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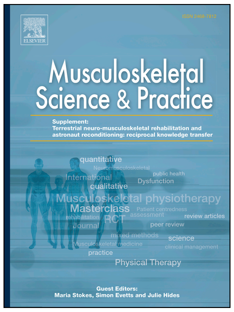

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Katrina Williams, BPhty, Ahmad Tarmizi, BPhty, Julia Treleaven, PhD

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Use of neck torsion as a specific test of neck related postural instability.

Katrina Williams BPhty, Ahmad Tarmizi BPhty, Julia Treleaven PhD

Division of Physiotherapy, School of Health and Rehabilitation Sciences, The University of Queensland, Brisbane 4072, Australia

**Corresponding author Address: Julia Treleaven, Division of Physiotherapy, School of Health and Rehabilitation Sciences, The University of Queensland, Brisbane 4067, Australia. E-mail address: j.treleaven@uq.edu.au*

Phone: 61733654568

Background: Disturbed postural stability in neck pain (NP) is likely due to abnormal cervical afferent function. Several potential causes requires specific diagnostic tests. The neck torsion (head still body rotated) manoeuvre stimulates cervical but not vestibular receptors and identified abnormal cervical afferent input as the cause in patients with NP compared to healthy controls. Comparison between vestibular and NP subjects is now needed.

Aims: To compare individuals with unilateral vestibular loss (UVL), persistent NP and asymptomatic controls. It was hypothesized that neck torsion will increase postural stability in NP compared to both the asymptomatic and UVL groups.

Methods: Twenty UVL, 20 persistent NP and 20 asymptomatic control subjects underwent measurement of postural stability on a computerised force plate with eyes closed in comfortable stance under 5 conditions: neutral head, head rotated 45 degrees (left and right) and neck torsion (left and right) . Root mean square (rms) amplitude of sway was measured in the anterior posterior (AP) and medial lateral (ML) directions. Average torsion and torsion difference (average torsion – neutral neck) were calculated.

Results: NP subjects had significantly greater ($p< 0.05$) AP sway with average torsion and torsion difference compared to both control and UVL. There were no significant differences between control and UVL and no between group differences for neutral neck, rotation or rotation difference.

Conclusion: The results of the study suggest that the torsion manouever may identify cervical afferent causes of disturbed postural stability. This is important for guiding assessment and management of balance disturbances in patients.

Introduction

Sensorimotor control disturbances such as altered head and eye movement control and postural stability have been demonstrated in those with neck pain (NP) of various causes but are generally more prevalent in traumatic NP (Treleaven, 2008, 2011). The cause of these disturbances are most likely due to damage or functional impairment of the abundant and important cervical proprioceptors. Cervical afferents, along with the vestibular and visual systems, provide information to the sensorimotor control system. Specifically, with regard to postural stability, impairments in both static and dynamic balance have been demonstrated. (Schieppati et al., 2003, Sjöström et al. , 2003, Field et al., 2008). Relationships to altered cervical proprioception and impaired postural stability have also been demonstrated experimentally in asymptomatic individuals and support the role of cervical afferent dysfunction as a cause of postural stability deficits in those with NP (McPartland et al. , 1997, Schieppati et al. , 2003, Vuillerme et al. , 2005). Nevertheless other possible causes of these disturbances need to be considered, especially in those with traumatic NP. Potential damage to the peripheral or central vestibular system can occur in conjunction with a whiplash injury, and associated elevated anxiety or medication intake may also alter postural stability(Sturzenegger et al. , 1995, Ernst, 2005). Whilst there is evidence that anxiety and medication intake do not influence mean group outcomes with respect to postural stability in those with persistent whiplash (Treleaven et al. , 2005b) and postural stability deficits due to vestibular disorders are less likely and or present differently to those with whiplash (Treleaven et al. , 2008), there is a need for specific diagnostic tests for differential diagnosis.

The neck torsion (head still body rotated) manoeuvre stimulates the cervical but not the vestibular receptors and has shown potential to identify abnormal cervical afferent input, as an underlying cause of sensorimotor control disturbances in NP (Tjell and Rosenhall, 1998, Treleaven et al. , 2005a, Yu et al. , 2011). It was first described in a test of eye movement control – the smooth pursuit neck torsion test (SPNT) (Tjell and Rosenhall, 1998). Essentially, it compares a person's performance on a test when the head is in a neutral compared to a torsioned position. If performance in torsion is worse compared to neutral it suggests a cervical afferent influence. Previous research has shown SPNT difference occurs in those with NP but not in those with peripheral or central vestibular disorders or asymptomatic individuals and thus justifies its use as a specific test (Tjell and Rosenhall, 1998, Treleaven et al. , 2005c).

The premise of the SPNT test was modified and tested on postural stability in a group of subjects with persistent whiplash compared to healthy asymptomatic controls (Yu et al., 2011). This showed that those with NP have worsening postural stability in torsion when compared to the neutral position. In order to determine its use as a specific test to assist the differential diagnosis of the cause of the postural stability disturbances in those with NP, it now needs to be tested in those with postural instability of another cause ie vestibular pathology (VP).

The aim of this study is to compare postural stability of individuals with VP, persistent NP and asymptomatic controls in various positions including neck torsion to determine whether the neck torsion position adversely affects balance responses. We hypothesised that postural stability will be adversely affected in the neck torsion compared to a neutral position in subjects with NP and there will be no differences in VP and healthy controls.

Methods

Design Overview

This cross-sectional, observational study, sought asymptomatic control subjects, subjects with VP and subjects with persistent NP of similar age and gender.

Setting and Participants

The study was conducted at the Neck pain and Whiplash Research Unit at the XXXXX. Recruitment was through general advertising in the greater XXX area, through vestibular pathology support groups and through University and private practice treatment clinics.

Asymptomatic control subjects were excluded if they had any existing vestibular or cervical pathology, cervical fracture/dislocation, history of traumatic head injury, lower limb disorders, Neck Disability Index (NDI) of greater than 10%, systemic diseases, neurological/respiratory/cardiovascular disorders affecting physical performance or postural stability.

Inclusion/exclusion criteria were ascertained via telephone interview. Inclusion criteria for subjects with NP included NP for greater than three months, and a NDI score greater than 10%(Vernon and Mior, 1991). Exclusion criteria were as listed above.

Inclusion criteria for subjects with VP included those with a medically diagnosed unilateral vestibular loss (ie acoustic neuroma or Meniere's disease) and active VP deficits confirmed by a clinical physical examination including tandem gait, clinical dynamic visual acuity and visual vertical. Exclusion criteria for this group also included other vestibular disorders such as Benign Paroxysmal Positional Vertigo, an NDI of greater than 10%, and any other health conditions listed above that could impair postural stability.

Any subject was also excluded if they lacked at least 45° head rotation to each side.

Ethical clearance for the study was obtained from the Human Medical Research Ethics Committee of XXX. All subjects gave their written informed consent to undertake the study.

Measures

Demographic data such as age, gender, height and weight as well as cause of VP and NP was collected. *The Neck disability index* (NDI) was used to quantify self-perceived disability associated with neck pain. The NDI is both valid and reliable with higher percentage scores indicating greater disability (Cleland et al. , 2006, Vernon, 2008). *The Dizziness Handicap Inventory short form (DHIsf)* (Tesio et al. , 1999) was used as it has been shown to be a reliable and valid measure of perceived handicap associated with symptoms of dizziness or unsteadiness. Lower scores indicate greater handicap.

Computerised posturography

Postural stability in comfortable stance was measured for 30 seconds with eyes closed on a computerised force plate (Kistler 9286A, Switzerland). Centre of pressure force changes in the medio-lateral (ML) and anterior-posterior (AP) directions were measured by four corner strain gauges mounted within the floor. The signal was converted to electrical signals by force transducers and charge amplifiers. An analogue low pass filter was used to restrict the frequency content on the signals to within 0-5Hz. The force signals were AD converted at a sampling rate of 15 Hz and recorded using a LabView (2000 National Instruments) programme.

The subject was positioned on the force platform with the following 5 conditions: 1) neutral – feet in the straight ahead position and the neck neutral, 2 and 3) neck rotation right and left – feet in the straight ahead position with the neck positioned 45° to the right and left measured with a goniometer, 4 and 5) neck torsion right and left – head, body and feet in the 45° position to start, then the head held still in the 45° position and turning the body and feet to the straight ahead position (Figure 1). The torsion manoeuvre was done as above to maintain a consistent foot position on the force plates throughout all tests. One researcher helped to verbally and manually reposition the subject's feet while the head position was maintained and stabilised by another. No manual contact occurred between the subject and the researchers during testing.

Procedure

Questionnaires were completed at the time of testing. Subjects then stood on the force platform for tests of standing balance. Instructions were given to stand as steadily as possible with their eyes closed and arms by their sides. Consistent clear instruction was given for all tests. Each tests lasted 30 seconds as this duration is sufficient to monitor sway and prevent exacerbation of pain from prolonged standing (Mientjes and Frank, 1999). Foot position was repositioned exactly using a paper trace as shown by (McIlroy and Maki, 1997). The starting position for the torsion tests (45 degrees) was also marked on the paper traces. The procedure was performed with each subject completing the five conditions in the same order as above.

Data management and Statistical analysis

Root mean square (rms) amplitude (mm) of sway was measured in the anterior posterior (AP) and medial lateral (ML) directions for each of the 5 test conditions using a labview program as directed by previous research (Field et al. , 2008, Yu et al., 2011).

The values for average torsion (left and right), torsion difference (left /right – neutral neck), and average torsion difference (average torsion – neutral neck) were calculated. Similarly average rotation, rotation difference and average rotation difference was calculated.

SPSS version 22 was used for statistical analysis. Preliminary exploration of the data was performed, outliers were removed, and the data was checked for normality. Differences between the groups for age and gender were assessed using a one-way ANOVA and Fishers exact test respectively. The generalised linear mode, MANOVA, was performed to compare group differences for postural stability- rms for each of the 5 conditions as well as average torsion, average rotation and average torsion and rotation differences. The α level was set at 0.05.

Results

Sixty individuals participated in the study: 20 individuals with unilateral VP, 20 with persistent NP and 20 asymptomatic controls. Group demographic data for age, gender, NDI, and DHIsf are presented in Table 1. There were no significant between group differences for age and gender. Nine subjects with VP had an Acoustic neuroma in situ or removed and 11 had Meneires disease. In the NP group the cause of NP was idiopathic in 7 subjects and whiplash in 13 subjects.

The means, standard errors and significant between group differences for the amplitude of sway are presented for each test condition (Table 2 and Figure 2). Individuals with NP demonstrated significantly greater increases in AP sway with right torsion, right torsion difference, average torsion and average torsion difference compared to both asymptomatic individuals and VP. There were no significant differences between control subjects and VP and no between group differences for neutral neck, rotation or rotation difference. There were no differences seen for ML sway on any of the measures.

Discussion

The results of the study suggest that increases in postural sway seen between neutral and the torsion manouever could be useful in specifically identifying cervical afferent causes of disturbed postural stability.

Subjects with NP demonstrated that postural instability was increased in AP direction in both the torsion position and in the torsion position compared to the neutral position when in an eyes closed, comfortable, stance position. These changes were not seen when the head was simply rotated relative to the trunk. Together these results imply that the altered cervical afferent input created by the neck torsion position is the reason for these changes in the neck pain group. The torsion position does not alter afferent input from the vestibular apparatus as the head is held still throughout. The neck rotation position however, may have stimulated and allowed a positive contribution from vestibular afferents and thus why no changes were seen with neck rotation alone**.** Additionally, the fact that changes were only seen the in the AP rather than the ML direction also suggests somatosensory impairment rather than vestibular impairment. (Shumway-Cook and Horak, 1986, Horak and Macperson, 1996, Ruhe et al. , 2013).

Further, such changes were not seen in the vestibular or control group. These results are similar to the previous study regarding balance in torsion and neck rotation between neck pain and asymptomatic controls (Yu et al., 2011). The results are also similar to those using the torsion manoeuver to demonstrate altered smooth pursuit eye movement in neck pain. In these studies, subjects with NP also demonstrate differences in the torsion position compared to neutral whilst subjects with VP and controls do not (Tjell and Rosenhall, 1998, Treleaven et al., 2005a). Interestingly no group differences were seen in the neutral position, which was also similar to the previous study on postural stability and other studies looking at smooth pursuit eye movement (Tjell and Rosenhall, 1998, Treleaven et al., 2005a, Yu et al., 2011), although significantly increased sway has previously been seen in those with whiplash compared to healthy individuals in the eyes closed neutral position (Treleaven et al., 2005b, Field et al., 2008) . This is likely due to either higher levels of pain and disability or dizziness or larger subject numbers. Overall, this suggests that testing balance in the neck torsion position might be more sensitive in determining balance deficits in those with neck pain.

Limitations

One limitation of this study is low subject numbers that may have affected statistical power for some of the measures, although the results support our hypothesis particularly regarding torsion difference. The VP participants studied were chosen to include those with discreet unilateral peripheral dysfunction which is not representative of all those with VP and future research may need to consider this. Further, in this study, age, medication use and other comorbidities, that may adversely affect balance, were not deliberately limited. It would be interesting to see for example if elders and others with comorbidities with neck pain also respond in a similar way to the neck torsion manoeuvre. Nevertheless, whilst such co-morbidities may influence the individual tests, they should not influence the main objective of the test, which is to compare responses in a neutral versus torsioned position, which should allow for these individual co-morbidities to be controlled for and eliminated.

Clinical implications and future directions

The immediate clinical implication of this study is that the torsion manoeuvre has potential to differentiate between cervical afferent compared to vestibular dysfunction. The knowledge obtained from this study is an additional step towards helping clinicians differentiate the underlying cause of sensorimotor dysfunctions in people with neck pain and vestibular disorders just as the SPNT test has been adopted for cervical afferent dysfunction in eye movement control (Tjell and Rosenhall, 1998, Treleaven et al., 2005c, L'Heureux-Lebeau, 2014 #4542). This also has important implications for enhancing the understanding of the origins of postural instability in patients. Specifically testing the difference in sway between the neutral and torsion position could allow clinicians to establish whether poor postural control in individuals is due to altered sensory input at the neck region rather than inner ear structures or other causes. There is also potential that this could also be useful in determining a cervical component in those with vestibular pathology who often demonstrate associated or concomitant neck complaints (Winteler et al. , 2009, Wilhelmsen and Kvale, 2014) but more research is required. Future research is also required in the use of clinical methods of balance assessment. This study used sophisticated force plates to measure the rms of the sway balance in both the AP and ML directions, which is not easily adapted to the clinic. Future research should determine whether using other clinically available methods of balance measurement using the torsion manoever can give similar results.

Conclusion

Overall, this study has demonstrated that the neck torsion position in the eyes closed comfortable stance position adversely affects AP balance responses in subjects with NP when compared to both asymptomatic and subjects with discreet unilateral vestibular pathology. The results affirm that somatosensory impairment is the most likely cause of balance disturbances with NP. This study demonstrated that the torsion test, specifically the difference between torsion and the neutral position, may be more suitable than others as a measure of altered cervical afferent input causing deficits in postural stability because vestibular stimulation is avoided and individual co-morbidities can be controlled.

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Figure 1. Neck torsion- participant starts with feet positioned 45degrees to the left or right. Participants head is held in this position while the feet are assisted to be placed in the neutral facing position.

Figure 2: Comparison of average and changes in root mean square (mm) between the three subject groups following the neck rotation and neck torsion manoeuvre to the left and right sides in comfortable stance eyes closed on a firm surface in the anterior-posterior direction. Error bars indicate the standard error of the measurement. =p<0.05 significant difference between the subject groups.

Table 1

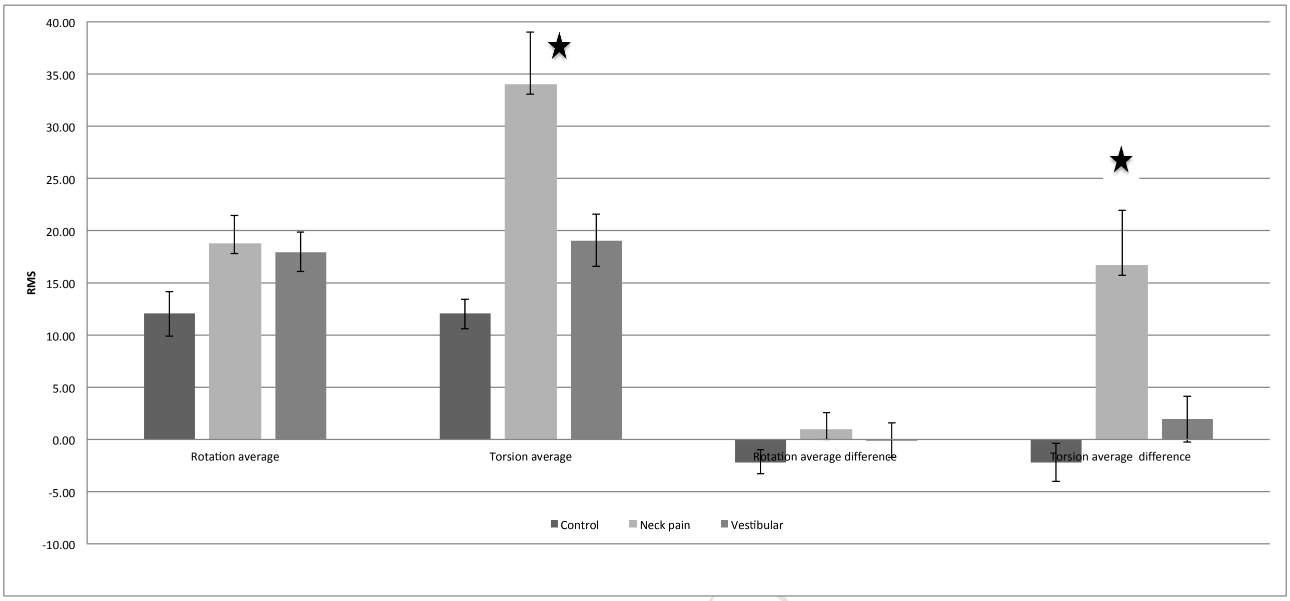
Subject demographics (means and standard deviation for the control, neck pain group and unilateral vestibular pathology group. p-values between neck pain and vestibular group are presented.

	Control (n=20)	Neck pain (n=20)	Vestibular (n=20)	p
Age/years	33.5(7)	39.7 (9.6)	45.35 (9.8)	0.08
NDI/%	0.20 (1)	38.9 (22)	2.11 (2.9)	0.00
DHIsf/13	13 (0)	8.3 (4.1)	6.73 (3.5)	0.49
Gender % females	30	65	55	0.9

NDI = Neck Disability Index, DHIsf = Dizziness Handicap Inventory short-form: a score of 13 indicates no handicap due to dizziness

Table 2 Mean, standard deviation and significant between group differences for the root mean square (rms) distance (mm) of each comfortable stance test in the anterior posterior (AP) direction. Bold indicates significant difference ($p<0.05$) between the groups.

Test	Control n=20	Neck pain n=20	Vestibular n=20	**P** value Control compared to neck pain	P value neck pain compared vestibular
Neutral	14.23 (9.5)	17.36 (9.4)	17.14 (8.7)	1.00	1.00
Rotation L	12.18 (9.4)	17.79 (11.9)	16.18 (7.9)	0.44	1.00
Rotation R	12.01 (9.8)	18.80 (12.6)	17.96 (10.2)	0.31	1.00
Torsion L	13.39 (7.4)	33.83 (25)	19.54 (14.7)	**0.002**	0.05
Torsion R	10.64 (7.3)	34.24 (25.8)	18.6 (12.2)	**0.001**	**0.02**
Rotation L diff	-2.2 (5.7)	1.44 (6.9)	0.83 (9.1)	0.74	1.00
Rotation R diff	-2.1 (5.4)	0.43 (7.8)	-0.96 (6.5)	0.36	1.00
Torsion L diff	-0.84 (11)	16.47 (26.6)	2.4 (13.8)	**0.01**	0.06
Torsion R diff	-3.59 (6.0)	16.88 (26.7)	1.46 (9.4)	**0.001**	**0.02**



Rotation average = (neck rotation left and right)/2, Torsion average = (neck torsion left and right)/2, Rotation difference= Difference between neutral and average rotation, Torsion difference = Difference between neutral and average torsion.

- Neck torsion adversely effects balance in AP comfortable stance in INP.
- Changes in balance stability in neck torsion may identify a cervical cause.
- This test avoids vestibular stimulation and co-morbidities can be controlled.