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DIZZINESS AND UNSTEADINESS FOLLOWING WHIPLASH INJURY: CHARACTERISTIC FEATURES AND RELATIONSHIP WITH CERVICAL JOINT POSITION ERROR

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Dizziness and/or unsteadiness are common symptoms of chronic whiplash-associated disorders. This study aimed to report the characteristics of these symptoms and determine whether there was any relationship to cervical joint position error. Joint position error, the accuracy to return to the natural head posture following extension and rotation, was measured in 102 subjects with persistent whiplash-associated disorder and 44 control subjects. Whiplash subjects completed a neck pain index and answered questions about the characteristics of dizziness. The results indicated that subjects with whiplash-associated disorders had significantly greater joint position errors than control subjects. Within the whiplash group, those with dizziness had greater joint position errors than those without dizziness following rotation (rotation (R) 4.5° (0.3) vs 2.9° (0.4); rotation (L) 3.9° (0.3) vs 2.8° (0.4) respectively) and a higher neck pain index (55.3% (1.4) vs 43.1% (1.8)). Characteristics of the dizziness were consistent for those reported for a cervical cause but no characteristics could predict the magnitude of joint position error. Cervical mechanoreceptor dysfunction is a likely cause of dizziness in whiplash-associated disorder.

Key words: cervical dizziness, whiplash, mechanoreceptors, proprioception.

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INTRODUCTION

Whiplash-associated disorders (WAD) are still relatively poorly understood from both a diagnostic and a management perspective. Although the majority of people recover within a few weeks or months, it is estimated that between 12 and 40% will go on to have persistent problems (1). After pain, dizziness and unsteadiness are the next most frequent complaints. Between 40 and 70% of those suffering from persistent WAD have these symptoms and they are often associated with reports of loss of balance and falls, revealing the significance of the problem to the sufferer (2).

There are many possible causes of dizziness and unsteadiness following a whiplash injury. Symptoms are often attributed to medications and the anxiety caused by the ongoing problems (3). Recent evidence suggests that disturbances to the postural control system are more likely to underlie these symptoms due to traumatic damage to the vestibular receptors, neck receptors, or directly to the central nervous system (2, 4–6). It can be difficult to determine exactly which of these is responsible for the dizziness following whiplash. When there is no traumatic brain injury, abnormal cervical afferent input from damaged or functionally impaired neck joint and muscle receptors is considered the likely cause (2, 5–8). Argument continues, as specific diagnostic criteria or measures to confirm the presence of a cervical cause of dizziness are limited (3, 9).

Dizziness of cervical origin has been defined as a non-specific sensation of altered orientation in space and dysequilibrium. It originates from abnormal afferent activity from the extensive neck muscle and joint proprioceptors, which converges in the central nervous system with vestibular and visual signals, confusing the postural control system (9, 10). True vertigo (environment and self spinning), which is associated with vestibular pathology, is not a common symptom of cervicogenic dizziness. Rather, more common complaints of cervicogenic dizziness are perceptual symptoms of disorientation and vague unsteadiness, which occurs in episodes lasting minutes to hours. Such dizziness is exacerbated with neck movements or increased neck pain. Cervicogenic dizziness should have a close temporal relationship with neck pain, injury or pathology and accordingly, relief of dizziness is often associated with relief of neck pain (11).

An objective measure of neck reposition sense (joint position error (JPE)), may relate well to cervicogenic dizziness, as it is considered primarily to reflect afferent input from the neck joint and muscle receptors. This measure is based on the ability to relocate the natural head posture (7, 12–14). Deficits in JPE have been shown in subjects with neck pain of both insidious and traumatic onset (7, 12). Heikkila & Wenngren (14), in an initial study of 27 subjects with WAD, suggested that subjects complaining of dizziness had greater neck repositioning errors than subjects who did not. This suggests that subjects with complaints of dizziness and unsteadiness may have these symptoms as a result of a greater degree of abnormal afferent input from the cervical mechanoreceptors.

This study aimed to explore in more detail the nature of dizziness in subjects with persistent WAD and links between dizziness and JPE. More specifically, the study sought to determine whether there was any difference in JPE between

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those subjects with persistent WAD who complained of dizziness and or unsteadiness compared with those not reporting these symptoms. Self-reports of dizziness and or unsteadiness were documented in detail, to examine whether any specific features of the complaints related to greater deficits in JPE.

METHODS

Subjects

A total of 105 subjects with a chronic WAD (greater than 3 months since injury) participated in this study (Group WAD). They were recruited from patients sequentially referred to a Whiplash Research Unit at The University of Queensland. WAD subjects were excluded if they reported either a period of unconsciousness or concurrent head injury at the time of the accident or if they had a history of dizziness prior to the injury. Ten subjects were not considered on these grounds. The WAD subjects accepted into the study comprised 76 females and 29 males, aged 18–67 years (mean 39.34 years, range 18–67 years). The mean time since injury was 1.24 years (range 0.26–12.0 years) and symptoms were not abating. Ninety-six subjects were categorized as WAD II and 9 subjects as WAD III according to the Quebec Task force classification (15). Subjects were not asked to refrain from taking any medication prior to the study. The control group (Group C) 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 comprised 44 subjects (29 females and 15 males) with a mean age of 34.1 years (range 19–62 years). Ethical approval 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

The WAD subjects completed a general questionnaire relating to the history of the whiplash injury, the presence or absence of dizziness and or unsteadiness and current medications. They also completed the Northwick Park Neck Pain Questionnaire to record current disability level (16). Specific questionnaires for dizziness of cervical origin do not exist. In response, a 9-part pro forma was devised (Appendix 1) to gain information about the symptoms and history of dizziness and or unsteadiness. The pro forma covered the description of symptoms, their frequency, severity, behaviour and history as well as the presence of any associated symptoms. The choices of responses in each part were based on Mallison & Longridge's work (6, 17, 18) who documented the symptoms reported by WAD subjects, as well as responses thought to be common to, and uncommon in dizziness of cervical origin (4, 17, 18). Characteristics of other possible causes of dizziness, such as vestibular and anxiety (4), were also included to ensure a broad choice. Subjects were not limited to one response per question and were free to circle any of the responses that best described their symptoms.

Cervical joint position error testing

JPE was assessed after the method of Revel et al. (12). The subject's ability to relocate the natural head posture was tested following active cervical movements into left and right rotation and extension. The measurement tool was the 3-Space Fastrak (Polhemus, Navagation Science Division, Kaiser Aerospace Vermont). The Fastrak is a non-invasive electromagnetic device, which tracks the positions of sensors relative to a source in 3-dimensions. It has previously been used to measure position error in the spine (19). The system has been shown to be accurate to $\pm 0.2°$ (20). In this study, one sensor was placed on a lightweight adjustable headband centred on the forehead of the subject. Another sensor was placed over the C7 spinous process using double-sided tape to prevent movement of the sensor in relation to the skin. The leads were also secured with tape to prevent traction on the sensor. The electromagnetic source was placed in a box attached to the back of a wooden chair. The Fastrak was connected to an IBM-compatible PC that continually recorded the position of the sensors relative to the source during each test sequence.

A software program was written to format and process the data for 3D analysis of the starting position (zero) and the position to which the head returned. An electronic switch marked the head return position. Data was converted into files and graphs so that the process could be visualized in real time to improve accuracy of testing. Data consisted of a 3×3 matrix of direction cosines, for the orientation of the forehead sensor relative to the sensor at C7. This was then analysed to give a 3-dimensional measurement of the position of the head relative to the C7. The difference between the starting (zero) and position on return was calculated in degrees for each of the 3 movements tested. This difference represented the accuracy with which the subjects could relocate the natural head posture, the JPE. The error in the primary plane of movement and the 2 associated movement planes were calculated for each direction tested. For example in the sagittal plane, extension was the primary movement and any simultaneous lateral flexion and rotation were the associated movements in the other 2 planes.

Procedure

Subjects with WAD first completed the general questionnaire and the neck disability index. Subjects who indicated that they had symptoms of dizziness or unsteadiness then completed the pro forma regarding the specific nature of these symptoms.

Both WAD and asymptomatic control subjects undertook the testing of JPE. The starting position for the JPE tests was in sitting with the head in the natural resting position. Subjects were asked to focus on this position. They were familiarized with the task and performed one practice movement in each direction of movement. For the formal tests, subjects were blindfolded and the natural head position was set as zero on the Fastrak. They were asked to perform the test neck movement within comfortable limits and return as accurately as possible to the starting position. Subjects indicated verbally when they had returned to the starting position and a research assistant marked this position electronically. Three trials were performed each of left and right neck rotation and extension. Before each subsequent trial the subject's head was manually repositioned back to the original starting position by the examiner, who was guided by the real time display on the computer screen (12). Prior to each new movement direction, the subject was able to re-centre their starting position using vision on an adjustable target, before being blindfolded again. No verbal cues were given to the subjects about their actual performance. All subjects were given the same instructions. Repeatability and reliability of this measure has been established (21).

Data management and statistical analysis

The responses to the general questionnaire including the presence or not of dizziness were collated. The WAD subjects were subsequently divided into 2 groups. Those who reported dizziness and or unsteadiness were allocated to 1 group (Group WAD D). Those not complaining of either symptom were allocated to a second group (Group WAD ND). The Northwich Park Neck Pain Questionnaire was scored following the methodology of Leak et al. (16) to calculate the neck pain and disability index. An analysis of deviance using the normal distribution was used to investigate any differences between WAD groups for the neck pain index.

JPEs were calculated by using the mean of the absolute errors for the 3 trials of each movement for the primary plane and the 2 associated movement planes. The frequency of overshoot and undershoot from the target and the precise target was derived from the primary movement direction and expressed as the percentage of times this occurred over the total number of trials. Errors equal to or less than 0.5° in either direction were arbitrarily nominated as the precise target.

Preliminary analysis was also performed to determine whether age should be considered as a co-variant between groups. Although age had a between subjects effect on JPE, it was not a significant between group factor and therefore was not considered in the final analysis.

The movement by direction data were combined and analysed for differences in joint position error as a generalized linear mixed model. The measurement error was modeled as a gamma distribution with log link function. The data were fitted using ASREML statistical software. In the first instance, the total WAD population (group WAD) was tested against the control (group C). Subsequently, analyses were conducted to

Table I. *Subject demographics (mean (SE))*

	Control subjects Group C ($n = 44$)	Whiplash subjects Group WAD D ($n = 76$)	Whiplash subjects Group WAD ND ($n = 26$)
Age, (years) n.s.	34.1 (1.8)	39.11 (1.3)	40.23 (1.9)
Gender (% Female) n.s.	66	71	73
Time since injury (years) n.s.	–	1.60 (0.47)	1.53 (0.5)
Pain at rest (VAS/10) n.s.	–	4.94 (0.25)	3.96 (0.4)
Neck pain index (%)*	–	55.3 (1.39)	43.1 (1.85)

SE = Standard error of the mean; n.s. = no significant differences; * = statistically significant at $p = 0.0002$.

test for differences between the WAD groups (WAD D and WAD ND) and Group (WAD ND) and the control group (group C).

The frequency of responses in each section of the dizziness pro forma was collated. In a preliminary analysis, each response was box plotted against JPE to search for any correlation between any of the responses concerning dizziness and or unsteadiness and the accuracy of head repositioning (JPE). Tree regression analysis was used to determine whether any particular combination of symptoms could predict JPE.

Medications taken by the whiplash subjects were varied in type and dose. To gain some basic insight into any medication effect on the complaint or not of dizziness and or unsteadiness, medications were grouped according to type only; analgesics, NSAIDs and psychotropic. No account of dosage was taken due to incomplete data. The number of subjects taking each category of medication as well as a combination of medications was collated. The frequency of subjects in each medication category for each group was analysed as a generalized linear model with Poisson errors to indicate if the distribution of medication usage differed between WAD subject groups. In addition, the effect of any medication use on the magnitude of JPE was investigated for each movement direction using an analysis of deviance with a gamma distribution model. The Statistical package R was used to perform all calculations apart from the ASREML.

RESULTS

Three WAD subjects were unable to complete the JPE testing due to marked restriction in neck motion and were excluded from the analysis. Of the 102 WAD subjects retained in the study, 76 complained of dizziness and/or unsteadiness (Group WAD D). Fifty-nine of these reported both dizziness and unsteadiness, 6 reported dizziness only and 11 reported unsteadiness only. The demographics of all subjects are presented in Table I. The only significant difference between the WAD D and WAD ND groups was in the neck pain index scores where the group reporting dizziness (WAD D) scored higher than the group without dizziness (55.3% (1.39) vs 43.1% (1.85), $p = 0.0002$).

The ASREML analysis revealed that the whiplash subjects (Group WAD) had significantly greater JPEs compared with the control group in each primary movement plane (extension: controls 2.4° (0.3) vs WAD 3.5° (0.3), rotation left: controls 2.0° (0.2) vs WAD 3.6° (0.3), and rotation right: controls 2.5° (0.3) vs WAD 4.1° (0.3); (all $p < 0.05$). No differences were found in JPEs in the associated movement planes. Within the whiplash group, those who reported dizziness and or unsteadiness (group WAD D) had significantly greater JPEs than the non-dizziness group (group WAD ND) in return from right rotation ($t = 2.70$, $p = 0.006$) and significance was approached in left rotation ($t = 1.83$, $p = 0.06$). No difference was found in extension ($t = 0.08$, $p > 0.05$). WAD subjects not reporting dizziness or unsteadiness had similar JPEs for rotation left and right as the control group, but had greater error in extension, although this did not reach statistical significance ($p = 0.06$). The means and standard errors for each movement are shown in Table II. No differences were found in JPEs in the associated movement planes of motion. Associated movements did not appear to influence primary direction JPEs.

The frequency with which each group either accurately targeted the starting position or undershot or overshot is presented in Table III. As can be observed, there were few differences between the control and WAD groups in rotation, but WAD subjects were more likely to overshoot in extension. There was no difference in percentage of overshoot between the WAD D and WAD ND subjects.

The frequency of use of words for the description, aggravating

Table II. *Differences in joint position error (degrees; mean (SE)) between groups in the primary planes of movement and the* p *values for between group analysis*

Movement	Control	WAD ND	WAD D	WAD vs C p value	ND vs D p value	C vs ND p value
Ext	2.4 (0.3)	3.5 (0.4)	3.5 (0.3)	0.02	0.96	0.06
Rot L	2.0 (0.2)	2.8 (0.4)	3.9 (0.3)	0.001	0.06	0.09
Rot R	2.5 (0.2)	2.9 (0.4)	4.5 (0.3)	0.003	0.006	0.3

C = Control group; WAD = Total WAD group; WAD ND = WAD non-dizzy group; WAD D = WAD dizzy group; Ext = Extension; Rot L = Rotation left; Rot R = Rotation right.

Table III. *Frequency (%) of trials of undershoot, precise target and overshoot of neutral starting position between control and whiplash-associated disorder (WAD) groups*

	Extension		Rotation left		Rotation right	
	Control	WAD	Control	WAD	Control	WAD
Undershoot	34	22	34	40	21	34
Precise target	24	13	13	15	7	9
Overshoot	42	65	53	45	72	57

and associated features of the dizziness/unsteadiness (parts 1, 5 and 8 of the pro forma) are presented in Table IV. The average number of dizziness descriptors used by WAD subjects was 5.5 (range 1–14). Similarly, an average of 4.5 (range 1–13) aggravating features and 3 associated symptoms were chosen (range 1–5). The most common words used to describe the dizziness were "lightheaded", "unsteady" and "off-balance". Sixty percent of the subjects reported a combination of lightheaded and unsteady or off-balance. The descriptions of the dizziness were then grouped into 5 broader categories of unsteadiness, lightheadedness, visual disturbances, giddiness and others for further analysis. One or more responses of off balance, imbalance on soft surfaces, vague imbalance, falling, imbalance in the dark, unsteady and might fall were recorded as unsteadiness. Lightheaded and faintness were grouped into a single category, while the giddiness category included responses of giddy, room spinning and the subject spinning but not the environment. Within these broader categories, unsteadiness was the most common description (90%), with 63% of subjects only using these words or lightheaded to describe the dizziness. Common exacerbating features were increased neck pain, headache, neck positions or movement. Concurrent symptoms of headache, nausea, blurred vision and decreased concentration were also reported (Table IV).

The average intensity of dizziness or unsteadiness was 4.8 (ranging from 1 to 9.8) as rated on the 10-cm visual analogue scale. Daily symptoms were reported by 52% of subjects, while 25% reported symptoms several times per week and 22% reported symptoms less frequently than weekly. The duration of symptoms was a few seconds to minutes in the majority of subjects (88%). Forty-eight percent reported 1 or more episodes of loss of balance and 21% reported actual falls associated with these symptoms. The vast majority of subjects (90%) eased symptoms by either standing or sitting still. The onset of symptoms was either immediately, or within 24 hours of the accident (68%). A further 15% reported onset within 1 week of the injury. Only 17% reported delayed onset of these symptoms. Mean JPEs for the subjects with delayed onset of symptoms had a tendency to be higher than those with early onset of symptoms (Rot (R) 4.6° (0.49) early vs 5.6° (0.45) late onset). Using the Tree regression analysis, no relationships could be found between the degree of JPE and any single or combination of the specific characteristics of the dizziness and or unsteadiness, and no justification could be found for continuing with more formal statistics.

The majority of WAD subjects (59%) were taking a combination of at least 2 types of medications. Eighteen percent were taking analgesics only, 9% NSAIDS only and 1% psychotropic medication only. Thirteen percent were not using any medication (15%, Group ND; 12%, Group D). The results of the analysis of deviance and Poisson errors revealed that there were no significant between group differences in the types of medications taken. In addition, there were no differences in JPEs (all $p > 0.05$), in any of the movement directions, between those WAD subjects taking any medication and those not using medication.

DISCUSSION

The results of this study indicate the presence of deficits in cervical mechanoreceptor function in WAD. JPEs were significantly greater in WAD subjects than in the healthy control

Table IV. *Frequencies (%) of symptom descriptions, exacerbating features and concurrent symptoms in whiplash subjects reporting dizziness/unsteadiness, Group WAD D (*n = 76*)*

Description							
Lightheaded	60	Giddy	27	Falling/veering to side	23	Vague imbalance	19
Unsteady	52	Imbalance	25	Trouble stairs	21	Faint	15
Off balance	48	Focus when walk	25	Imbalance in dark	21	Might fall	15
Clumsy	30	Motion sickness	25	Vision/eyes jiggle	21	All others	<13
Exacerbating features							
Increased neck pain	60	Neck movements	44	Moving quickly	36	Stress	21
Standing/sitting up	57	Neck positions	42	Moving neck quickly	30	All others	<15
Associated features							
Headache	56	Decreased concentration	35	Sweating	30	Confusion	21
Nausea	40	Blurred vision	38	Tinnitus	25	All others	<17

group, confirming results from previous studies (7, 14). Direct comparison of JPEs between our study and others is difficult due to the different measurement methods. Nevertheless the proportion of JPE between control and WAD subjects is similar to that determined by Heikkila and colleagues (7, 14). As observed in other studies, WAD subjects overshot the neutral position on return from extension more often than controls. Overshooting is thought to compensate for decreased proprioceptive information, by searching for additional information from stretched antagonistic muscles (7, 12, 14).

The results of this study also indicate that the WAD subjects with dizziness have greater deficits in cervical mechanoreceptor function. They displayed greater deficits in JPE from rotation but not extension, than those WAD subjects without dizziness. The latter subjects had JPE values similar to the control group for rotation, but approached significantly greater JPE from extension. This suggests that the WAD group without dizziness may demonstrate some deficits in cervical mechanoreceptor dysfunction, but to a lesser or different degree than those complaining of dizziness/unsteadiness.

The frequency of the complaint of dizziness was high in our WAD group (74.5% of 105 subjects). As the complaint of dizziness is high in the general population (4) our results might merely reflect a random selection of the general population. However, potential participants with whiplash were excluded if they had reported dizziness prior to their accident. In addition the majority of WAD subjects (83%) reported that the dizziness commenced immediately after or within one week of the accident. This may be due to direct damage to the cervical mechanoreceptors following the accident, the barrage of abnormal afferent input due to the sudden acceleration/deceleration forces placed on cervical structures and/or the effects of pain and inflammatory mediators on proprioceptive activity (22). Interestingly, the 17% who reported delayed onset of symptoms tended to have higher joint position errors than the group with early onset. This perhaps suggests that the development of symptoms may be as a result of prolonged altered range of movement (23) and decreased neuromuscular control (24) rather than a random occurrence. The tendency for larger JPEs in the group with delayed onset may also suggest that prolonged altered range of movement and neuromuscular control generates as much if not more problems for cervical proprioception than the initial proprioceptive barrage following the accident.

The increased JPE in the WAD subjects complaining of dizziness suggests a cervical cause of the dizziness. The description of the dizziness and or unsteadiness provided by the WAD subjects reinforces this suggestion. The common reports of unsteadiness (90%) and lightheadedness (65%) (Table II) are those previously nominated for dizziness of cervical origin (10, 11). Furthermore, 48% of subjects with these symptoms reported at least one episode of loss of balance with 21% reporting an associated fall which relates well to those symptoms reported from experimentally induced cervical vertigo, i.e. unsteadiness, ataxia and a tendency to fall (9, 25). Similarly the reported duration and frequency of the symptoms, as well as the exacerbating and associated features, were similar to dizziness of cervical origin. The majority of subjects (83%) also reported early onset of the symptoms in relation to the cervical injury (9, 10).

The descriptors nominated by the WAD group were not indicative of other causes of dizziness. Features suggestive of anxiety were seldom reported (4). Vestibular deficits have been identified in WAD (26), but both the descriptors of the dizziness and the presence of JPEs do not support a predominantly vestibular origin of symptoms in our group. Mendel et al. (27) studied persons with vestibular disorders, and found the majority (78%) reported all 3 complaints of spinning, lightheadedness, swimming and unsteadiness while few reported unsteadiness and lightheadedness alone. In contrast, 90% of our whiplash subjects who reported symptoms, complained of either or both, unsteadiness and lightheadedness, while only 25% reported spinning. Nevertheless, our results differ to those of Mallison & Longridge's (17) study of 19 WAD subjects without head injury, where half reported spinning as a symptom. Our group may have suffered some selection bias and it is possible that those with obvious vestibular deficits may have been referred to sources other than ours.

The descriptive nature of the pro forma (Appendix 1), although useful as a guide to the types of responses given by this group, cannot be regarded as highly as a validated questionnaire. It has not been rigorously tested for use with this or any other dizzy group to determine its ability to differentiate between dizziness of a cervical cause and other causes. However, it forms a basis for future research towards developing a questionnaire specifically for patients with dizziness of cervical origin.

Many drugs can cause dizziness and affect postural control and may be underlying these symptoms in WAD subjects (3). Our basic data on type of medication intake indicated no relationship between medication intake and JPE or medication intake and the complaint of dizziness or unsteadiness.

Overall, we contend that our results support a likely cervical cause of dizziness and or unsteadiness rather than other causes of dizziness in these subjects with persistent WAD and the JPE findings highlight the role of cervical mechanoreceptor dysfunction. This agrees with Tjell & Rosenhall's work (8, 22) on eye movement dysfunction in WAD as a result of altered cervical afferent input. They demonstrated altered smooth pursuit eye movement control in WAD subjects when the neck was in a torsioned position compared with a neutral position. Eye movement control was affected to a greater extent in WAD subjects complaining of dizziness. In contrast, altering the cervical input via neck torsion did not influence eye movement control in the subjects with vestibular disorders and central nervous system dysfunction. In a follow-up study (22), subjects with non-traumatic neck pain demonstrated some differences from the control group, however, WAD subjects displayed the greatest deficits, especially those subjects who reported dizziness. The difference in eye movement control between non-traumatic and traumatic neck pain may be due to the sudden acceleration and deceleration forces placed on the neck muscles attachments and their proprioceptors initially and the situation is then perpetuated by pain and associated increased muscle tension (22). Whether the degree of JPE deficit in WAD is also greater than those with non-traumatic neck pain is not known at this time. Studies to date have not excluded trauma in their neck pain group (12). The one study which did exclude trauma, may have flawed methodology as their reported JPEs were excessively large in both the control and neck pain groups compared with other studies (28)

We found no single characteristic or group of characteristics of the dizziness and or unsteadiness that correlated with either greater or lower JPE. Therefore identification of JPE deficits purely from patient self-reports is unlikely, suggesting measurement of JPE is necessary in assessment of WAD. The WAD subjects reporting dizziness and or unsteadiness, not only had greater JPE, but scored higher on the neck pain index suggesting the need to better understand the role of abnormal cervical afferent input in chronic WAD. It is possible that the subjects with higher disability and pain will have heightened abnormal afferent activity from the cervical proprioceptors due to both greater initial damage and ongoing functional impairment of cervical structures resulting in disturbance to the postural control system and the complaint of dizziness.

The specific nature of the findings of JPE in those with and without dizziness and or unsteadiness in WAD may assist this understanding. JPE deficits were not universal for all movement directions. In those with dizziness and or unsteadiness, it was significantly greater following active rotation but not extension. Although this occurrence has not been directly addressed in other studies, there is other evidence to suggest the deficits in rotation and not extension may have some relationship to the complaint of dizziness. Heikkila & Wenngren (14) reported similar findings for WAD subjects with oculomotor dysfunction, who were significantly less accurate in head repositioning following rotation only, than those with normal oculomotor function. In a follow-up study investigating the effects of different therapies for WAD subjects complaining of dizziness, Heikkila et al. (29) demonstrated short term improvements in extension repositioning error following acupuncture and manipulation, while rotation errors remained unchanged.

Hypothetical consideration for these direction specific differences in WAD subjects with dizziness may be useful. One possible explanation is that rotation movements present a greater challenge to the postural control system. Although cervical JPE is thought to primarily reflect cervical mechanoreceptor function, pure rotation movements of the head are likely to also stimulate the vestibular apparatus more so than cervical extension (4). Cervical rotation could cause a mismatch between abnormal information from cervical and normal information from vestibular input with dizziness the consequence (4). Extension deficits may on the other hand reflect overall alteration of cervical afferent input from the cervical mechanoreceptors in isolation thus explaining why all WAD subjects, whether complaining of dizziness or not, demonstrated some extension deficits. Management such as acupuncture and manipulation may address some but not all of the deficits, where others such as Revel et al.'s (13) protocol which is mainly concerned with improving eye/head co-ordination, gaze stability and repositioning practice may be an important additional management tool as it addresses cervical mechanoreceptor input when in conflict with vestibular and ocular input.

The results of this study confirm greater degrees of JPE in a group with persistent WAD compared with a control group. WAD subjects with reports of dizziness and or unsteadiness had greater degrees of both JPE and disability and pain than those not reporting these symptoms. Although the characteristics of the dizziness and/or unsteadiness support a cervical cause of the dizziness, specific characteristics could not predict those with greater or lesser deficits in JPE. The study highlights the role of cervical mechanoreceptor dysfunction and the importance of assessment and management of this impairment in persistent WAD, particularly in those complaining of dizziness and unsteadiness.

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Appendix 1. *Dizziness/unsteadiness pro forma*

1. *Which of the following words below describes your dizziness/unsteadiness?*
Circle ONLY those words that best describe it. If none of the words describe it please select other.

Room spinning	Off-balance	Tilting
Unsteady	Drunkenness	Clumsy
Giddy	Vague imbalance	Motion sickness
Falling/veering to one side	Fogginess	Must focus when walk
Sea legs	Imbalance	Like stepping off an elevator
Might fall	Cloudiness	Light headed
Swimming	Trouble on stairs	Imbalance in dark
Dislike things moving past me fast	Vision moving/eyes jiggle	Faintness
Dissociated from body	Imbalance on soft surfaces	You’re spinning not environment
Floating	Not secure	Other____________

2. *Judging by the last month, how often do you get these symptoms*?

All the time/constant doesn’t vary	Once per day	Once per fortnight
All the time/varies in intensity	Several times week	Less than once per fortnight
Several times per day	Once per week	Other____________

3. *How long does it last?*

Few seconds	Few minutes	Hours
Several seconds	Several minutes	Other____________

4. *Rate your symptoms on a scale from 0–10*
0__________________10
(No symptoms) (The worst you can imagine)

5. *Is there anything in particular that brings on these symptoms?*

Rolling over in bed	Lying down	If anxious about something
Moving neck quickly	Coughing/sneezing	Walking busy/crowded places
Lying on side	Loud noises	Stress
Sitting up/standing up	Lying on side	Neck movements
Increased neck pain	Unsure	Moving quickly
Headache	Certain neck positions	Other____________

6. *When you experience these symptoms do you*:

Stop and sit down/lie down	Stand still and hold on to something	Slow down a little
Change position of body	Change head position	Keep doing what doing
Stand still	Breath slowly and deeply	Other____________

7. *Have you actually fallen over/lost balance due to your symptoms?*

No	Yes	If Yes how many times?

8. *Is there anything else that occurs at the same time as these symptoms?*

Blurred vision	Hearing loss	Sweating
Ringing in the ears	Lump in throat	Decreased concentration
Tight chest	Pins and needles	Pallor
Shortness of breath	Nausea	Nausea
Confusion	Headache	Headache
Vomiting		Other____________

9. *How soon after the accident did these symptoms start?*

Immediately	Within one week	After one month
Within 24 hours	Within one month	Other____________