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SMOOTH PURSUIT NECK TORSION TEST IN WHIPLASH-ASSOCIATED DISORDERS: RELATIONSHIP TO SELF-REPORTS OF NECK PAIN AND DISABILITY, DIZZINESS AND ANXIETY

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Objective: **The smooth pursuit neck torsion test is thought to be a measure of neck afferent influence on eye movement control and is useful in assessing subjects with whiplash, especially those complaining of dizziness. Nevertheless, it is not known whether impairments identified relate only to abnormal cervical afferentation or are influenced by levels of anxiety or neck pain.**

Design: **A prospective, 3-group, observational design.**

Subjects: **One hundred subjects with persistent whiplash (50 complaining of dizziness, 50 not complaining of dizziness) and 50 healthy controls.**

Methods: **The smooth pursuit neck torsion test was performed and analysed taking into account subjects' reported levels of pain, anxiety and dizziness.**

Results: **The results confirm that there are significant ($p < 0.01$) differences in the smooth pursuit neck torsion test between subjects with persistent whiplash both with dizziness (mean 0.11) and without dizziness (mean 0.07) compared with healthy control subjects (mean 0.01). The results suggest that the test is not influenced by a patients' level of anxiety, but may be influenced by both nocioceptive and proprioceptive factors.**

Conclusion: **The results provide further evidence of the usefulness of the smooth pursuit neck torsion test to identify eye movement disturbances in patients with whiplash, which are likely to be due to disturbed cervical afferentation.**

Key words: eye movement, smooth pursuit, whiplash, postural control, proprioception, dizziness.

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INTRODUCTION

Patients with whiplash-associated disorders (WAD) often present with complaints of dizziness, unsteadiness as well as visual disturbances in association with their neck pain syndrome (1, 2). A number of studies have identified disturbances in smooth pursuit eye movement in these patients as well as those with idiopathic neck pain (3–8, 9). These symptoms may reflect injury to cervical or peripheral vestibular structures, injury to the brain stem or higher centres in the central nervous system (CNS). Alternatively, such patients are often taking medication and have elevated anxiety levels, all of which could also contribute to symptoms of dizziness or visual disturbances (10–13). It has also been suggested that malingering and symptom amplification for financial gain could underlie such symptoms in some cases of WAD (14, 15).

Recently Tjell & Rosenhall (7) reported on a method (the Smooth Pursuit Neck Torsion Test (SPNT)), which is thought to test the proprioceptive reflexes of the neck, the cervico-collic reflex (CCR) and the cervico-ocular reflex (COR). Abnormal values in the SPNT are thought to result primarily from erroneous postural proprioceptive activity in the neck transmitted by these reflexes. The SPNT appears to be able to differentiate between smooth pursuit abnormalities from a peripheral vestibular, brain stem or higher CNS cause from that of a cervical cause. In the test, eye movement is measured with the head in a neutral forward facing position and then with the trunk rotated beneath the head (a torsion manoeuvre of the neck). The latter position would stimulate the cervical receptors but not the vestibular receptors. Tjell & Rosenhall (7) demonstrated that a change in smooth pursuit eye movement from the neutral to the neck torsioned position does not occur in normal subjects or in subjects with brain stem infarcts, higher CNS or peripheral vestibular dysfunction. It does however occur in subjects with neck disorders of both traumatic and non-traumatic origin (7, 9). Subjects with neck pain caused by trauma, however, displayed greater deficits than those with idiopathic neck pain (9). Furthermore, the SPNT appears to be able to differentiate neck injured patients from healthy controls, those with peripheral vestibular and CNS disorders such as brain stem infarcts, patients with fibromyalgia as well as patients with idiopathic neck pain (7, 9). This test demonstrated good sensitivity (72%) and specificity (91%) as a specific test for diagnosing WAD (7, 9).

Nevertheless there has not been extensive investigation of other factors that could influence test results. Medications might influence test performance but are unlikely to affect results as they could be expected to impair pursuit quality equally in both neutral and torsioned directions and not cause an asymmetry. Eye movement would be difficult to alter voluntarily in a

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consistent manner over many cycles (malingering), as this would likely cause bizarre saccades of varying amplitudes (7). In contrast, anxiety and any associated increased neck muscle tension with attendant abnormal proprioceptive signals could influence the SPNT (7), but the effects of self-reported anxiety have not been investigated. Nor has there been extensive investigation of the effects of levels of neck pain and disability on the results of the SPNT. It was shown that subjects with WAD complaining of dizziness have higher levels of pain (2) and higher SPNT values (7), but the relationship between the levels of pain and disability or the handicap associated with the dizziness and the SPNT measures in subjects with WAD is unknown.

The aims of this study were to further investigate the value of the SPNT in identifying differences in whiplash subjects with and without dizziness and healthy controls and to determine whether responses were influenced by anxiety level. Secondly, the relationships between the SPNT and characteristics of neck pain and disability, and dizziness and disability were sought in order to better understand the proprioceptive or nocioceptive mechanisms behind the SPNT. This study also took into account medication intake and whether the whiplash patient had a current compensation claim.

METHODS

Subjects

One hundred subjects with persistent pain and disability associated with a whiplash disorder (longer than 3 months since injury) participated in this study. All subjects were categorized as WAD 11 according to the Quebec Task force classification (16) and their symptoms were not abating. Fifty subjects with WAD reported dizziness and unsteadiness and 50 did not report these symptoms in association with their pain. Subjects were recruited from consecutive eligible patients attending the Whiplash Research Unit in the Division of Physiotherapy at The University of Queensland and from advertising in the local media. Subjects with WAD were not considered if they reported either a period of unconsciousness or concurrent head injury at the time of the motor vehicle crash or if they had a history of dizziness prior to the injury. Subjects with known or suspected vestibular pathology such as benign paroxysmal positional vertigo were also not included in the study. Likewise they were not considered if they did not have at least 30 degrees of cervical rotation to either side, as these would preclude their undertaking the SPNT. The 50 subjects with dizziness (WAD D) comprised 38 females and 12 males, with a mean age of 35.5 years (range 19–46 years). The mean time since injury was 1.4 years (range 0.35–3 years). The 50 without dizziness (WAD ND) comprised 38 females and 12 males, with a mean age of 35.0 years (range 18–46 years). The mean time since injury was 1.6 years (range 0.3–3 years). Subjects were asked to refrain from taking any medication at least 24 hours prior to the study.

The control group was drawn from healthy volunteers who responded to advertising in a local newspaper and on the university campus. Volunteers were included in the study provided that they had no current or past history of whiplash or neck pain, did not suffer from headaches and had no history of dizziness. The control group consisted of 50 subjects (30 females and 20 males) with a mean age of 29.9 years (range 19–45 years). Ethical clearance for this study was granted from the Medical Ethics Committee of The University of Queensland and all participants provided their informed consent.

Instrumentation and measurement

Questionnaires. The subjects with WAD completed a general questionnaire that provided information related to the history of the whiplash injury, compensation status, current pain level using a 10-cm visual analogue scale (VAS) and current usual medications. They also completed a series of questionnaires to provide measures of pain, dizziness and anxiety and perceived disability to pain and dizziness. These included the Neck Disability Index (NDI) (17), which incorporates pain and functional limitations, to determine the disability level associated with the neck pain and the State Trait Anxiety Inventory-Short Form (STAIT) (18). Both the "state" (how they felt at the time of the investigation) and the "trait" (how they generally felt) were used as a measure of anxiety associated with the whiplash disorder. Subjects complaining of dizziness also completed the Dizziness Handicap Inventory (DHI) (short form) (19) to determine the perceived handicap associated with symptoms of dizziness/unsteadiness.

Smooth Pursuit Neck Torsion Test. Electrooculography (EOG) was used to measure and record eye movement while following a moving target. The procedure was adapted and is similar to that described by Tjell and Rosenhall (7). The target consisted of a laser light driven by a motor to move through a visual angle of 40 degrees. The target was electronically controlled to provide a moving sinusoidal stimulus with a maximum velocity of 20 degrees per second and a frequency of 0.2 Hz. Pairs of Ag/AgCl surface electrodes (Cleartrace ConMed USA) were placed on the skin just lateral to the eyes bilaterally to record eye movement via changes in the corneo-retinal potential. A ground electrode was placed on the forehead. The signals were passed through a 70 Hz low pass filter and stored on an IBM-compatible PC that continually recorded the change in corneo-retinal potential and eye position relative to the target during each test sequence. The data was stored for later analysis. Data collection and analysis were performed by the same examiner (JT), however the subject data was de-identified prior to analysis by an independent member of the research team to ensure the examiner was blinded to the subject group.

For each test the data was graphed using a Labview program. The average velocity of the eye movements as they followed the target, was calculated by subtracting the corrective movements from the total excursion of the gaze. A software program (Labview) was written to calculate the total excursion of each gaze and to allow manual identification and subtraction of the corrective saccades. The program then formulated the corrected gain for each cycle. Square waves as defined by Schalen (20) and blinks (judged from recorded examples of an actual blink from each subject) were disregarded from the analysis. The mean gain (i.e. the ratio between the eye movements and of target) from the sixth to the ninth cycles was the measure used to define smooth pursuit movements. The smooth pursuit (SP) gain was calculated with the neck in a neutral position, and also with the neck in a torsioned position. The average gain for neutral (SP neutral) and torsion to the left (SP left) and right (SP right) was calculated. The difference between the gain in neutral and the average values in torsion equalled the smooth pursuit neck torsion difference (SPNT).

Procedure

The subjects with WAD first completed the questionnaires and were asked to rate their current levels of pain and anxiety prior to the SPNT test. The SPNT procedure was performed as described by Tjell & Rosenhall (7). The subject was seated in a chair with a back support, facing the laser light projected onto a screen. The skin adjacent to the eyes and forehead was washed, lightly abraded and swabbed with alcohol. The electrodes were then applied. The subjects were instructed to follow the light as closely as possible with their eyes, trying not to blink while keeping their head still. To assist with interpretation of the signal, the examiner asked the subject to perform 3 blinks (as a recording of likely blinks for that subject) immediately prior to when the target commenced moving. The examiner also gently held the head still during the testing procedure to prevent head movement. The test was performed in 3 different starting positions. The first was with the neck in a neutral position, that is, the subject facing straight ahead. For the second test, the head was kept in a neutral position, and the subject's torso was actively turned to an angle of approximately 45 degrees. In rare instances where this angle caused any pain or discomfort the angle was reduced (minimum 30 degrees) until these symptoms subsided and the angle recorded. The examiner gently maintained the head and trunk position. Once in the desired neck torsion position, and after a short pause, the visual stimulus was presented again and the test repeated. The procedure was repeated in the opposite direction of neck torsion. Thus the subjects' ability to follow the target was measured in 3 test positions; torso and neck neutral, torso to the left with neck neutral (right neck torsion) and torso turned to the right neck neutral (left neck torsion).

Data management and statistical analysis

Both the "state" (how they felt at the time of the investigation) and the "trait" (how they generally felt) scores of the State trait anxiety inventory-short form (18) were prorated to the full score. The scores were calculated out of a possible score of 80, where a score of 20 indicates little anxiety and a score of 80 indicates maximum anxiety. The NDI was scored following the methodology of Vernon & Moir (17) to calculate the neck pain and disability index. The DHI (short form) (19) was scored out of a possible score of 13, where 13 indicates no dizziness handicap and 0 maximum handicap. An analysis of deviance using the normal distribution was used to investigate any differences between WAD groups for the neck disability index, VAS, age, duration since injury and anxiety scores.

A generalized linear model MANOVER was used to compare the values of SP neutral, SP left neck torsion and SP right neck torsion, the average SP for the left and right torsioned position (Av SP) and the difference between neutral and torsioned positions (SPNT value) between the 3 groups (controls, WAD D, WAD ND). To determine whether regular medication intake or compensation status could account for differences in SPNT values, subjects were categorized as either not, or usually taking medication, not seeking or seeking compensation. Medication use, compensation status, current and general anxiety levels, the NDI, VAS and age were included as separate factors in the MANOVA both for the WAD D group and the WAD ND group. If any of the factors had a significant influence on between subjects SPNT measures, it was included as a co-variate into the final between groups analysis.

A correlation analysis, Spearman's rho, was performed to determine any correlation between DHI, NDI, STAIT- trait and state, VAS and SPNT. The statistical program SPSS was used for all calculations.

RESULTS

There were no significant differences between the WAD groups for age, gender, anxiety scores (State and Trait), compensation status, medication status or duration of symptoms (Table I). There was a significant difference between the WAD D and WAD ND groups in the measures of pain on both the current pain level (VAS) and the NDI scores. For both measures, the group reporting dizziness (WAD D) scored higher than the group without dizziness (WAD ND) (Table I). The control group was significantly younger ($p < 0.02$) than both WAD groups. To ensure these factors did not influence the results, they were included as factors in the between-group analysis.

The mean and standard errors for the SP neutral, SP left torsion, SP right torsion, average SP torsion and the difference between the neutral and torsion position (the SPNT) for the WAD D, WAD ND and control groups are presented in Table II. Age, VAS and NDI scores were included as factors in the analysis. The results indicated that the SPNT difference was statistically greater in the WAD D group compared with the WAD ND group. All values were significantly greater in the WAD ND group compared with the controls.

The results for the between-subjects effects for both the WAD D and the WAD ND groups for medication use, compensation status, current and general anxiety levels, the NDI, VAS, duration of symptoms and age on the SPNT difference are presented in Table III. There were no between-subjects' effects for medication use, compensation status, age, duration of symptoms, current pain level (VAS) or general or current anxiety levels on the SPNT difference. However there were

Table I. *Demographics of the subjects with whiplash-associated disorders (WAD)*

	WAD D ($n = 50$) Mean (SE)	WAD ND ($n = 50$) Mean (SE)
Time since injury (years)	1.4 (0.11)	1.6 (0.14)
Pain at rest (VAS/10)	4.1 (0.32)	2.8 (0.29)*
Neck disability index (%)	46.4 (2.1)	34.4 (2.0)*
State anxiety/80	32.2 (1.4)	32.4 (1.4)
Trait anxiety/80	48.9 (2.0)	44.7 (1.5)
Involved in compensation (%)	74	68
Usually take medications (%)	70	52
DHI	6.42 (0.37)	–

D = complaining of dizziness; ND = not complaining of dizziness; VAS = visual analogue scale; DHI = Dizziness Handicap inventory; SEM = standard error of the mean.
* Statistically significant at $p = 0.05$.

Table II. *Mean and standard errors for the smooth pursuit (SP) gain in neutral, SP left torsion, SP right torsion, average SP torsion and the difference between neutral and average torsion (SPNT) for the whiplash associated disorders not complaining of dizziness (WAD ND): whiplash associated disorders complaining of dizziness (WAD D) and control groups*

	WAD D $n = 50$	WAD ND $n = 50$	Control $n = 50$
SP Neutral	0.81 (0.01)	0.82 (0.01)	0.88 (0.01)#
SP Left	0.70 (0.02)	0.74 (0.02)	0.87 (0.02)#
SP Right	0.69 (0.02)*	0.78 (0.12)	0.88 (0.02)#
Av SP	0.70 (0.02)*	0.76 (0.02)	0.87 (0.02)#
SPNT (Difference)	0.11 (0.01)*	0.07 (0.01)	0.01(0.01)#

* Significant difference WAD D and WAD ND $p < 0.004$.
# Significant difference WAD ND and controls $p < 0.002$.

Table III. *Between subjects effects (F and p values) on the Smooth Pursuit Neck Torsion Test for both whiplash associated disorders complaining of dizziness (WAD D) and whiplash associated disorders not complaining of dizziness (WAD ND) subjects concerning age, compensation status, duration of symptoms, medication use, current and general anxiety levels, the Neck Disability Index (NDI), and VAS. (Degrees of freedom = 1)*

	WAD D $n = 50$		WAD ND $n = 50$	
	F	p	F	p
Age	1.43	0.24	1.20	0.28
Compensation	1.73	0.20	0.21	0.65
Duration	0.98	0.33	0.28	0.60
Medication	2.16	0.48	0.73	0.40
NDI	1.56	0.22	3.893	0.05*
State	0.92	0.34	0.03	0.86
Trait	0.01	0.94	0.08	0.77
VAS	2.22	0.14	0.19	0.66
DHI	4.92	0.03*		

* Significant between-subjects effect.

Table IV. *Correlation coefficients (Spearman's rho) between smooth pursuit average torsion and Dizziness Handicap inventory (DHI), Neck disability index (NDI), Neck pain intensity (VAS), Anxiety level at time of testing (STATE), General anxiety level (TRAIT) scores*

	Smooth Pursuit Neck Torsion Test (SPNT)		
	WAD D	WAD ND	WAD (Total)
Smooth pursuit neck torsion (SPNT)	–	–	–
Dizziness Handicap Inventory (DHI)	−0.31*	–	–
Neck Disability Index (NDI)	0.18	−0.22	0.09
Neck pain intensity (VAS)	0.26	0.11	0.27*
Anxiety level at time of testing (STATE)	−0.15	0.09	−0.02
General anxiety level (TRAIT)	−0.05	−0.08	−0.01

* Significant at $p = 0.05$.

significant negative between-subjects' effects for the WAD ND group, for reported levels of pain and disability (NDI), that is, those with greater pain tended to have less SPNT deficits. For the WAD D group there were no significant between-subjects' effects for NDI, but the level of handicap associated with the dizziness (DHI) demonstrated an effect on the SPNT difference.

The correlation coefficients (Spearman's rho) between the SPNT difference and the DHI, NDI, VAS, STATE, and TRAIT scores are presented in Table IV. When the WAD groups were considered individually, there was no correlation between the SPNT and either the State or Trait level of anxiety, duration, age, NDI or VAS. In the WAD D group, DHI scores demonstrated a mild correlation to the SPNT difference. When all subjects with WAD were considered together, a significant but weak correlation was seen between VAS scores and the SPNT ($r = 0.27$).

DISCUSSION

The results of this study confirm that the SPNT can detect deficits in those subjects with persistent WAD who do, and do not complain of dizziness and or unsteadiness compared with healthy control subjects. Subjects complaining of dizziness (WAD D) had greater deficits in eye movement control as measured by the SPNT than those subjects not complaining of dizziness (WAD ND). Our results in the neck torsion positions are similar to those documented by Tjell and colleagues (7, 9) and Hildingson et al. (4) although the overall difference (SPNT) was slightly smaller on average than that of Tjell and colleagues (7, 9). The results add support to the validity of the SPNT test to detect physiological impairments in patients following a whiplash injury. This is further substantiated by the findings that reported levels of anxiety did not influence the SPNT results. As expected, Trait and State anxiety scores for the WAD group were higher than normative values (10, 13), but neither the subjects' general perceived level of anxiety (trait), nor their anxiety at the time of testing (state), had any influence on the SPNT measure. Furthermore, the results of the SPNT were not influenced by medication or compensation status.

The lack of influence of anxiety, medication and compensation status on the differences found in the SPNT test in this study suggests that the differences between the whiplash and control subjects are most likely due to disturbances to the postural control system, specifically, primary altered afferent input from the cervical spine. It could be argued that the torsion manoeuvre could stress the vertebral artery, which has the potential to be damaged in a whiplash injury (21). However trauma to the vertebral artery is considered to be rare in those with a pure whiplash injury (that is a primary injury to the neck without associated concussion, head injuries, or fractures) (22). Furthermore, any reduced blood flow in the vertebral artery is likely to be asymptomatic in neck torsion manoeuvres due to compensation by collateral vessels (23, 24). Concomitant arteriosclerosis associated with vertebral artery insufficiency is also unlikely to be a cause of the SPNT differences in our relatively young cohort of pure whiplash subjects.

While it is possible that brain stem and/or peripheral vestibular dysfunction could occur in a whiplash injury, it is generally felt that peripheral vestibular, brain injury and brain stem dysfunctions are also rare in those with a pure whiplash injury (25–28). In this study, all of our subjects had a pure whiplash injury and were excluded if they had a known or suspected peripheral vestibular or a brain injury. Furthermore, as other studies have shown that differences in smooth pursuit in the neck torsion position have not been identified in subjects with peripheral vestibular dysfunction, brain stem infarcts or higher CNS disorders (7), these sites are unlikely to be the cause of the SPNT deficits seen in our study. Nevertheless concomitant pathology and, or secondary adaptive changes in brain stem mechanisms as a result of the altered central modulation of cervical afferent input, are possible and future studies to determine the importance of these factors following a whiplash injury are necessary.

Our contention is that the most likely primary cause of the disturbances in our whiplash group classifiable as WAD II, is abnormal cervical afferent input from damaged neck joint and muscle receptors. The debate continues, however, as to whether the cause of abnormal cervical afferent input is proprioceptive or nocioceptive in nature. Altered proprioceptive input could arise from tissue/receptor damage or possibly altered muscle tension in the cervical region. Muscle activity was not measured in this study. However Tjell (29) determined abnormalities using the SPNT test in a group of subjects with maxillo-facial pain, and proposed that the origin of the disturbance could have been increased tension in the neck muscles. The maxillo-facial pain subjects had similar patterns of disturbance to WAD subjects although the disturbances were significantly less than those observed in WAD subjects. This implies that there are additional influences on the postural control system following a whiplash injury, possibly due to either direct damage to neck receptors or the influence of local neck pain or both.

This study determined a positive but weak relationship between the current level of pain (VAS) and the SPNT measures in the whiplash group as a whole, which is in agreement with the results of Tjell et al.'s (9) study of patients with neck pain of both traumatic and insidious origin. However the relationship between the findings of the SPNT test and the symptoms of pain and dizziness as well as their related functional disabilities, is far from clear. Our whiplash patients with dizziness had higher SPNT values and higher average levels of resting pain (VAS) and higher scores of neck pain and disability (NDI) than the group without dizziness but there was no relationship between NDI scores and SPNT results in the whiplash patients with dizziness. While these subjects had greater deficits in the SPNT test, there was only a weak relationship between the level of handicap associated with the dizziness (DHI) and disturbances in eye movement control (SPNT). Tjell et al. (9) found a strong relationship between deficits in the SPNT test and dizziness but not with current pain level. Thus the underlying mechanisms of the deficits measured in the SPNT test are not obvious at this time but it appears that both cervical proprioceptive and nocioceptive factors, as well as others, may contribute to the eye movement disturbances found in patients with persistent whiplash associated disorders.

In conclusion, this study has determined that smooth pursuit neck torsion eye movement disturbances are present in patients with persistent neck pain following a whiplash injury and that disturbances are greater in those patients also reporting the symptom of dizziness in association with their pain. These disturbances were not influenced by the subjects' reported levels of anxiety, medication or compensation status and are likely due to altered afferent input from the cervical spine. It is likely that proprioceptive and nocioceptive factors influence the results of the SPNT, but further research is necessary to clarify the underlying causes.

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