Identification of Timed Up and Go Components in Elderly with Chronic Neck Pain.

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Abstract

Elderly with chronic neck pain (CNP) showed impaired dynamic balance as indicated by longer duration during the Timed Up and Go (TUG) test. TUG contains several components including sit-to-stand (STS), walk, turn, turn-to-sit (TTS), but it is unclear which component of TUG was markedly impaired in the elderly with chronic neck pain (CNP). This study aimed to identify which component of the Timed Up and Go test was impaired in elderly with CNP as compared with those without neck pain. This cross-sectional study compared the duration used to complete the TUG task between 21 healthy elderly aged 64.57 ± 4.03 years and 15 elderly with CNP aged 64.00 ± 4.05 years. Each TUG component was identified by using inertial sensors attached to the body. The elderly with CNP were classified further into mild and moderate disability using the Neck Disability Index. The duration of STS, TTS, and total TUG were significantly longer in CNP with mild disability ($p < 0.05$). CNP with moderate disability showed larger peak angular trunk velocity in all TUG components than healthy and CNP with mild CNP. The STS and TTS components of the TUG test were markedly impaired in elderly with chronic neck pain. Those impairments can be reflected by the longer duration of STS and TTS components or larger peak angular trunk velocity.

Keywords: *Musculoskeletal pain, neck disability, dynamic balance, functional activity*

1. Introduction

Chronic musculoskeletal pain is one of the health conditions that receive a lot of concern worldwide (Goldberg & McGee, 2011). One of the most common chronic musculoskeletal pain is neck pain. The definition of chronic neck pain was based on its anatomical location and duration of symptoms. Chronic neck pain (CNP) is defined as pain perceived at any area in the posterior region of the cervical spine, from the superior nuchal line to the first thoracic spinous process, for the duration of 3 months or more (Misailidou et al., 2010). CNP leading to diminished physical activities is more pronounced in aging, as the above global age-standardized point prevalence of neck pain increased to 8.0% in people with age more than 60 years (Hoy et al., 2014).

Signs and symptoms of people with CNP include neck pain, dizziness, impaired body structure and body function of the neck, and limitation of physical activity. Decreased neck range of motion in all planes and reduced neck muscle strength were commonly found in people with CNP (Woodhouse & Vasseljen, 2008); Meisingset et al., 2015). The elderly with CNP also complained of dizziness and unsteadiness regarding eye-head movement and postural control. These symptoms could be due to alteration of somatosensory function originating from the cervical spine, which may mismatch with information from the vestibular system (Treleaven, 2008). The sensorimotor test by electro-oculography was used in the smooth pursuit neck torsion (SPNT) test to assess disturbances in the eye movement control in the elderly with CNP. Results demonstrated the deficits of smooth pursuit control during SPNT and difficulty in perceiving the vertical linear when the reference frame was rotated to 10° and 15° anticlockwise. Such findings supported the impairment of receptors in the cervical region that connected to the visual, vestibular, and central nervous systems (Uthaikhup et al., 2012). Furthermore, it was found that the duration of inflammation and severity of pain were associated with sensorimotor impairment and decreasing physical function.

Concerning gait and balance impairment, it was found that the elderly with CNP took a longer time to complete the Timed Ten Metre Walk Test and performed smaller steps than the healthy elderly (Poole et al., 2008). Previous literature also demonstrated the relationship between neck pain and the decrease in physical performance leading to higher fall risk in elderly with CNP (Kendall et al., 2016). Disturbance of balance and gait characteristics found in elderly with CNP included decreased self-selected gait speed, step length, stride length, and step width during walking with head turn (Uthaikhup et al., 2014). Another study supported dynamic balance deficits during walking in elderly with CNP such that they took longer time to complete the Timed Up and Go (TUG) test and they received lower scores in the Dynamic Gait Index (DGI) test, as compared with the healthy elderly (Quek et al., 2014). Impaired static balance was also evident in elderly with CNP as they were unstable when standing in 3 conditions; comfortable stance foot position with eye closed on a firm surface, the eye opens on a soft surface, and the eye opens on a soft surface with the narrow stance (Poole et al., 2008; Quek et al., 2014). It was suggested that impaired static balance could be due to impaired proprioceptive information from the neck that connected with the vestibular system used in maintaining postural stability during eye closed stance. Therefore, the impaired static standing balance was evident during the standing condition where information from the vestibular or proprioceptive system was required such as during standing on foam surface or standing with eyes closed (Quek et al., 2014).

Timed Up and Go (TUG) test is the clinical scale that was developed to identify a person with dynamic balance deficits by measuring the time they took to complete the test. The test includes 4 complex components; sit-to-stand (STS), walk 3 meters, turning, walk back and turn to sit (TTS) on the chair (Wall et al., 2000). TUG is often used in clinical and community settings as compared with other balance tests because TUG can be completed within 1-2 minutes, does not require much testing equipment and shows acceptable psychometric properties in identifying elderly fallers (Guner et al., 2000). Total time of TUG has been commonly used to assess dynamic balance and mobility in individuals including elderly people with CNP (Poole et al., 2008). Older adults with CNP demonstrated impairments in the total time of TUG. This may be due to the decrease in musculoskeletal proprioceptive recruitment in the elderly so that they relied more on the vestibular system for postural stability (Quek et al., 2014). However, each component of TUG represents a different functional activity that underlies different movement control mechanisms. For example, turning is a demanding activity and it has been suggested that this task requires greater cognitive ability and sensory information processing than walking in a straight line (Hollands et al., 2014; Y. Takei et al., 1997; Yasuhiko Takei et al., 1996). A previous study also showed that not all components of TUG were affected equally in the elderly with neurological disorders. The elderly with stroke revealed that longer TUG total time was caused by impairment in the turning, turn-to-sit, and walking components, but not during sit-to-stand components, as compared with the healthy elderly (Chaikeeree et al., 2018). Such impairments consisted of reduced peak angular velocity during the turn and turn-to-sit, decreased stride length and stride velocity, and increased single-leg stance time during walking. Information regarding TUG components will help the clinician in adding useful information for planning task-specific training for persons with dynamic balance problems. Nevertheless, there is no information regarding which TUG components are impaired in the elderly with CNP.

2. Objectives

To identify the component of the Timed Up and Go test that was impaired in the elderly with chronic neck pain as compared with those without neck pain

3. Materials and Methods

3.1. Participants

This cross-sectional study was conducted in 30 older participants, consisting of 15 elderly with chronic neck pain (CNP) (mean age = 64.00 ± 4.05 years) and 15 healthy older adults (mean age = 64.57 ± 4.03 years). They were recruited from the Nonthaburi metropolitan and Tha-sai public health centers using the purposive sampling technique. Participants with CNP were 60 years or older, had neck pain for more than 3 months, and had an average neck disability index (NDI) of 13.60 ± 6.98 scores, The exclusion criteria were 1) unable to follow a command, 2) unable to walk independently for 6 m, 3) had neurological conditions such as stroke or Parkinson's disease, 4) had a vestibular disorder, 5) had a systemic condition such as cancer, peripheral neuropathy in the leg, 6) had a history of fall, 7) underwent recent orthopedic surgery, 8) had arthritis that required active management, and 9) had acute musculoskeletal injuries. All participants provided informed consent as outlined by the Human Ethics Committee of the Srinakharinwirot University and all procedures were conducted according to the Declaration of Helsinki.

3.2. Questionnaire

Demographic details such as age, medical intake, and comorbidities were obtained from the participants. The Neck Disability Index (NDI), the Activity-specific Balance Confidence scale (ABC scale), the Dizziness Handicap Inventory (DHI) were used to assess self-reported neck pain, fear of fall, and perceived handicap in participants.

3.3. TUG components measure

The assessment of the Timed Up and Go (TUG) test was performed in the quiet laboratory setting by another researcher who was blinded to the patient's group and demographic data. Participants were asked to perform the TUG test once. The instrumented Timed Up and Go (iTUG) from APDM Mobility Lab system (APDM, Inc., Portland, USA), a set of portable inertial sensors and software was used to identify the components of TUG. The iTUG is a reliable and valid tool to measure TUG performance in several groups of participants such as persons with neurological disorders and elderly fallers (Salarian et al., 2010; Wüest et al., 2016). This system has excellent test-retest reliability (intraclass correlation coefficients (ICC) ranged from 0.43-0.99) (Salarian et al., 2010). Six portable 3-dimensional inertial sensors where each sensor consisted of a gyroscope and accelerometer used to capture angular velocity and acceleration at the sampling rate of 200 Hz (Salarian et al., 2007). During the assessment, each participant started by sitting on the chair with six-inertial sensors attached to their body (Salarian et al., 2007). Two portable inertial sensors were placed at both sides of the middle anterior shank above the ankle joints. Two portable inertial sensors were placed on the dorsum of each wrist. One sensor was attached to the chest on the sternum at 2 cm below the sternum notch. The last sensor was placed on the posterior trunk at the level of L5, near the body center of mass of each participant (Figure 1). Before the assessment, the researcher demonstrated the TUG procedure and let the participants practice the TUG several times until they became familiar with the task and their performance was consistent before start recording. At the "Go" command, the participants stood up without using their hands to push on the chair and walked barefoot at a comfortable pace. The total duration of TUG was calculated starting from when participants moved their back away from the backseat of the chair until they sat down and their back touched the chair again. One researcher walked beside participants during the TUG test for safety precaution.

The components of TUG, including sit-to-stand (STS), walking (walk), turning (180^{o}) (turn), walking back, and turn-to-sit (TTS) are classified by trunk velocity and acceleration using APDM iTUG software (Zampieri et al., 2010). The iTUG software used the signal of the gyroscope on the trunk to record the degree of trunk movement. Peak angular velocity of trunk movement was used to represent postural transition during each component of TUG by a special pattern in each signal axis. The first peak on the pitch axis (an axis lying on horizontal) corresponded to the STS phase (a). The first peak in the Yaw axis (an axis lying the same as the gravity line) corresponded to the turn phase and the second peak corresponded to the TTS transition (b) as shown in Figure 2 (Chaikeeree et al., 2018). Total TUG duration and duration of each TUG component in each participant were calculated. Besides, peak trunk angular velocity of TUG components; STS, turn, and TTS, were analyzed.

Figure 1 Wearable inertial sensors' placements on the body

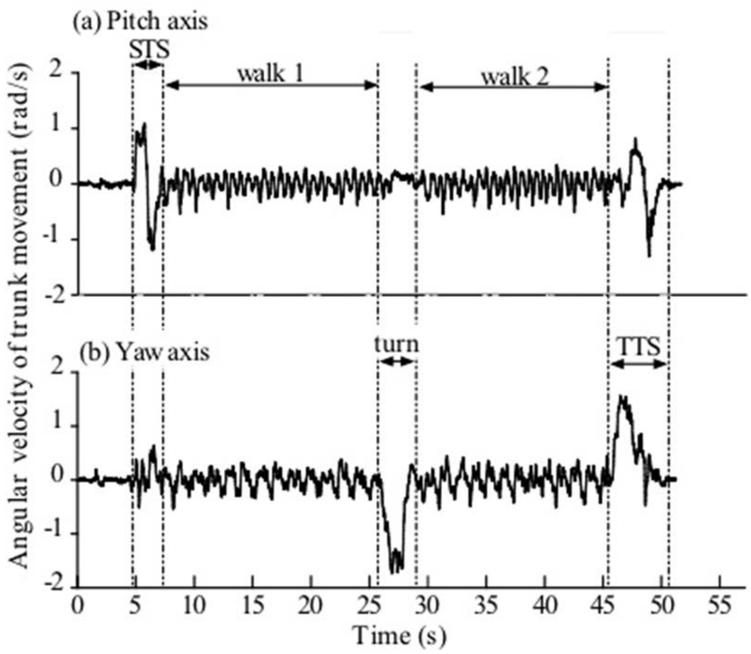

Figure 2 Raw signal derived from an inertial sensor

3.4. Sample size calculation

The sample size was calculated based on data from a previous study by Quek J. et al (Quek J. et al 2014) that examined the total TUG time in the elderly with CNP during the TUG task as compared with the healthy elderly. By assuming the power of 0.80, an alpha level of 0.05, and the effect size of 0.95, it gives rise to the total sample size of thirty participants; 15 persons in each group (CON, CNP).

3.5. Statistical analyses

Descriptive statistics were used to describe the participant's demographic data. An independent *t*-test was used for comparing general characteristics such as age, height, and weight, and duration of TUG and TUG components between the elderly with CNP and healthy elderly participants. Additional statistical test was conducted to perform subgroup analysis between healthy older adults and CNP elderly with mild disability and between healthy older adults and CNP elderly with a moderate disability using non-parametric statistics; independent-samples Mann-Whitney U Test. Statistical significance was set at $p < 0.05$.

4. Result and Discussion

4.1 Results

Table 1 compares the demographic data and clinical scores between healthy elderly and elderly with CNP. There were no differences in general characteristics such as age, gender, BMI between the healthy elderly and elderly with CNP. However, the elderly with CNP showed a greater score of NDI, DHI, VAS ($p < 0.001$), and longer duration of neck pain ($p < 0.001$) than the healthy control. The ABC scale was not significantly different between the elderly with CNP and the healthy control group ($p = 0.951$), indicating no difference in fear of fall between the 2 groups.

Table 1 Demographic and clinical characteristics of participants

	Controls (n=15)	CNP (n=15)	*p*-value
Age (yrs, mean ± SD)	64.57 ± 4.03	64.00 ± 4.05	0.678
Gender (female, n (%))	11 (73.33)	13 (86.67)	-
BMI (kg/m2, mean ± SD)	24.85 ± 3.43	24.17 ± 4.17	0.951
NDI (0-100, mean ± SD)	0	13.60 ± 6.98	0.001*
ABC scale (%)	93.63 ± 7.3	89.29 ± 11.05	0.132
DHI (points, mean ± SD)	0	1.93 ± 5.16	0.001*
VAS (0-10, mean ± SD)	0	4.33 ± 1.35	0.001*
Duration of neck pain (months, mean ± SD)	0	14.87 ± 14.31	0.001*
Side of neck pain (side, n (%))			
Right side	-	2 (13.33)	-
Left side	-	3 (20.00)	-
Both sides	-	10 (66.67)	-
Comorbidities (condition, n (%))			
Lumbar spine or lower limb pain (VAS < 3/10)	2 (5.13)	1 (6.67)	-
Dizziness	1 (2.56)	4 (26.67)	-
Head or neck injury	-	-	-

CON=healthy elderly, CNP= chronic neck pain, *p < 0.05 between CON and CNP

Table 2 shows the total TUG duration and durations of each TUG component between elderly with CNP and healthy. There was no difference in total TUG duration between healthy elderly and elderly with CNP. Similarly, no significant differences were found in the duration of each TUG component between the 2 groups. Further subgroup analysis was shown in Table 3. The elderly with CNP was classified into 2 groups according to the NDI score as mild disability (NDI score ≤ 10) and moderate disability (NDI score > 10) groups. CNP elderly with mild disability showed significantly longer total TUG duration and durations of STS and TTS components than healthy elderly. However, no difference was found between healthy elderly and CNP elderly with a moderate disability on the duration of TUG total and TUG components (Table 3)

Table 2 Duration of TUG and each TUG component in healthy elderly and elderly with CNP
CON=healthy elderly, CNP=chronic neck pain, STS=sit-to-stand, TTS=turn-to-sit

	CON (n=15)	CNP (n = 15)		95% confidence interval of difference		
	Mean±SD	Mean±SD	Mean difference	Lower	Upper	*p*-value
STS	1.39±0.46	1.64±0.54	-0.25	-0.59	0.09	0.15
Walk	3.97±0.91	3.62±0.63	0.35	-0.20	0.91	0.21
Turn	1.53±0.38	1.77±0.45	-0.24	-0.52	0.05	0.10
TTS	2.78±0.44	3.04±0.72	-0.27	-0.70	0.17	0.21
TUG duration	9.66±1.26	10.06±1.49	-0.40	-1.34	0.53	0.39

Table 3 Duration of TUG and each TUG component in healthy elderly and CNP elderly with mild and moderate disability

	CON (n=15)	CNP with mild disability (n = 7)		CNP with moderate disability (n = 8)	
	Mean±SD	Mean±SD	*p*-value	Mean±SD	*p*-value
STS	1.39±0.46	1.85±0.37	0.01*	1.45±0.62	0.94
Walk	3.97±0.91	3.84±0.71	0.96	3.43±0.53	0.11
Turn	1.53±0.38	1.66±0.46	0.72	1.86±0.44	0.08
TTS	2.78±0.44	3.53±0.55	0.01*	2.62±0.58	0.40
TUG duration	9.66±1.26	10.88±0.97	0.01*	9.36±1.54	0.52

CON=healthy elderly, CNP=chronic neck pain, STS=sit-to-stand, TTS=turn-to-sit, *$p < 0.05$ between CON and CNP with mild disability

We further analyzed the trunk angular velocity during TUG components to identify the movement strategy used during those TUG components by independent Kruskal-Wallis. Although there were no statistical differences in peak trunk angular velocity between each group, it can be seen from Table 4 that peak trunk angular velocity of TUG components in CNP elderly with moderate disability tended to be larger than other groups during all TUG components. In contrast, CNP elderly with mild disability tended to have smaller peak trunk angular velocity during all TUG components than healthy elderly.

Table 4 Peak trunk angular velocity of TUG components between sub-group elderly with CNP and control

	CON (n=15)		CNP with mild disability (n = 7)		CNP with moderate disability (n = 8)		*p*-value
	Mean	SD	Mean	SD	Mean	SD	
STS	72.67	25.27	63.29	13.63	66.92	31.04	0.63
Walk	35.68	13.29	33.69	5.55	38.11	6.67	0.45
Turn	119.36	28.65	116.66	22.07	122.9	20.27	0.65
TTS	150.42	34.89	135.51	27.55	167.66	40.52	0.35

CON=healthy elderly, CNP=chronic neck pain, STS=sit-to-stand, Walk=walk (frontal plane), Turn =180 degree turn, TTS=turn-to-sit

4.2 Discussion

This study focused on the gait and balance impairment in elderly with chronic neck pain (CNP) by identifying specific activity during the test of Timed Up and Go (TUG) that older persons with CNP demonstrated their marked impairment. Results showed that elderly with CNP did have more pronounced gait and balance impairment during sit-to-stand (STS) and turn-to-sit (TTS) components of TUG, as seen by the longer duration of those TUG components, especially in the elderly with mild disability.

Previous literature reported that the total duration of TUG can be used to represent balance impairment in the elderly with CNP (Quek et al., 2014). They found that elderly with CNP took a longer time to complete the TUG test than the elderly without CNP. Our study, on the other hand, demonstrated that not all balance impairment in the elderly with CNP can be evaluated by using the total duration of TUG but the sign of balance impairment in the CNP group can also be revealed by other outcomes variables. In this study, older persons with moderate disability (as measured by NDI score >10) showed larger peak angular trunk velocity during all components of TUG, which led to larger trunk acceleration as an indicator of higher trunk sway during TUG performance. These findings indicated poor balance control in CNP elderly with moderate disability. In contrast, impaired balance control in CNP elderly with mild disability (as measured by NDI score $\leq$ 10) can be seen on different outcome variables. CNP elderly with mild disability demonstrated longer total TUG duration while maintaining relatively lower peak angular trunk velocity during all TUG components. The explanation could be due to the tradeoff between speed (accuracy) of trunk control vs speed of movement, such that CNP with mild disability prioritized their trunk control over the speed of movement. The tradeoff between trunk (or balance) control and speed of movement was also seen in patients with stroke when performing arm lifting such that they slowed down their arm movement velocity to maintain standing balance (Garland et al., 1997).

Timed Up and Go (TUG) test is the popular clinical scale used to assess impairment of mobility or dynamic balance in several populations (Poole et al., 2008). However, this test contains several sub-activities, which may be impaired differently among groups of people. In this study, older persons with CNP showed marked impairments in the “sit-to-stand (STS)” and “turn-to-sit (TTS)” components but not in the “walk” component of TUG. STS and TTS components are the postural transition components where a person changes from one to another body posture, thus, they involve larger movement of the head and neck in several planes of movement, as compared with the movement of the head and neck during straight walking. The fact that STS and TTS components triggered larger movements of the neck and head, which are impaired in the elderly with CNP could be the possible explanation for the marked impairment seen during the STS and TTS components of TUG.

The study has some limitations. Participants in this study were active older persons in the community with no fear of fall. Findings in our study could not be generalized to other groups of elderly persons. In addition, this study selected the NDI score to classify the elderly with CNP into 2 groups. Further studies are required to explore whether the use of the NDI score is the most appropriate method to categorize the elderly with CNP when assessing their balance impairment.

Results from this study could benefit the clinicians in planning the assessment for the elderly with CNP. The clinicians should be aware that the elderly with CNP not only have the neck problem, but they also have dynamic balance impairment to some extent, especially when performing activities that require larger neck movement in multiple planes, such as during STS and TTS activities. To assess dynamic balance impairment in the elderly with CNP, this study suggested the measurement of both TUG duration and trunk velocity because the elderly with CNP may use different compensation strategies to safely complete their movement and activity.

5. Conclusion

The “sit-to-stand” (STS) and “turn-to-sit” (TTS) components of the Timed Up and Go test were marked impaired in elderly with chronic neck pain. Those impairments can be reflected by the longer duration of STS and TTS components or larger peak angular trunk velocity.

6. Reference

Chaikeeree, N., Chinsongkram, B., Saengsirisuwan, V., & Boonsinsukh, R. (2018). Effect of cognitive task on components of 7 meter timed up-and-go test in persons with stroke. *ScienceAsia.*, *44*, 247-256.

Garland, S. J., Stevenson, T. J., & Ivanova, T. (1997). Postural responses to unilateral arm perturbation in young, elderly, and hemiplegic subjects. *Archives of Physical Medicine and Rehabilitation*, *78*(10), 1072-1077.

Goldberg, D. S., & McGee, S. J. (2011). Pain as a global public health priority. *BMC Public Health*, *11*(1), 1-5.

Gunter, K. B., White, K. N., Hayes, W. C., & Snow, C. M. (2000). Functional mobility discriminates nonfallers from one-time and frequent fallers. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *55*(11), M672-M676.

Hen, S. S. T. A., Geurts, A. C., van't Pad Bosch, P., Laan, R. F., & Mulder, T. (2000). Postural control in rheumatoid arthritis patients scheduled for total knee arthroplasty. *Archives Physical Medicine and Rehabilitation*, *81*(11), 1489-1493.

Hollands, K. L., Agnihotri, D., & Tyson, S. F. (2014). Effects of dual task on turning ability in stroke survivors and older adults. *Gait & Posture*, *40*(4), 564-569.

Hoy, D., March, L., Woolf, A., Blyth, F., Brooks, P., Smith, E., ... & Buchbinder, R. (2014). The global burden of neck pain estimates from the global burden of disease 2010 study. *Annals of The Rheumatic Diseases*, *73*(7), 1309-1315.

Kendall, J. C., Boyle, E., Hartvigsen, J., Hvid, L. G., Azari, M. F., Skjødt, M., & Caserotti, P. (2016). Neck pain, concerns of falling and physical performance in community-dwelling Danish citizens over 75 years of age: a cross-sectional study. *Scandinavian Journal of Public Health*, *44*(7), 695-701.

Meisingset, I., Woodhouse, A., Stensdotter, A. K., Stavdahl, Ø., Lorås, H., Gismervik, S., ... & Vasseljen, O. (2015). Evidence for a general stiffening motor control pattern in neck pain: a cross sectional study. *BMC Musculoskeletal Disorders*, *16*(1), 1-14.

Misailidou, V., Malliou, P., Beneka, A., Karagiannidis, A., & Godolias, G. (2010). Assessment of patients with neck pain: a review of definitions, selection criteria, and measurement tools. *Journal of Chiropractic Medicine*, *9*(2), 49-59.

Poole, E., Treleaven, J., & Jull, G. (2008). The influence of neck pain on balance and gait parameters in community-dwelling elders. *Manual Therapy*, *13*(4), 317-324.

Quek, J., Brauer, S. G., Clark, R., & Treleaven, J. (2014). New insights into neck-pain-related postural control using measures of signal frequency and complexity in older adults. *Gait & Posture*, *39*(4), 1069-1073.

Salarian, A., Horak, F. B., Zampieri, C., Carlson-Kuhta, P., Nutt, J. G., & Aminian, K. (2010). iTUG, a sensitive and reliable measure of mobility. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *18*(3), 303-310.

Salarian, A., Russmann, H., Vingerhoets, F. J., Burkhard, P. R., & Aminian, K. (2007). Ambulatory monitoring of physical activities in patients with Parkinson's disease. *IEEE Transactions on Biomedical Engineering*, *54*(12), 2296-2299.

Takei, Y., Grasso, R., Amorim, M. A., & Berthoz, A. (1997). Circular trajectory formation during blind locomotion: a test for path integration and motor memory. *Experimental Brain Research*, *115*(2), 361-368.

Takei, Y., Grasso, R., & Berthoz, A. (1996). Quantitative analysis of human walking trajectory on a circular path in darkness. *Brain Research Bulletin*, *40*(5-6), 491-495.

Treleaven, J. (2008). Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control. *Manual Therapy*, *13*(1), 2-11.

Uthaikhup, S., Jull, G., Sungkarat, S., & Treleaven, J. (2012). The influence of neck pain on sensorimotor function in the elderly. *Archives of Gerontology and Geriatrics*, *55*(3), 667-672.

Uthaikhup, S., Sunkarat, S., Khamsaen, K., Meeyan, K., & Treleaven, J. (2014). The effects of head movement and walking speed on gait parameters in patients with chronic neck pain. *Manual Therapy*, *19*(2), 137-141.

Wall, J. C., Bell, C., Campbell, S., & Davis, J. (2000). The Timed Get-up-and-Go test revisited: measurement of the component tasks. *Journal of Rehabilitation Research and Development*, *37*(1).

Woodhouse, A., & Vasseljen, O. (2008). Altered motor control patterns in whiplash and chronic neck pain. *BMC Musculoskeletal Disorders*, *9*(1), 1-10.

Wüest, S., Masse, F., Aminian, K., Gonzenbach, R., & De Bruin, E. D. (2016). Reliability and validity of the inertial sensor-based Timed" Up and Go" test in individuals affected by stroke. *Journal of Rehabilitation Research & Development*, *53*(5).

Zampieri, C., Salarian, A., Carlson-Kuhta, P., Aminian, K., Nutt, J. G., & Horak, F. B. (2010). The instrumented timed up and go test: potential outcome measure for disease modifying therapies in Parkinson's disease. *Journal of Neurology, Neurosurgery & Psychiatry*, *81*(2), 171-176.