- ☐ สามารถอ่านได้มากตามที่ต้องการ โดยมีอาการปวดคอปานกลาง
- ☐ ไม่สามารถอ่านได้มากตามที่ต้องการ เพราะมีอาการปวดคอปานกลาง
- ☐ แทบจะไม่สามารถอ่านได้เลยเพราะมีอาการปวดคอมาก
- ☐ ไม่สามารถอ่านได้เลย

ข้อที่ 5 อาการปวดศีรษะ

- ☐ ไม่มีอาการปวดศีรษะเลย
- ☐ มีอาการปวดศีรษะเพียงเล็กน้อย และนาน ๆ ครั้ง
- ☐ มีอาการปวดศีรษะปานกลาง และนาน ๆ ครั้ง
- ☐ มีอาการปวดศีรษะปานกลาง และบ่อยครั้ง
- ☐ มีอาการปวดศีรษะมาก และบ่อยครั้ง
- ☐ มีอาการปวดศีรษะเกือบตลอดเวลา

ข้อที่ 6 การตั้งสมาธิ

- ☐ สามารถตั้งสมาธิได้อย่างที่ต้องการ โดยไม่มีความยากลำบาก
- ☐ สามารถตั้งสมาธิได้อย่างที่ต้องการ โดยมีความยากลำบากเพียงเล็กน้อย
- ☐ มีความยากลำบากปานกลางในการตั้งสมาธิเมื่อต้องการ
- ☐ มีความยากลำบากอย่างมากในการตั้งสมาธิเมื่อต้องการ
- ☐ มีความยากลำบากมากที่สุดในการตั้งสมาธิเมื่อต้องการ
- ☐ ไม่สามารถตั้งสมาธิได้เลย

ข้อที่ 7 การทำงาน

- ☐ สามารถทำงานได้มากตามที่ต้องการ
- ☐ สามารถทำงานประจำได้เท่านั้น ไม่มากไปกว่านั้น
- ☐ สามารถทำงานประจำได้เกือบทั้งหมด แต่ไม่มากไปกว่านั้น
- ☐ ไม่สามารถทำงานประจำได้เลย
- ☐ แทบจะทำงานอะไรไม่ได้เลย
- ☐ ไม่สามารถทำงานอะไรได้เลย

ข้อที่ 8 การขับขี่รถ

☐ สามารถทำได้โดยไม่มีอาการปวดคอ

☐ สามารถทำได้นานตามที่ต้องการ โดยมีอาการปวดคอเพียงเล็กน้อย

☐ สามารถทำได้นานตามที่ต้องการ โดยมีอาการปวดคอปานกลาง

☐ ไม่สามารถทำได้นานตามที่ต้องการ เพราะมีอาการปวดคอปานกลาง

☐ แทบจะทำไม่ได้เลย เพราะมีอาการปวดคอมาก

☐ ไม่สามารถทำได้เลย

ข้อที่ 9 การนอนหลับ

☐ ไม่มีความยากลำบากในการนอนหลับ

☐ การนอนหลับถูกรบกวนเพียงเล็กน้อย (นอนไม่หลับน้อยกว่า 1 ชั่วโมง)

☐ การนอนหลับถูกรบกวนเล็กน้อย (นอนไม่หลับ 1-2 ชั่วโมง)

☐ การนอนหลับถูกรบกวนปานกลาง (นอนไม่หลับ 2-3 ชั่วโมง)

☐ การนอนหลับถูกรบกวนเป็นอย่างมาก (นอนไม่หลับ 3-5 ชั่วโมง)

☐ การนอนหลับถูกรบกวนอย่างสิ้นเชิง (นอนไม่หลับ 5-7 ชั่วโมง)

ข้อที่ 10 กิจกรรมนันทนาการ/การพักผ่อนหย่อนใจ

☐ สามารถทำกิจกรรมทุกอย่างได้ โดยไม่มีอาการปวดคอเลย

☐ สามารถทำกิจกรรมทุกอย่างได้ แต่มีอาการปวดคออยู่บ้าง

☐ สามารถทำกิจกรรมได้เป็นส่วนใหญ่ แต่ไม่ทั้งหมด เพราะมีอาการปวดคอ

☐ สามารถทำกิจกรรมได้เพียงบางอย่าง เพราะมีอาการปวดคอ

☐ แทบจะทำกิจกรรมต่าง ๆ ไม่ได้เลย เพราะมีอาการปวดคอ

☐ ไม่สามารถทำกิจกรรมใด ๆ ได้เลย

<u>หมายเหตุ</u>

- คะแนนเต็มทั้งหมดเท่ากับ 50 คะแนน แต่ละข้อมีช่วงคะแนน 0-5
- คะแนนรวม 0-4 หมายถึง ไม่มีการรบกวนต่อความสามารถในการจัดการชีวิตประจำวัน, 5-14 หมายถึง รบกวนน้อย
- 15-24 หมายถึง รบกวนปานกลาง 25-34 หมายถึง รบกวนมาก >35 หมายถึง รบกวนอย่างสมบูรณ์

(Vernon and Mior, 1991)

Translated and validated by Uthaikhup et al, 2010

Funded by Faculty of Associated Medical Sciences, Chiang Mai University

APPENDIX II

แบบประเมินความมั่นใจในการทรงตัวขณะปฏิบัติกิจกรรม

แบบประเมิน Activities- specific Balance Confidence (ABC) Scale

ฉบับภาษาไทย

กรุณาให้คะแนนความมั่นใจของท่านในการปฏิบัติกิจกรรมแต่ละกิจกรรม โดยให้คะแนนความมั่นใจตามระดับดังต่อไปนี้

0% 10 20 30 40 50 60 70 80 90 100%

ไม่มั่นใจ **มั่นใจมาก**

"ท่านมีความมั่นใจมากแค่ไหนว่าท่านจะไม่สูญเสียการทรงตัว หรือ รู้สึกไม่มั่นคงเมื่อท่าน..."

1. ...เดินรอบบ้าน? _________%
2. ...เดินขึ้น หรือลงบันได? _________%
3. ...โน้มตัวลงหยิบรองเท้าแตะที่พื้นทางด้านหน้า? _________%
4. ...เอื้อมมือขึ้นไปหยิบกระป๋องขนาดเล็กบนชั้นในระดับสายตา? _________%
5. ...เขย่งปลายเท้าเพื่อหยิบของเหนือศีรษะ? _________%
6. ...ยืนบนเก้าอี้และเอื้อมหยิบสิ่งของ? _________%
7. ...กวาดพื้น? _________%
8. ...เดินออกนอกบ้านไปที่รถที่จอดอยู่ทางเข้าบ้าน? _________%
9. ...ก้าวขึ้น หรือลงจากรถ? _________%
10. ...เดินผ่านที่จอดรถเข้าไปในห้าง/ตลาด? _________%
11. ...เดินขึ้นหรือลงทางลาด? _________%
12. ...เดินในห้าง/ตลาดที่แออัด และมีคนเดินผ่านท่านอย่างรวดเร็ว? _________%
13. ...ถูกชนจากผู้อื่น ขณะที่ท่านเดินในห้าง/ตลาด? _________%
14. ...ก้าวขึ้น หรือลงบันไดเลื่อนขณะจับราวบันได? _________%
15. ...ก้าวขึ้น หรือลงบันไดเลื่อนในขณะที่ถือของมากมายจนไม่สามารถจับราวบันไดได้? _________%
16. ...เดินนอกบ้านบนทางเดินที่ลื่น? _________%

*Powell, LE & Myers AM. The Activities-specific Balance Confidence (ABC) Scale. J Gerontol Med Sci 1995; 50(1): M28-34

APPENDIX III

Instructions: The purpose of this scale is to identify difficulties that you may be experiencing because of your dizziness or unsteadiness.

Please check "*Yes*", "*Sometimes*", or "*No*" to answer each question.

*****Answer each question as it pertains to your dizziness or unsteadiness problem only*****

Item	Yes (4)	Sometimes (2)	No (0)
1. Does looking up increase your problem?			
2. Because of your problem, do you feel frustrated?			
3. Because of your problem, do you restrict your travel for business or recreation?			
4. Does walking down the aisle of a supermarket increase your problem?			
5. Because of your problem, do you have difficulty getting into or out of bed?			
6. Does your problem significantly restrict your participation in social activities such as going out to dinner, going to the movies, dancing, or to parties?			
7. Because of your problem, do you have difficulty reading?			
8. Does performing more ambitious activities like sports, dancing, household chores such as sweeping or putting dishes away, increase your problem?			
9. Because of your problem, are you afraid to leave your home without having someone accompany you?			
10. Because of your problem, have you been embarrassed in front of others?			
11. Do quick movements of your head increase your problem?			
12. Because of your problem, do you avoid heights?			
13. Does turning over in bed increase your problem?			
14. Because of your problem, is it difficult for you to do strenuous housework or yardwork?			
15. Because of your problem, are you afraid people may think you are intoxicated?			
16. Because of your problem, is it difficult for you to go for a walk by yourself?			
17. Does walking down a sidewalk increase your problem?			
18. Because of your problem, is it difficult for you to concentrate?			
19. Because of your problem, is it difficult for you to walk around your house in the dark?			

Item	Yes (4)	Sometimes (2)	No (0)
20. Because of your problem, are you afraid to stay home alone?			
21. Because of your problem, do you feel handicapped?			
22. Has your problem placed stress on your relationship with members of your family or friends?			
23. Because of your problem, are you depressed?			
24. Does your problem interfere with your job or household responsibilities?			
25. Does bending over increase your problem?			

Total Functional	Total Emotional	Total Physical	Total score

Scores: Scores greater than 10 points should be referred to balance specialists for further evaluation.

16-34 Points (mild handicap)

36-52 Points (moderate handicap)

54+ Points (severe handicap)

APPENDIX IV

Dynamic Gait Index (original 8-item test)

1. Gait level surface _____

Instructions: Walk at your normal speed from here to the next mark (20')

Grading: Mark the lowest category that applies.

(3) Normal: Walks 20', no assistive devices, good sped, no evidence for imbalance, normal gait pattern

(2) Mild Impairment: Walks 20', uses assistive devices, slower speed, mild gait deviations.

(1) Moderate Impairment: Walks 20', slow speed, abnormal gait pattern, evidence for imbalance.

(0) Severe Impairment: Cannot walk 20' without assistance, severe gait deviations or imbalance.

2. Change in gait speed _____

Instructions: Begin walking at your normal pace (for 5'), when I tell you "go," walk as fast as you can (for 5'). When I tell you "slow," walk as slowly as you can (for 5').

Grading: Mark the lowest category that applies.

(3) Normal: Able to smoothly change walking speed without loss of balance or gait deviation. Shows a significant difference in walking speeds between normal, fast and slow speeds.

(2) Mild Impairment: Is able to change speed but demonstrates mild gait deviations, or not gait deviations but unable to achieve a significant change in velocity, or uses an assistive device.

(1) Moderate Impairment: Makes only minor adjustments to walking speed, or accomplishes a change in speed with significant gait deviations, or changes speed but has significant gait deviations, or changes speed but loses balance but is able to recover and continue walking.

(0) Severe Impairment: Cannot change speeds, or loses balance and has to reach for wall or be caught.

3. Gait with horizontal head turns _____

Instructions: Begin walking at your normal pace. When I tell you to "look right," keep walking straight, but turn your head to the right. Keep looking to the right until I tell you, "look left," then keep walking straight and turn your head to the left. Keep your head to the left until I tell you "look straight, " then keep walking straight, but return your head to the center.

Grading: Mark the lowest category that applies.

(3) Normal: Performs head turns smoothly with no change in gait.

(2) Mild Impairment: Performs head turns smoothly with slight change in gait velocity, i.e., minor disruption to smooth gait path or uses walking aid.

(1) Moderate Impairment: Performs head turns with moderate change in gait velocity, slows down, staggers but recovers, can continue to walk.

(0) Severe Impairment: Performs task with severe disruption of gait, i.e., staggers outside 15" path, loses balance, stops, reaches for wall.

4. Gait with vertical head turns _____

Instructions: Begin walking at your normal pace. When I tell you to "look up," keep walking straight, but tip your head up. Keep looking up until I tell you, "look down," then keep walking straight and tip your head down. Keep your head down until I tell you "look straight, " then keep walking straight, but return your head to the center.

Grading: Mark the lowest category that applies.

(3) Normal: Performs head turns smoothly with no change in gait.

(2) Mild Impairment: Performs head turns smoothly with slight change in gait velocity, i.e., minor disruption to smooth gait path or uses walking aid.

(1) Moderate Impairment: Performs head turns with moderate change in gait velocity, slows down, staggers but recovers, can continue to walk.

(0) Severe Impairment: Performs task with severe disruption of gait, i.e., staggers outside 15" path, loses balance, stops, reaches for wall.

5. **Gait and pivot turn _____**

Instructions: Begin walking at your normal pace. When I tell you, "turn and stop," turn as quickly as you can to face the opposite direction and stop.

Grading: Mark the lowest category that applies.

(3) Normal: Pivot turns safely within 3 seconds and stops quickly with no loss of balance.

(2) Mild Impairment: Pivot turns safely in > 3 seconds and stops with no loss of balance.

(1) Moderate Impairment: Turns slowly, requires verbal cueing, requires several small steps to catch balance following turn and stop.

(0) Severe Impairment: Cannot turn safely, requires assistance to turn and stop.

6. **Step over obstacle ____**

Instructions: Begin walking at your normal speed. When you come to the shoebox, step over it, not around it, and keep walking.

Grading: Mark the lowest category that applies.

(3) Normal: Is able to step over the box without changing gait speed, no evidence of imbalance.

(2) Mild Impairment: Is able to step over box, but must slow down and adjust steps to clear box safely.

(1) Moderate Impairment: Is able to step over box but must stop, then step over. May require verbal cueing.

(0) Severe Impairment: Cannot perform without assistance.

7. **Step around obstacles _____**

Instructions: Begin walking at normal speed. When you come to the first cone (about 6' away), walk around the right side of it. When you come to the second cone (6' past first cone), walk around it to the left.

Grading: Mark the lowest category that applies.

(3) Normal: Is able to walk around cones safely without changing gait speed; no evidence of imbalance.

(2) Mild Impairment: Is able to step around both cones, but must slow down and adjust steps to clear cones.

(1) Moderate Impairment: Is able to clear cones but must significantly slow, speed to accomplish task, or requires verbal cueing.

(0) Severe Impairment: Unable to clear cones, walks into one or both cones, or requires physical assistance.

8. **Steps _____**

Instructions: Walk up these stairs as you would at home, i.e., using the railing if necessary. At the top, turn around and walk down.

Grading: Mark the lowest category that applies.

(3) Normal: Alternating feet, no rail.

(2) Mild Impairment: Alternating feet, must use rail.

(1) Moderate Impairment: Two feet to a stair, must use rail.

(0) Severe Impairment: Cannot do safely.

TOTAL SCORE: ___ / 24

<u>References:</u>

1. Herdman SJ. *Vestibular Rehabilitation*. 2nd ed. Philadelphia, PA: F.A.Davis Co; 2000.
2. Shumway-Cook A, Woollacott M. *Motor Control Theory and Applications*, Williams and Wilkins Baltimore, 1995: 323-324

APPENDIX V

BESTest

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Subjects should be tested with flat heeled shoes or shoes and socks off. If subject must use an assistive device for an item, score that item one category lower. If subject requires physical assistance to perform an item score the lowest category (0) for that item.

SUMMARY OF PERFORMANCE: CALCULATE PERCENT SCORE

Section I:	________/15 x 100	= _______	Biomechanical Constraints
Section II:	________/21 x 100	= _______	Stability Limits/Verticality
Section III:	________/18 x 100	= _______	Transitions/Anticipatory
Section IV	________/18 x 100	= _______	Reactive
Section V:	________/15 x 100	= _______	Sensory Orientation
Section VI:	________/21 x 100	= _______	Stability in Gait

TOTAL: ________/108 points = ________ Percent Total Score

I. BIOMECHANICAL CONSTRAINTS SECTION I (15 POINTS)

1) BASE OF SUPPORT

(3) Normal: Both feet have normal base of support with no deformities or pain

(2) One foot has deformities and/or pain

(1) Both feet have deformities OR pain

(0) Both feet have deformities AND pain

2) COM ALIGNMENT

(3) Normal AP and ML CoM alignment and normal segmental postural alignment

(2) Abnormal AP OR ML CoM alignment OR abnormal segmental postural alignment

(1) Abnormal AP OR ML CoM alignment AND abnormal segmental postural alignment

(0) Abnormal AP AND ML CoM alignment

3) ANKLE STRENGTH & RANGE

(3) Normal: Able to stand on toes with maximal height and to stand on heels with front of feet up

(2) Impairment in either foot of either ankle flexors or extensors (i.e. less than maximum height)

(1) Impairment in two ankle groups (eg; bilateral flexors or both ankle flexors and extensors in 1 foot)

(0) Both flexors and extensors in both left and right ankles impaired (i.e. less than maximum height)

4) HIP/TRUNK LATERAL STRENGTH

(3) Normal: Abducts both hips to lift the foot off the floor for 10 s while keeping trunk vertical

(2) Mild: Abducts both hips to lift the foot off the floor for 10 s but without keeping trunk vertical

(1) Moderate: Abducts only one hip off the floor for 10 s with vertical trunk

(0) Severe: Cannot abduct either hip to lift a foot off the floor for 10 s with trunk vertical or without vertical

5) SIT ON FLOOR AND STANDUP TIME______________ SECS

(3) Normal: Independently sits on the floor and stands up

(2) Mild: Uses a chair to sit on floor OR to stand up

(1) Moderate: Uses a chair to sit on floor AND to stand up

(0) Severe: Cannot sit on floor or stand up, even with a chair, or refuses

II. STABILITY LIMITS SECTION II (21 POINTS)

6) SITTING VERTICALITY AND LATERAL LEAN

Lean			Verticality		
Lt.	Rt.		Lt.	Rt.	
(3)	(3)	Maximum lean, subject moves upper shoulders beyond body midline, very stable	(3)	(3)	Realigns to vertical with very SMALL or no OVERSHOOT
(2)	(2)	Moderate lean, subject's upper shoulder approaches body midline or some instability	(2)	(2)	Significantly Over- or undershoots but eventually realigns to vertical
(1)	(1)	Very little lean, or significant instability	(1)	(1)	Failure to realign to vertical
(0)	(0)	No lean or falls (exceeds limits)	(0)	(0)	Falls with the eyes closed

7) FUNCTIONAL REACH FORWARD DISTANCE REACHED:

(3) Maximum to limits: >32 cm (12.5 in)

(2) Moderate: 16.5 cm - 32 cm (6.5 – 12.5 in)

(1) Poor: < 16.5 cm (6.5 in)

(0) No measurable lean – or must be caught

8) FUNCTIONAL REACH LATERAL DISTANCE REACHED:

Lt.	Rt.	
(3)	(3)	Maximum to limit: > 25.5 cm (10 in)
(2)	(2)	Moderate: 10-25.5 cm (4-10 in)
(1)	(1)	Poor: < 10 cm (4 in)
(0)	(0)	No measurable lean, or must be caught

III. TRANSITIONS-ANTICIPATORY POSTURAL ADJUSTMENT SECTION III (18 POINTS)

9) SIT TO STAND

(3) Normal: Comes to stand without the use of hands and stabilizes independently

(2) Comes to stand on the first attempt with the use of hands

(1) Comes to stand after several attempts or requires minimal assist to stand or stabilize or requires touch of back of leg or chair

(0) Requires moderate or maximal assist to stand

10) RISE TO TOES

(3) Normal: Stable for 3 sec with good height

(2) Heels up, but not full range (smaller than when holding hands so no balance requirement) -OR- slight instability & holds for 3 sec

(1) Holds for less than 3 sec

(0) Unable

11) STAND ON ONE LEG

Time in Seconds = Lt. Trial 1: ____Trial 2: ____ Rt. Trial 1: ____Trial 2: ____

Lt.	Rt.	
(3)	(3)	Normal: Stable for > 20 s
(2)	(2)	Trunk motion, OR 10-20 s
(1)	(1)	Stands 2-10 s
(0)	(0)	Unable

12) ALTERNATE STAIR TOUCHING

(3) Normal: Stands independently and safely and completes 8 steps in < 10 seconds

(2) Completes 8 steps (10-20 seconds) AND/OR show instability such as inconsistent foot placement, excessive trunk motion, hesitation or arhythmical

(1) Completes < 8 steps – without minimal assistance (i.e. assistive device) OR > 20 sec for 8 steps

(0) Completes < 8 steps, even with assistive devise

13) STANDING ARM RAISE

(3) Normal: Remains stable

(2) Visible sway

(1) Steps to regain equilibrium/unable to move quickly w/o losing balance

(0) Unable, or needs assistance for stability

IV. REACTIVE POSTURAL RESPONSE SECTION IV (18 POINTS)

14) IN PLACE RESPONSE- FORWARD

(3) Recovers stability with ankles, no added arms or hips motion

(2) Recovers stability with arm or hip motion

(1) Takes a step to recover stability

(0) Would fall if not caught OR requires assist OR will not attempt

15) IN PLACE RESPONSE- BACKWARD

(3) Recovers stability at ankles, no added arm / hip motion

(2) Recovers stability with some arm or hip motion

(1) Takes a step to recover stability

(0) Would fall if not caught -OR- requires assistance -OR- will not attempt

16) COMPENSATORY STEPPING CORRECTION- FORWARD

(3) Recovers independently a single, large step (second realignment step is allowed)

(2) More than one step used to recover equilibrium, but recovers stability independently OR 1 step with imbalance

(1) Takes multiple steps to recover equilibrium, or needs minimum assistance to prevent a fall

(0) No step, OR would fall if not caught, OR falls spontaneously

17) COMPENSATORY STEPPING CORRECTION- BACKWARD

(3) Recovers independently a single, large step

(2) More than one step used, but stable and recovers independently OR 1 step with imbalance

(1) Takes several steps to recover equilibrium, or needs minimum assistance

(0) No step, OR would fall if not caught, OR falls spontaneously

18) COMPENSATORY STEPPING CORRECTION- LATERAL

Lt.	Rt.	
(3)	(3)	Recovers independently with 1 step of normal length/width (crossover or lateral OK)
(2)	(2)	Several steps used, but recovers independently
(1)	(1)	Steps, but needs to be assisted to prevent a fall
(0)	(0)	Falls, or cannot step

V. SENSORY ORIENTATION SECTION V (15 POINTS)

19) SENSORY INTEGRATION FOR BALANCE (MODIFIED CTSIB)

A - EYES OPEN, FIRM SURFACE

Trial 1 ______sec, Trial 2 ______sec

(3) 30s stable

(2) 30s unstable

(1) < 30s

(0) Unable

B -EYES CLOSED, FIRM SURFACE

Trial 1 ______sec, Trial 2 ______sec

(3) 30s stable

(2) 30s unstable

(1) < 30s

(0) Unable

C -EYES OPEN, FOAM SURFACE

Trial 1 ______sec, Trial 2 ______sec

(3) 30s stable

(2) 30s unstable

(1) < 30s

(0) Unable

D -EYES CLOSED, FOAM SURFACE

Trial 1 ______sec, Trial 2 ______sec

(3) 30s stable

(2) 30s unstable

(1) < 30s

(0) Unable

20) INCLINE- EYES CLOSED

Toes Up

(3) Stands independently, steady without excessive sway, holds 30 sec, and aligns with gravity

(2) Stands independently 30 SEC with greater sway than in item 19B -OR- aligns with surface

(1) Requires touch assist -OR- stands without assist for 10-20 sec

(0) Unable to stand >10 sec -OR- will not attempt independent stance

VI. STABILITY IN GAIT SECTION V (21 POINTS)

21) GAIT – LEVEL SURFACE TIME________SECS.

(3) Normal: walks 20 ft., good speed (≤ 5.5 sec), no evidence of imbalance.

(2) Mild: 20 ft., slower speed (>5.5 sec), no evidence of imbalance.

(1) Moderate: walks 20 ft., evidence of imbalance (wide-base, lateral trunk motion, inconsistent step path) – at any preferred speed.

(0) Severe: cannot walk 20 ft. without assistance, or severe gait deviations OR severe imbalance

22) CHANGE IN GAIT SPEED

(3) Normal: Significantly changes walking speed without imbalance

(2) Mild: Unable to change walking speed without imbalance

(1) Moderate: Changes walking speed but with signs of imbalance

(0) Severe: Unable to achieve significant change in speed AND signs of imbalance

23) WALK WITH HEAD TURNS – HORIZONTAL

(3) Normal: performs head turns with no change in gait speed and good balance

(2) Mild: performs head turns smoothly with reduction in gait speed

(1) Moderate: performs head turns with imbalance

(0) Severe: performs head turns with reduced speed AND imbalance AND/OR will not move head within available range while walking.

24) WALK WITH PIVOT TURNS

(3) Normal: Turns with feet close, FAST (< 3 steps) with good balance.

(2) Mild: Turns with feet close SLOW (>4 steps) with good balance

(1) Moderate: Turns with feet close at any speed with mild signs of imbalance

(0) Severe: Cannot turn with feet close at any speed and significant imbalance.

25) STEP OVER OBSTACLES TIME________SEC

(3) Normal: able to step over 2 stacked shoe boxes without changing speed and with good balance

(2) Mild: steps over 2 stacked shoe boxes but slows down, with good balance

(1) Moderate: steps over shoe boxes with imbalance or touches box.

(0) Severe: cannot step over shoe boxes AND slows down with imbalance or cannot perform with assistance.

26) TIMED “GET UP & GO” GET UP & GO: TIME _____________SEC

(3) Normal: Fast (<11 sec) with good balance

(2) Mild: Slow (>11 sec with good balance)

(1) Moderate: Fast (<11 sec) with imbalance.

(0) Severe: Slow (>11 sec) AND imbalance.

27) TIMED “GET UP & GO” WITH DUAL TASK DUAL TASK: TIME ____SEC

(3) Normal: No noticeable change between sitting and standing in the rate or accuracy of backwards counting and no change in gait speed.

(2) Mild: Noticeable slowing, hesitation or errors in counting backwards OR slow walking (10%) in dual task

(1) Moderate: Affects on BOTH the cognitive task AND slow walking (>10%) in dual task.

(0) Severe: Can’t count backward while walking or stops walking while talking

APPENDIX VI

Ethical Approve

MF-04-version-2.0
วันที่ 18 ต.ค. 61

ใบรับรองจริยธรรมการวิจัยของข้อเสนอการวิจัย
เอกสารข้อมูลคำอธิบายสำหรับผู้เข้าร่วมการวิจัยและใบยินยอม

หมายเลขข้อเสนอการวิจัย SWUEC-039/2562F (ต่อใบรับรองครั้งที่ 2)

ข้อเสนอการวิจัยนี้และเอกสารประกอบของข้อเสนอการวิจัยตามรายการแสดงด้านล่าง ได้รับการพิจารณาจาก คณะกรรมการจริยธรรมสำหรับพิจารณาโครงการวิจัยที่ทำในมนุษย์ มหาวิทยาลัยศรีนครินทรวิโรฒแล้ว คณะกรรมการฯ มีความเห็นว่าข้อเสนอการวิจัยที่จะดำเนินการมีความสอดคล้องกับหลักจริยธรรมสากล ตลอดจนกฎหมาย ข้อบังคับและข้อกำหนดภายในประเทศ จึงเห็นสมควรให้ดำเนินการวิจัยตามข้อเสนอการวิจัยนี้ได้

ชื่อโครงการวิจัยเรื่อง : การระบุความบกพร่องด้านการทรงตัวในผู้สูงอายุที่มีปัญหาปวดคอเรื้อรัง
ชื่อผู้วิจัยหลัก : นางสาวธันยา หมัดสะและ
สังกัด : คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ
เอกสารที่เสนอพิจารณาทบทวน :
แบบรายงานความก้าวหน้าของการวิจัย เพื่อขอต่ออายุการรับรอง ฉบับลงวันที่ 27 กรกฎาคม 2564
วันที่ประชุม : 17 พฤศจิกายน 2564 **การประชุมครั้งที่ :** 11/2564
ผลการพิจารณา : รับรอง
ข้อเสนอแนะ : โปรดปฏิบัติตามแนวปฏิบัติการดำเนินงานโครงการวิจัยในมนุษย์ช่วงที่มีการระบาดของโรคติดเชื้อไวรัสโคโรนาสายพันธุ์ใหม่ 2019 (COVID-19)

(ลงชื่อ)..
(ผู้ช่วยศาสตราจารย์ ดร. ทันตแพทย์หญิงณปภา เอี่ยมจิรกุล)
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(ลงชื่อ)..
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APPENDIX VII

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Can the balance evaluation systems test be used to identify system-specific postural control impairments in older adults with chronic neck pain?

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Background: Older adults with chronic neck pain (CNP) demonstrate impaired postural control. The Balance Evaluation Systems Test (BESTest) is used to assess systems underlying postural control impairments, but its use in CNP has not been reported. This study assessed whether the BESTest can identify postural control impairments in CNP as well as the level of BESTest item difficulty by Rasch analysis.

Materials and methods: This cross-sectional study recruited thirty young adults (YOUNG) aged 20–40 years and eighty older adults aged 60 years or older [without neck pain (OLD) = 60, with chronic neck pain (CNP) = 20]. Questionnaires were administered to collect demographic data, intensity of neck pain (VAS), patient's self-rated neck pain and disability (NDI), and balance confidence in daily activities (ABC). The BESTest was used to assess postural control.

Results: The CNP group showed the lowest ABC scores. Compared to the YOUNG group, the BESTest score was significantly lower in the OLD group, while the CNP group showed the lowest score, suggesting that balance control deteriorated from the normal aging process and further declined in the CNP group, especially in biomechanical constraints, transitions–anticipatory postural adjustment, and reactive postural response ($p < 0.05$). Using scores from these three sections, the BESTest was accurate at the cutoff score of 48.5 out of 51 for differentiating the older adults whose daily life are affected by neck problems (using the NDI as a reference) with a high AUC (0.79), sensitivity (72%), and specificity (69%). The Rasch analysis revealed that the Timed Up and Go with dual task test was the most difficult BESTest item for all groups, whereas 14 items showed more difficulty for the CNP group.

Conclusion: The BESTest can be used to identify postural control impairments in CNP patients, even those with moderate pain and mild disability with a high level of physical functioning. The combined score of biomechanical constraints, transitions–anticipatory postural adjustment, and reactive postural response domains was suggested for the detection of older adults whose daily lives are affected by neck problems. This will also help clinicians consider the management of neck pain to prevent falls in CNP.

KEYWORDS

elderly, geriatrics, fall, clinical scale, assessment

Introduction

Falls are a major public health problem globally. People aged 60 years or older suffer the greatest number of fatal falls leading to unintentional injury or death (1). The incidence of falls in older adults is increased by age-related declines in the systems responsible for controlling balance, also known as the postural control system (2). This includes declines in the musculoskeletal system, internal representations, adaptive mechanisms, anticipatory mechanisms, sensory strategies, individual sensory systems, and neuromuscular synergies (3).

Among chronic musculoskeletal conditions, neck pain is one of the most common complaints in the elderly population and ranks as the fourth leading cause of disability worldwide (4). Much evidence has confirmed that older adults with chronic neck pain (CNP) demonstrate a fear of falling, decreased physical performance and increased risk of falls more than older adults without CNP (5–8). In addition to decreased mobility of the cervical joint (9) and muscle strength (10), older adults with CNP also demonstrate a decrease in sensorimotor integration presented by reduced gait speed, impaired postural control, and cervical position sense (8). Alterations in sensory integration can be caused by pain (11, 12), inflammatory events (13), awkward postures (14), static and repetitive work, or trauma (15) that affect the sensitivity of the cervical joint and muscle receptors in both supraspinal processing and local reflexes. Inputs from the cervical area are involved in the cervico-collic reflex, the cervico-occular reflex and the tonic neck reflex, which provide information about the movement and position of the head in space that are crucial for both neck movement and postural control (16).

The cervical afferent input plays an important role to build up the internal reference frame for the control of posture and locomotion. Significant effects of head in space and head to trunk relation are observed in sensorimotor tasks (17, 18). If the input deteriorates or alters, the central nervous system (CNS) might increase the weighting of input from other locations (19). It is hypothesized that in healthy individuals, the preferred source of sensory inputs is somatosensory input from the feet in contact with the supporting surface (20). In contrast, older adults with CNP rely more on vision and other somatosensory inputs for postural control, and thus deficits will be greatest when these inputs are reduced (6–8). The modified Clinical Test of Sensory Integration on Balance (mCTSIB) is one of the most common clinical tools used in patients with postural control impairment to determine how well a patient uses the input from three sensory balance systems (somatosensory system, visual system, and vestibular system) during different balance activities. These activities include standing with eyes open/firm surface, eyes closed/firm surface, eyes open/soft surface, and eyes closed/soft surface (8, 21). However, mCTSIB with an adjusted base of support (mCTSIB-aBoS), including comfortable and narrow stance, has been used in previous studies to challenge the postural control system in older adults with CNP (21, 22). The tandem stance was excluded due to difficulty even in healthy older adults (23). The results showed that older adults with CNP demonstrated poorer postural control than healthy controls across sensorimotor integration tasks by increasing postural sway in the anteroposterior direction during the comfortable stance with eyes closed on a firm surface and eyes open on a soft surface and increasing postural sway in the mediolateral direction during the narrow stance with eyes open on a firm surface (21). Previous studies in older adults with CNP also reported a slower self-selected gait speed and cadence during the Timed Up and Go (TUG) test and the Ten Meter Walk (TMW) test with head turn condition, in addition to demonstrating a longer gait cycle duration in the TMW test both with and without head turns (6, 21). Furthermore, the studies demonstrated worse scores on the Dynamic Gait Index (DGI) in older adults with CNP than in healthy controls (6, 7). These problems may alter their functional balance, leading to restriction of walking or limited social participation and falls (6–8, 21).

Although impaired sensory integration is evident in older adults with CNP, other systems for postural control, i.e., the musculoskeletal system, internal representations, adaptive mechanisms, anticipatory mechanisms and neuromuscular synergies, have not been thoroughly investigated. Therefore, the extent of postural control impairments in older adults with CNP remains unclear. The Balance Evaluation Systems Test (BESTest) was developed based on the postural control system and was constructed to be a comprehensive balance measure in clinical settings for mixed populations (24). Six

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domains underlying the postural control system, biomechanical constraints, stability limits, transitions–anticipatory postural adjustment, reactive postural response, sensory orientation, and stability in gait, are included in the BESTest (24). The advantage of the BESTest is that it covers almost all systems underlying postural control so that clinicians can determine the types of balance training that are specific to the causes of postural control problems. The BESTest has been shown to be a reliable and valid measure of balance components in individuals with neurological disease (e.g., Parkinson's disease, multiple sclerosis, and stroke). The BESTest can also be used to detect the function of the postural system in healthy individuals, which starts to decline as early as in the middle age group (41–60 years) (25). Furthermore, the BESTest can be used to discriminate between high vs. low risk of falls in adults aged 50 years and older (26). However, evidence of its use in older adults with CNP has not been reported.

Assessment of all postural control domains, as in the BESTest, could lead to early detection of balance impairment in older adults with CNP, so the specific intervention for improving balance can be promptly implemented. Therefore, this study aimed to investigate the use of the BESTest in older adults with CNP compared to older adults without CNP using young adults as the reference. We hypothesized that the BESTest would be able to identify system-specific postural control impairments in older adults with CNP. Rasch analysis (partial credit model) could provide valuable information related to item difficulty to determine the progression of balance exercises from easy to more difficult stages (27). In addition, this study revealed the level of BESTest item difficulty for older adults with and without CNP for further use in balance rehabilitation and fall prevention purposes.

Materials and methods

Participants

The sample size was determined based on a prior study (6), which showed an effect size of 0.52 between older adults with and without CNP and was used to estimate the sample size for this study. A power analysis performed with G*Power version 3.1.9.4 indicated that at least 15 participants in each group would be needed to ensure an adequate power level of 0.80 for the Kruskal–Wallis test at an alpha level of 0.05. Participants from three groups of subjects, healthy young participants aged 20–40 years and older adults aged 60 years or older with and without CNP were included in the study through a method of convenience sampling. All participants were able to walk independently. Neck pain was defined as pain and stiffness in the neck with or without radiating pain. To be eligible for the CNP group, participants had to suffer neck pain with an average weekly intensity of at least 3 cm on the 10 cm Visual Analog Scale (VAS) as a predominant complaint for at least 3 months.

Participants were excluded if they had major comorbidities that could affect balance measurements based on the following criteria: a previous history of neck and head trauma, recent orthopedic surgery or fracture (within the last 6 months), recent acute musculoskeletal injury or inflammatory joint disease/arthritis that required active management, known or suspected vestibular pathology, vertigo or dizziness from ear or brain disorders, neurological conditions, systemic conditions, use of medication that could affect balance, and cognitive impairment [as measured by the Montreal Cognitive Assessment (MoCA) with a total score of less than 24/30]. Ethical approval for the study was granted by the Human Research Ethics Committee of Srinakharinwirot University (SWUEC-039/2562F). Written informed consent was obtained before participation.

Measurement tools

Several clinical scales were administered in this study. The demographic data of each participant were obtained *via* interviews and medical records. Age, sex, and body mass index (BMI) were collected from all participants. The medication intake, comorbidities, self-rated neck pain and disability, self-perceived handicap associated with dizziness, and balance confidence in daily activities were obtained from older adults with and without neck pain.

Questionnaires

Neck pain intensity was assessed as "pain at the moment" on a blank 10 cm visual analog scale (VAS), on which 0 cm corresponds to "no pain at all" and 10 cm corresponds to "worst imaginable pain."

The Neck Disability Index (NDI) Thai version (28) was administered *via* an interviewer-assisted questionnaire to assess the degree of self-reported neck pain and disability. It consists of 10 items concerning daily living, pain and concentration. Each item is scored from 0–5, with 0 representing no disability and 5 signifying extreme disability, giving a total score of 50 or 100 percent. The total scores can be interpreted into the following 5 levels of disability in performing activities of daily living: 0–8%, no disability; 10–28%, mild disability; 30–48%, moderate disability; 50–64%, severe disability; and 70–100%, complete disability (29).

The Activities-specific Balance Confidence scale (ABC) was used to assess participants' balance confidence. The ABC requires patients to indicate their confidence in performing 16 activities without losing their balance or becoming unsteady on an 11-point scale (0–100%). Each item describes a specific activity that requires progressively increased balance control. Greater scores indicate higher balance confidence.

The Dizziness Handicap Index (DHI) was used to examine the self-perceived handicap associated with dizziness. The DHI consists of 25 items divided into three subscales: physical, functional, and emotional. Higher scores indicate the maximum perceived disability, with a maximal score of 100. The DHI can be used to classify individuals into 3 levels of disability; a total score of 0–30 indicates mild disability, 31–60 indicates moderate disability, and 61–100 indicates severe disability (30).

Clinical balance tool

The participants were instructed to perform 27 tasks of the Balance Evaluation Systems test (BESTest) for a total of 36 items, as some items consist of 2–4 subitems (e.g., for left and right sides). Each item is scored on a 4-level ordinal scale from 0 (worst performance) to 3 (best performance). The scores are summed to obtain a total score out of a possible maximum score of 108 points. Scores for the total test, as well as for each section, are expressed as a percentage of total points (24).

Procedures

After obtaining informed consent, demographic data were gathered by rater 1. The BESTest was administered in a quiet laboratory setting by rater 2, who was blinded to the demographic data and participant groups. The intrarater reliability of rater 2 for using the BESTest was calculated in 10 older participants using an intraclass correlation coefficient (ICC). The results showed that the intrarater reliability of rater 2 was high (ICC = 0.96).

The testing items were grouped into 6 sequences, which were initiated with different sections of the BESTest and followed by the subsequent sections. For example, in the 1st sequence, Section I of the BESTest was administered first, followed by Sections II, III, IV, V, and VI, and in the 2nd sequence, Section II was administered first, followed by Sections III, IV, V, VI, and I. The participants were randomly assigned into each sequence, and the researcher ensured that there was an equal number of participants in each sequence. Participants were encouraged to rest for 5 min as needed between each section of the test to avoid fatigue. The total testing time was approximately 2 h, but if the test could not be completed within 1 day, it was continued the next day. To verify the accuracy of the scoring, the entire testing session of each participant was videotaped for subsequent review.

Statistical analysis

Descriptive statistics were used to describe demographic data. To compare the percentage of the BESTest total and each section score between three groups, the Kruskal–Wallis test was selected. The pairwise comparison was used to pinpoint the difference between group. The Mann–Whitney U test was used to compare the BESTest item scores between older adults with and without CNP in the selected BESTest section. The significance level was set to 0.05 for all tests.

Once the BESTest domains that were significantly different between older adults with and without CNP had been identified, receiver operating characteristic (ROC) curve analysis was further conducted on those BESTest domains to differentiate the older adults whose daily life had been affected by neck problems using the NDI scores as a reference: participants with disability (total score $\geq$ 10%) and without disability (total score $<$ 10%). The area under the curve (AUC) and the specificity, sensitivity, and cutoff points were calculated. An AUC value of 0.7–0.9 is generally considered to be acceptable for differentiation (31). The largest Youden index (sensitivity + [1 − specificity]) was chosen as the cutoff score. Positive likelihood ratios (+LR) were calculated as sensitivity/(1 − specificity). Negative likelihood ratios (−LR) were calculated as (1 − sensitivity)/specificity. The greater the +LR is than 1.0, the more valuable the positive test result. The −LR indicates the usefulness of a negative test result: the greater the value is less than 1.0, the more valuable the negative test result (32). Posttest accuracy was later calculated from the proportion of true positives and true negatives in all tested cases.

The item difficulty measure was estimated from the BESTest item score of each participant group by Rasch analysis (partial credit model) (27) using WINSTEPS software 5.2.2 (Winsteps®, Portland, OR, USA). The "simulate data" option was used to strengthening the findings due to the small sample size. The item difficulty was expressed in a logit scale, in which the highest logit represents the most difficult item, and the lowest logit represents the easiest item.

Results

One hundred and ten participants from three groups of subjects, 30 healthy young participants aged 20–40 years and eighty older adults aged 60 years or older with (n = 20) and without CNP (n = 60), were included in the study. The demographic data of the young adults (YOUNG), older adults without chronic neck pain (OLD) and older adults with chronic neck pain (CNP) are presented in Table 1. As expected, there were significant differences in age between young and older adults ($p < 0.05$), whereas older adults with and without CNP did not significantly differ in age or comorbidities. Most of the participants in all groups were female, without a significant difference in body mass index. The CNP group had moderate pain and none to mild disability of daily living affected by neck problems (from the NDI score) and were significantly worse than the OLD group ($p < 0.05$). Moreover, those with CNP had less balance confidence in performing daily activities than those without CNP ($p < 0.05$).

TABLE 1 Characteristic of participants.

	Young (n = 30)	Old (n = 60)	CNP (n = 20)
Age (years, mean ± SD)	24.20 ± 4.13	64.70 ± 3.74†	63.85 ± 3.73‡
Gender [female, n (%)]	21 (70.00)	46 (76.67)	16 (80.00)
BMI (kg/m^2, mean ± SD)	22.14 ± 2.25	23.56 ± 2.97	23.65 ± 3.75
NDI (0–100, mean ± SD)	–	0.63 ± 1.35	13.63 ± 6.74*
ABC scale (%, mean ± SD)	–	94.08 ± 5.79	88.78 ± 10.67*
DHI (points, mean ± SD)	–	0.03 ± 0.26	1.45 ± 4.51*
VAS (0–100, mean ± SD)	–	–	4.50 ± 1.47
Duration of neck pain (months, mean ± SD)	–	–	14.63 ± 14.15
Side of neck pain [sides, n (%)]			
- Right side	–	–	4 (20.00)
- Left side	–	–	4 (20.00)
- Both side	–	–	12 (60.00)
Comorbidities [conditions, median (SE)]	–	1.00 (0.71)	1.00 (0.63)
Taking more than four medications [n (%)]	–	5 (8)	2 (10)

NDI, Neck Disability Index; ABC, Activities-specific Balance Confidence scale; DHI, Dizziness Handicap Index; VAS, Visual Analog Scale; OLD, Older Adults without Chronic Neck Pain; YOUNG, Young Adults; CNP, Older Adults with Chronic Neck Pain.
$^{\dagger}p < 0.05$ comparison of YOUNG and OLD.
$^{\ddagger}p < 0.05$ comparison of YOUNG and CNP.
$^{*}p < 0.05$ comparison of OLD and CNP.

The BESTest scores from three groups of participants, young adults and older adults with and without CNP, are presented in Table 2. Older adults with and without CNP demonstrated significantly lower BESTest total scores than young subjects. The comparison between the two groups of older adults showed that the CNP group had a lower BESTest total score than the OLD group. Regarding the section scores, the OLD group had a significantly lower score than the YOUNG group in all sections, except Section I (Biomechanical Constraints) and Section V (Sensory Integration), while the CNP group had lower scores than the YOUNG group in all sections except Section V. In addition, the CNP group had a significantly lower score than the OLD group in three sections: Biomechanical Constraints (Section I), Transitions–Anticipatory Postural Adjustment (Section III), and Reactive Postural Response (Section IV), which is 93.67 ± 5.91, 94.44 ± 6.74, and 89.17 ± 12.29, respectively ($p < 0.05$). Therefore, scores from these three sections (I, III, and IV) were selected for the following analyses.

The frequency distribution of the BESTest scores within Sections I, III, and IV between older adults with and without CNP are shown in Table 3. Compared to the OLD group, the CNP group demonstrated a lower percentage of individuals who scored "normal" (three scores), which differed significantly in the following items: Section I, hip/trunk lateral strength; Section III, stand on non-dominant leg; and Section IV, compensatory stepping correction–forward and backward.

Findings from the ROC analysis on the summative scores from Sections I, III and IV are shown in Table 4. The AUC was 0.79, indicating good diagnostic accuracy for classifying older adults with mild disability from neck pain, with a cutoff score of 48.5 out of 51. The sensitivity and specificity were high (72 and 69%, respectively), with acceptable LRs and good posttest accuracy (71.25%).

Closer examination of each BESTest item difficulty level of older adults with and without CNP is presented in Tables 5, 6, respectively. The item order was determined by its difficulty from the easiest to the most difficult. All items of the BESTest were found to be too easy for young adults (item difficulty = −7.54, standard error = 2.04), except one item, the Timed Up and Go with dual task test, which was the most difficult item. Similarly, the Timed Up and Go with dual task item was also found to be the most difficult item for older adults with and without CNP. In contrast, eleven items were found to be the easiest items for both older adults with and without CNP, including base of support, center of mass alignment, sit on floor and standup, sit to stand, alternate stair touching, standing arm raise, sensory integration for balance—eyes open on firm surface, eyes closed on firm surface, eyes open on soft surface, and incline–eyes closed—and walk with pivot turns. Apart from these similarities, hip/trunk lateral strength, stand on non-dominant leg, and compensatory stepping correction–forward and backward were found to be harder for the CNP group than for the OLD group.

Discussion

The BESTest is a comprehensive clinical tool for balance measurement based on the conceptual model of balance control in which 6 different systems contribute to the control of balance and posture. This study is the first to investigate the use of the BESTest in older adults with CNP to identify which

TABLE 2 Percentage score in total and each section of the BESTest.

BESTest	Young (n = 30)	Old (n = 60)	CNP (n = 20)
Total (%)	99.73 ± 0.64	94.26 ± 3.35†	91.58 ± 3.11‡*
Section I: Biomechanical constraints (%)	99.33 ± 0.06	97.56 ± 4.42	93.67 ± 5.91‡*
Section II: Stability Limits/Verticality (%)	100.00 ± 0.00	88.97 ± 6.88†	89.29 ± 8.30‡
Section III: Transitions-anticipatory postural adjustment (%)	100.00 ± 0.00	97.41 ± 4.95†	94.44 ± 6.74‡*
Section IV: Reactive postural response (%)	100.00 ± 0.00	95.56 ± 5.58†	89.17 ± 12.29‡*
Section V: Sensory orientation (%)	100.00 ± 0.00	99.56 ± 2.08	99.33 ± 2.05
Section VI: Stability in gait (%)	99.05 ± 0.48	86.51 ± 7.55†	83.57 ± 4.76‡

OLD, Older Adults without Chronic Neck Pain; YOUNG, Young Adults; CNP, Older Adults with Chronic Neck Pain.
$^{†}p$ < 0.05 comparison of YOUNG and OLD.
$^{‡}p$ < 0.05 comparison of YOUNG and CNP.
$^{*}p$ < 0.05 comparison of OLD and CNP.

TABLE 3 The frequency distribution of the BESTest scores in section I, III, IV.

BESTest	Frequency (%)			
	Old (n = 60)		CNP (n = 20)	
	Normal	Abnormal	Normal	Abnormal
Section I: Biomechanical constraints				
- Base of support	100	0.00	100	0.00
- COM alignment	100	0.00	100	0.00
- Ankle strength and range	78.3	21.7	60.0	40.0
- Hip/Trunk lateral strength	88.3*	11.7	60.0*	40.0
- Sit on floor and standup	100	0.00	100	0.00
Section III: Transitions-anticipatory postural adjustment				
- Sit to stand	100	0.00	100	0.00
- Rise to toes	88.3	11.7	90.0	10.0
- Stand on non-dominant leg	85.0*	15.0	55.0*	45.0
- Stand on dominant leg	88.3	11.7	75.0	25.0
- Alternate stair touching	100	0.00	100	0.00
- Standing arm raise	100	0.00	100	0.00
Section IV: Reactive postural response				
- In place response: Forward	100	0.00	95.0	5.00
- In place response: Backward	93.3	6.70	85.0	15.0
- Compensatory stepping correction: Forward	96.7*	3.33	75.0*	25.0
- Compensatory stepping correction: Backward	90.0*	10.0	60.0*	40.0
- Compensatory stepping correction: Lateral (Non-dominant)	73.3	26.7	60.0	40.0
- Compensatory stepping correction: Lateral (Dominant)	71.7	28.3	60.0	40.0

OLD, Older Adults without Chronic Neck Pain; CNP, Older Adults with Chronic Neck Pain; Normal, Able to perform the test perfectly and score as 3; Abnormal, Unable to perform the test perfectly and score as 2, 1, or 0. Percentage of frequency was calculated by dividing the amount of participant in each score by the total participants of each group, and then multiplying the result by 100.
$^{*}p$ < 0.05 comparison of OLD and CNP.

system of balance control would be impaired as a result of CNP. The OLD and YOUNG groups were also investigated in this study to control for the effect of confounding age factors. Corresponding to the study's hypothesis, our results demonstrated that the BESTest can be used to identify system-specific postural control impairments in CNP. The BESTest scores showed that balance control was deteriorated from the normal aging process and further declined in the CNP group, such that CNP affected three balance control systems, biomechanical constraints, transitions–anticipatory postural adjustment, and reactive postural response, when compared with the OLD group.

Biomechanical constraints correspond to the musculoskeletal system, including muscle strength, range

TABLE 4 Cutoff points for the summation score of section I, III, and IV from the BESTest with associated area under the curve of receiver operating characteristic curve, sensitivity and specificity, and likelihood ratios in older adults with and without disability (*N* = 80).

Variables	Total score of section I, III, and IV
Area under the curve	0.79
Cutoff score (/51)	48.5
Sensitivity	0.72
Specificity	0.69
Positive likelihood ratio	2.32
Negative likelihood ratio	0.41
Accuracy (%)	71.25%

of motion and body alignment. In contrast to a previous study (33), this study demonstrated no significant differences between the OLD and YOUNG groups. This disagreement could be due to different participant characteristics; those in our OLD group were younger and a high level of physical functioning, as indicated by an ABC score of more than 80 (34). However, the problem with biomechanical constraints was found to be declining in the CNP group. Closer examination (Table 3) showed that decreased hip/trunk lateral strength in the CNP group is a major problem. According to previous studies, CNP was found to increase concerns about falling and decrease physical performance (5), whereas hip muscle strength was reported to be an important indicator of physical performance, especially in elderly women (35). This finding was associated with the results of transitions–anticipatory postural adjustment (Section III), which was found to decline from the aging process and further declined when an individual experienced CNP. Standing on the non-dominant leg was the item from Section III that showed a significant difference between the OLD and CNP groups. A previous study (36) showed that vibratory stimulation directed to the dorsal neck muscles in human perturbed proprioceptive information and led to postural control instability during standing, suggesting that cervical afferent inputs play a dominant role in postural control in an upright stance. Altered cervical afferent inputs can be caused by CNP from a pain-induced change in nociceptor and mechanoreceptor activity at the spinal cord and within the CNS (12) or from chemical changes caused by inflammatory events that affect the sensitivity of the receptors (13). Other factors involve awkward postures, static and repetitive work, or trauma that disturbs the sensitivity of the cervical joint and muscle receptors (15). Thus, disturbed lower extremity muscle activity by altered cervical afferent inputs combined with decreased hip/trunk lateral strength from declining physical performance in individuals with CNP can affect their balance control.

There was a greater deficit in the reactive postural response in older adults with CNP than in those with normal aging, suggesting that most of them had failed to preserve postural stability by activating the stepping strategy. Compared to the OLD group, a higher number of older adults with CNP had significant problems with compensatory stepping correction in both forward (25%) and backward directions (40%), where participants were asked to stand with feet shoulder width apart, arms at their sides and lean forward/backward against the researcher's hands until their shoulders and hips were out of line with their toes and the researcher suddenly released the support to elicit the step. The central nervous system (CNS) is responsible for integrating afferent inputs and sending postural adjustments to maintain the center of gravity over the base of support. If somatosensory inputs are impaired, the CNS will be unable to select the correct strategies in time (37). The cervical spine has an important role in providing afferent inputs for the internal reference frame to maintain postural stability, since the main input comes from at least three sources, including somatosensory (local and distal), visual, and vestibular systems (20). Furthermore, cervical proprioceptors provide the CNS with information about the movement and location of the head in relation to the trunk. The cervical muscles, which have a high concentration of muscle spindles, relay information to and receive information from the CNS, and there are specific connections between the cervical receptors, the visual and vestibular apparatus and the autonomic nervous system (38). Cervical proprioceptors are involved in the cervico-collic reflex, the cervico-occular reflex and the tonic neck reflex, which provide information about the movement and position of the head in space (16). Older adults with CNP demonstrated sensorimotor disturbances caused by altered cervical afferent inputs in terms of greater deficits in eye movement control, vertical perception, and postural control (6–8, 21). Therefore, impairments in sensorimotor integration caused by CNP may lead to impaired reactive postural responses. In addition, our study demonstrated a trend for those with CNP to have problems with the compensatory stepping correction in backward directions more than forward directions when compared to the OLD group. Backward stepping requires more effort than forward stepping since the margin of stability is smaller and there is greater instability in the backward direction (39). Furthermore, aging was found to affect the recruitment of proper muscle synergies during reactive backward stepping. Changes in the contribution of tibialis anterior, biceps femoris (long head) and gastrocnemius muscles in the stance limb of older adults may contribute to decrease in step length during reactive backward stepping when compared to young adults (40). Although no differences between the OLD and CNP groups were found during the compensatory stepping correction on either lateral side, both groups demonstrated lower scores than the YOUNG group. Thus, compensatory stepping correction in all directions needs to be considered in CNP.

This study demonstrates that aging has a deteriorating effect on multiple aspects of postural control, except sensory orientation. Our result was not in accordance with previous

TABLE 5 Item difficulty measures of the BESTest in older adults with chronic neck pain (CNP).

Items	Item difficulty	Standard error (SE)	Items	Item difficulty	Standard error (SE)
Base of support	−3.34	1.84	Walk with head turns—Horizontal	−0.87	0.63
COM alignment	−3.34	1.84	In place response—Backward	−0.87	0.63
Sit on floor and standup	−3.34	1.84	Sitting lateral lean to non-dominant side	−0.87	0.63
Sit to stand	−3.34	1.84	Sitting verticality (Dominant side)	−0.23	0.51
Alternate stair touching	−3.34	1.84	Compensatory stepping correction Forward	0.02	0.48
Standing arm raise	−3.34	1.84	Stand on dominant leg	0.02	0.48
Sensory integration for balance - Eyes open on firm surface	−3.34	1.84	Compensatory stepping correction - Backward	0.43	0.44
Sensory integration for balance - Eyes closed on firm surface	−3.34	1.84	Ankle strength and range	0.43	0.44
Sensory integration for balance - Eyes open on foam surface	−3.34	1.84	Compensatory stepping correction - Lateral (Dominant side)	0.79	0.41
Sensory integration for balance Incline-eyes closed	−3.34	1.84	Compensatory stepping correction Lateral (Non-dominant side)	0.96	0.40
Walk with pivot turns	−3.34	1.84	Functional reach lateral (Dominant side)	0.96	0.40
Step over obstacles	−2.10	1.03	Functional reach forward	0.96	0.40
Change in gait speed	−2.10	1.03	Hip/Trunk lateral strength	0.96	0.40
In place response—Forward	−2.10	1.03	Stand on non-dominant leg	1.12	0.39
Sitting lateral lean-to dominant side	−2.10	1.03	Functional reach lateral (Non-dominant side)	1.12	0.39
Sensory integration for balance - Eyes closed, foam surface	−1.34	0.75	Gait—Level surface	1.56	0.38
Rise to toes	−1.34	0.75	Timed "Get Up and Go"	1.84	0.37
Sitting verticality (Non-dominant side)	−1.34	0.75	Timed "Get Up and Go" with dual task	4.08	0.44

COM, Centre of Mass.

studies that reported a significant difference in the sensory integration declined by both aging and CNP (6–8, 21, 41). The discrepancy of findings may be because the tasks and measurement tools are not entirely comparable. In this study, the participants were examined by a clinical tool (BESTest) that included the mCTSIB and standing balance test with eyes closed on an inclined surface to determine sensory integration without using laboratory tools, whereas in previous studies (6–8, 21, 41), the participants were examined by various tests using laboratory tools. Furthermore, Rasch analysis showed that all items in Section V (Sensory Orientation) of the BESTest were the easiest items. Thus, the BESTest alone might not be suitable for clinically examining sensory integration in those who have a high level of physical functioning.

In this study, stability in gait scores (Section VI) in both older adult groups were significantly lower than those in the YOUNG group, but we did not find a section score difference between the OLD and CNP groups. Our findings do not agree with those of previous studies (6, 8, 21), which found slower walking speed during the Timed Up and Go (TUG) test, poorer scores on the Dynamic Gait Index (DGI), and gait parameter disturbance during the Timed Ten Meter Walk test with and without head movement in CNP. This may be caused by the differences in age and disability level caused by neck problems, where participants in the previous study were older and had moderate disability. However, according to the results of the Rasch analysis of the BESTest, gait assessment was more challenging for the CNP group than for the OLD group. The Timed Up and Go with dual task test was found to be the most difficult item for the CNP group, followed by the TUG and gait-level surface tests, which may be attributed to both cognitive decline of normal aging and impaired balance control from CNP. Most participants in the OLD (67–85%) and CNP (85–90%) groups were unable to complete walking 20 feet on an even surface within 5.5 s and TUG within 11 s. Gait speed is an essential component for identifying a history of falls (42), and the TUG test alone is a sensitive and specific test for identifying risk factors for falls in older adults (43). The dual task used in the BESTest is a cognitive task (counting backward by threes from 100); when combined with the TUG test, it can be used to detect the risk of falls and mild cognitive impairment-related changes in older adults (44). Impairments in stability in gait combined with lower extremity muscle weakness and impaired balance should be a concern, since all are considered risk factors for falls (45).

TABLE 6 Item difficulty measures of the BESTest in older adults without chronic neck pain (OLD).

Items	Item difficulty	Standard error (SE)	Items	Item difficulty	Standard error (SE)
Base of support	−4.22	1.84	Sitting lateral lean to dominant side	−0.95	0.46
COM alignment	−4.22	1.84	Sitting verticality (Dominant side)	−0.95	0.46
Sit on floor and standup	−4.22	1.84	Compensatory stepping correction - Backward	−0.95	0.46
Sit to stand	−4.22	1.84	Rise to toes	−0.75	0.43
Alternate stair touching	−4.22	1.84	Sitting lateral lean to non-dominant side	−0.58	0.40
Standing arm raise	−4.22	1.84	Hip/Trunk lateral strength	−0.42	0.39
Sensory integration for balance - Eyes open on firm surface	−4.22	1.84	Sitting verticality (Non-dominant side)	−0.28	0.37
Sensory integration for balance - Eyes closed on firm surface	−4.22	1.84	Stand on non-dominant leg	−0.28	0.37
Sensory integration for balance - Eyes open on foam surface	−4.22	1.84	Stand on dominant leg	−0.14	0.36
Sensory integration for balance - Incline-eyes closed	−4.22	1.84	Ankle strength and range	0.10	0.34
Walk with pivot turns	−4.22	1.84	Compensatory stepping correction - Lateral (Non-dominant side)	0.50	0.31
In place response—Forward	−4.22	1.84	Compensatory stepping correction - Lateral (Dominant side)	0.68	0.29
Compensatory stepping correction - Forward	−2.23	0.74	Functional reach forward	1.38	0.36
Change in gait speed	−2.23	0.74	Gait—Level surface	1.58	0.26
Step over obstacles	−1.77	0.62	Functional reach lateral (Dominant side)	1.97	0.25
In place response—Backward	−1.44	0.54	Timed "Get Up and Go"	2.22	0.25
Sensory integration for balance - Eyes closed, foam surface	−1.44	0.54	Functional reach lateral (Non-dominant side)	2.40	0.25
Walk with head turns—Horizontal	−1.44	0.54	Timed "Get Up and Go" with dual task	4.08	0.44

COM, Centre of Mass.

The BESTest has been known for its long administration time such that it would take up to 35 min to complete the test. Our study demonstrated that not all BESTest domains were found to be deficit in older adults with chronic neck pain. Also, the sensory orientation domain of the BESTest was found too easy to perform for both older adults with and without chronic neck pain. To reduce the assessment time, this study proposed using the combined score from BESTest domains that were significantly different between older adults with and without CNP, as a screening test. Results revealed that the BESTest can be used in the detection of system-specific postural control impairments in older adults with CNP by using the total score of Sections I, III, and IV as a screening tool for differentiating older adults whose daily life had been affected by neck problems with a high AUC (0.79), sensitivity (72%), and specificity (69%). The BESTest also has a good posttest accuracy (71.25%) using the suggested cutoff score of 48.5 out of 51. The participants in the CNP group presented with relatively moderate levels of neck pain intensity (average pain intensity = 4.50/10) and mild neck disability (average NDI score = 13.63/100). Although the average ABC scale, which represented the fear of falling, was significantly lower in the CNP group than in the OLD group, the scores of the CNP group were relatively good and they were considered to have a high level of physical functioning (34) (average ABC scale = 88.78/100). This is relevant, as it highlights that decreased postural control as measured by the BESTest can be found in the CNP, even with relatively moderate pain, mild disability and a high level of physical functioning.

Our study has several implications. First, the BESTest can be used to assess system-specific postural control impairments in older adults with and without chronic neck pain, as the BESTest total scores were significantly different among three groups of participants (YOUNG, OLD, and CNP). However, clinicians should be aware that these differences, especially the score differences between OLD and CNP, may not be clinical significance, as their values may not reach minimal clinically important differences (MCID). Second, the results revealed that the BESTest can be used in the detection of system-specific postural control impairments in older adults with CNP by using the total score of Sections I, III, and IV as a screening tool. Third, the results suggested that older adults with CNP who have moderate pain and mild disability may have lower extremity muscle imbalance and a reduced ability to compensate for stepping correction, especially in the forward and backward directions. However, other balance problems can also be found, since significant differences were reported in almost all subsystems except sensory integration when compared to young adults. Impairments in stability in gait combined with lower extremity muscle weakness and impaired balance are considered risk factors for falls (45). Therapists need to be mindful of the balance problem caused by normal aging and CNP. We suggest that therapists administer Sections II and VI of the BESTest after finding a positive result by screening, with the total score of Sections I, III, and IV used to obtain complete information on postural control system impairment. Lastly, the hierarchical order of the item difficulty suggested that 11 out of 36 items of the BESTest do not challenge older adults with CNP who have moderate pain and mild disability. However, the remaining items can provide valuable information for therapists to implement specific training and determine the progression of balance training from easy to more difficult stages. For example, if a patient is unable to complete hip/trunk lateral strength and stand on one leg, it is recommended to start with hip/trunk muscle strengthening before progressing to standing on one leg.

The results of this study should be interpreted in light of its limitations. First, to control the effects of the aging process in the CNP group, older adults with any kind of pathology related to balance control were excluded from this study, resulting in the small sample size of individual with CNP. It is well-known that older adults with CNP in general have multiple health problems and complications; thus, a higher severity of balance problems could be expected. Nevertheless, individuals with CNP with other comorbidities typically found in older adults should be recruited in future studies to confirm this speculation. Second, most participants in the CNP group had moderate pain and mild disability. It is necessary to be concerned that the severity of the problem may vary with patients who have different levels of pain and disability. Third, the current study did not compare each of the BESTest domain score with specific measurements, such as muscle strength, endurance, EMG responses, rather this study used the performance of the older adults without CNP as the comparison for identifying system-specific balance impairments. Therefore, future studies with direct comparison of the BESTest score and other standardized tools are required to confirm the construct validity of the BESTest in older adults with CNP.

Conclusion

The BESTest can be used to identify system-specific postural control impairments in older adults with CNP. The BESTest scores showed that balance control deteriorated from the normal aging process and further declined in CNP. Three sections of the BESTest, biomechanical constraints, transitions–anticipatory postural adjustment, and reactive postural response, were suggested for the detection of system-specific postural control impairments in older adults whose daily life was affected by neck problems. The Rasch analysis revealed 14 items of the BESTest that were difficult for older adults with CNP and could be further used for balance rehabilitation and fall prevention.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Human Research Ethics Committee of Srinakharinwirot University (SWUEC-039/2562F). The patients/participants provided their written informed consent to participate in this study.

Author contributions

RB conceived and designed the project, procured funding, analyzed the data, and prepared the final manuscript. TM prepared instrument, collected and analyzed the data, and wrote the first draft of the manuscript. TT helped with the data analysis. CC helped in the preparation of the final manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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APPENDIX VIII

Clinical Research Advantage

หนังสือรับรองการใช้ประโยชน์ของผลงานวิจัย

ชื่อหน่วยงานที่รับรอง งานกายภาพบำบัด กลุ่มงานเวชกรรมฟื้นฟู โรงพยาบาลพานทอง

ที่อยู่หน่วยงานที่รับรอง โรงพยาบาลพานทอง เลขที่ 1/10 หมู่ที่ 8 ต.พานทอง อ.พานทอง จ.ชลบุรี 20160

วัน เดือน ปีที่ให้การรับรอง 22 พฤษภาคม 2566

เรื่อง การรับรองการใช้ประโยชน์ของผลงานวิจัย

เรียน คณบดีบัณฑิตวิทยาลัย มหาวิทยาลัยศรีนครินทรวิโรฒ

ข้าพเจ้า นางสาวกัญฑิมา เพชรรื่น **ตำแหน่ง** รองหัวหน้างานกายภาพบำบัด

ขอรับรองว่าได้มีการนำปริญญานิพนธ์เรื่อง

การระบุความบกพร่องด้านการทรงตัวในผู้สูงอายุที่มีปัญหาปวดคอเรื้อรัง

ผู้วิจัยโดย นางสาวธันยา หมัดสะและ

นำไปใช้ประโยชน์ ดังนี้ (กรุณาเลือกโดยการทำเครื่องหมาย ☑ หน้าข้อความที่ตรงกับความเป็นจริง และกรุณาให้รายละเอียดการใช้ประโยชน์เพิ่มเติมท้ายข้อความที่เลือก)

☑ การนำไปใช้ประโยชน์เชิงสาธารณะ (การใช้งานวิจัยให้เกิดประโยชน์แก่สาธารณชนในเรื่องต่างๆ ที่ทำให้สุขภาพ คุณภาพชีวิตและเศรษฐกิจของประชาชน/ชุมชนดีขึ้น เช่น ด้านสาธารณสุข การจัดการSME เป็นต้น)

นำไปประยุกต์ใช้ในทางคลินิก เพื่อตรวจคัดกรองปัญหาด้านการทรงตัวในผู้สูงอายุที่มีปัญหาปวดคอเรื้อรัง

☐ การใช้ประโยชน์เชิงนโยบาย (เช่น การนำผลจากการวิจัยไปประกอบเป็นข้อมูลการประกาศใช้กฎหมาย หรือมาตรการ กฎเกณฑ์ต่างๆ โดยองค์กร หรือหน่วยงานภาครัฐและเอกชน เป็นต้น)

☐ การใช้ประโยชน์ในเชิงพาณิชย์ (เช่น งานวิจัยหรืองานสร้างสรรค์ที่นำไปสู่การพัฒนาสิ่งประดิษฐ์ หรือผลิตภัณฑ์ซึ่งก่อให้เกิดรายได้ หรือนำไปสู่การเพิ่มประสิทธิภาพการผลิต เป็นต้น)

☐ การใช้ประโยชน์ทางอ้อมของงานวิจัย/งานสร้างสรรค์ ซึ่งเป็นการสร้างคุณค่าทางจิตใจ ยกระดับจิตใจ ก่อให้เกิดสุนทรีภาพ สร้างความสุข

ช่วงเวลาในการใช้ประโยชน์

☑ **ตั้งแต่**............1 พฤษภาคม 2566............**จนถึงปัจจุบัน**

☐ **ตั้งแต่**..**จนถึง**...

โดยการใช้ประโยชน์นั้น ก่อให้เกิดผลดีหรือประโยชน์ ดังนี้

- สามารถนำไปใช้ในการตรวจคัดกรองปัญหาด้านการทรงตัวเบื้องต้นในผู้สูงอายุที่มีปัญหาปวดคอเรื้อรัง
- ช่วยให้การออกแบบและวางแผนการรักษามีระสิทธิภาพมากยิ่งขึ้น
- ช่วยป้องกันความเสี่ยงต่อการล้มของผู้ป่วยที่อาจเกิดขึ้นในอนาคต
- ช่วยให้นักกายภาพบำบัดตระหนักถึงปัญหาด้านการทรงตัวในผู้ป่วยที่มีปัญหาปวดคอเรื้อรังมากยิ่งขึ้น

ลงชื่อ..

(นางสาวกัญฑิมา เพชรรื่น)

รองหัวหน้างานกายภาพบำบัด

หมายเหตุ: ท่านสามารถประทับตราของหน่วยงานในเอกสารนี้ได้ (ถ้ามี)

VITA

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