Discriminative validity of sensory evaluation in a whiplash-associated disorder II population

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Aim: *Evidence suggests chronic whiplash is associated with sensory hypersensitivity. Understanding the degree of sensory impairment could enhance rehabilitation strategies. This preliminary study determined whether differences in sensory evaluation occur post whiplash injury.*

Methods: *Single-blinded, case control observational study using a convenience sample of 20 participants (median age 28.5 years, low disability) with chronic grade II whiplash-associated disorder (CWADII) and 22 control participants (median age 26 years) with no history of whiplash/neck injury. Outcome measures included vibration and cold pain perception threshold, and joint position error.*

Results: *Significant associations using Kendall's tau correlation coefficient were found between: vibration thresholds (thenar and hypothenar eminences) for the CWADII group ($p<0.01$); cold pain thresholds (thenar, 5th metacarpophalangeal, mid cervical spine) in both groups ($p<0.01$); joint positioning errors (global positioning following right/left rotations, left rotation/extension) ($p<0.01$) in the CWADII group; and between vertical direction errors (following right/left rotation) in both groups ($p<0.01$). Discrimination between groups was not identified using separate logistic regressions on vibration or cold pain thresholds (thenar eminence) or on global flexion/extension/right rotation position errors ($p>0.01$).*

Conclusions: *The findings do not support the use of vibration, cold pain threshold or joint position error to identify individuals with CWADII with low disability.*

Key words: ■ Whiplash injury ■ Vibration ■ Thermal ■ Proprioception

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Whiplash injuries of the cervical spine commonly occur when a person is involved in a rear automobile collision involving a mechanism of acceleration and recoil (table et al, 1995). Insurance statistics suggest that 300,000 patients present with whiplash-associated disorder (WAD) per year in the , with an incidence of approximately 500 cases per 100 000 head of population (Burton, 2003). WAD represents the clinical signs and symptoms attributed to a whiplash injury, classified as grades 0 to IV (Spitzer et al, 1995). The classification system is advocated in practice (Sterling, 2004) and within clinical guidelines (Moore et al, 2005).

Grade II classification of WAD (WADII) is used to describe patients presenting with neck pain and stiffness or tenderness, and musculoskeletal signs, such as reduced range of movement. A recent review reported that the diagnosis of WADII is made on patient-reported symptoms in the absence of neurological signs (indicative of WADIII) and any evidence to support the use of imaging (Sterling, 2014). Furthermore, WADII patients have been identified as a major group seeking physiotherapy for conservative rehabilitation (Sterling, 2004), with a literature review (Jansen et al, 2008) recommending that the focus of research should be directed towards the most common WADI/II populations.

Clinical diagnosis and management of WAD is still relatively poorly understood (Rushton et al, 2011). Inconclusive evidence for the effectiveness of physiotherapy management for WADII was reported in a recent systematic review by Rushton et al (2011). This may be partly attributable to differing levels of disability, symptomatic sensory dysfunction and populations used. Likewise, to date, few studies have investigated management of this specific sub-group.

After whiplash injury, most patients recover within 3 months (Kampner et al, 2008). Persistent pain and disability might account for the 12–61% of those injured going on to develop chronic symptoms (Kampner et al, 2008; Carroll et al, 2008). Chronic WAD (CWAD), therefore, represents a major health and socio-economic problem. Increasing evidence suggests that CWAD presentations (>3 months) are associated with generalised sensory hypersensitivity resulting from sensitised nociceptive pathways (Curatolo et al, 2002; Chien et al, 2009; Chien and Sterling, 2010; Stone et al, 2012) and psychological distress (Chien and Sterling, 2010; Kasch et al, 2005). A literature review found that participants with CWAD demonstrated increased sensitivity to pressure, cold, heat, flexor withdrawal, electrical stimulation and the brachial plexus provocation test (Stone et al, 2012), suggesting alterations of central pain processing mechanisms.

There is some evidence for the role of elevated vibration threshold (VT) as an early indicator of neural pathology (Lundborg, 1988; Greening and Lynn, 1998; Martina et al, 1998; Greening et al, 2003), owing to the large diameter nerve fibres (that mediate vibratory sensation) being the most vulnerable to ischemia (Martina et al, 1998). Preliminary evidence suggests that VT could distinguish symptomatic from control participants, although investigation in a WAD population is limited. In a literature review, Stone et al (2012) identified one good-quality study (Chien et al, 2008) demonstrating significantly elevated VTs in CWAD participants compared to controls.

Thermal sensitivity, specifically decreased cold pain threshold (CPT) (Sterling et al, 2003; Scott et al, 2005; Wallin and Raak, 2008; Sterling, 2010; Sterling et al, 2011; Wallin et al, 2012) and thermal hypoesthesia (elevated thermal detection thresholds) (Chien et al, 2010; Wallin et al, 2012), are consistent findings in CWAD. There is moderate evidence supporting cold hyperalgesia as predictive of poor outcome following whiplash injury (Goldsmith et al, 2012). More importantly, a trial has shown that WAD individuals with cold hyperalgesia do not respond well to physiotherapy (Jull et al, 2007). Cold hyperalgesia might be indicative of peripheral nerve injury (Sterling et al, 2003a; Chien et al, 2009). In a literature review, Stone et al (2012) identified five good-quality studies (Sterling et al, 2003b; Scott et al, 2005; Raak and Wallin, 2006; Chien et al, 2008; Wallin and Raak, 2008) demonstrating significantly elevated CPTs in CWAD participants compared to controls, in the head/neck/upper thoracic and upper limb sites.

Dysfunction of the postural control system is common in CWAD (Treleaven et al, 2006). Afferent input from the cervical facet joint and muscle receptors is evaluated by the assessment of cervical joint position error (JPE) and cervicocephalic kinaesthesia (Treleaven et al, 2006; Swait et al, 2007). For head-to-neutral repositioning JPE tests, there is moderate-quality evidence for greater errors in a CWAD group compared to controls, following movement in the sagittal or transverse planes (Sterling et al, 2003b; Hill et al, 2009). However, one study evaluated acute and recovering WAD (Sterling et al, 2003b), and only one study evaluated a CWAD population (Hill et al, 2009). There is no quality evidence available regarding head-to-neutral repositioning JPE in the frontal plane.

The aim of this preliminary study was to investigate whether sensory measures (vibration, thermal and JPE) could distinguish between CWADII and control populations.

METHODS

Methodology

A case control observational study design involving blinding of the assessors compared sensory measures in participants with CWADII to control. Two researchers recruited and screened potential participants. Two further researchers blinded to participants' group membership to avoid potential bias were responsible for data collection. Informed consent was obtained following ethical approval by a UK university. The study was carried out at a UK university, with data collected in 2012.

Participants

A convenience sample of participants (n=42) was recruited from staff and students at a UK university (CWADII n=20; control n=22). Ten participants per outcome variable were recommended for logistic regression analysis (Tabachnick and Fidell, 2013). Potential participants were screened by an experienced musculoskeletal physiotherapist using pre-stated eligibility criteria. Participants included in the CWADII group were aged 18–55, presented with WADII (Spitzer et al, 1995) with >6 months symptom duration (Sterling, 2010), and had no history of neck pain or headaches before the accident. Participants included in the control group had no history of whiplash injury/neck pain, headaches or upper quadrant injuries. In addition, the following exclusion criteria were applied to both groups: previous neuromusculoskeletal spinal presentations including surgery, osteoporosis or fracture, altered neurological function (sensory or motor), other diseases known to induce peripheral neuropathy, diabetes, rheumatoid arthritis, epilepsy, HIV, tuberculosis, cancer, uncontrolled hypertension, current pregnancy or infection, peripheral nerve lesions, alcoholism, and medication such as non-steroidal anti-inflammatory drugs (NSAIDS).

CWADII group characteristics

The Neck Disability Index (NDI), Leeds Assessment of Neuropathic Symptoms and Signs (S-LANSS), and the Hospital Anxiety and Depression Scale (HADS) were used to describe participants in the CWADII group:

- The NDI is a condition-specific functional status questionnaire that determines level of disability (Vernon and Mior, 1991). It comprises 10 items, each scored from 0 (no disability) to 5 (complete disability), giving a maximum score of 50. Scores 0–4 represent no disability; 5–14 mild; 15–24 moderate; 25–34 severe; and >34 complete disability. NDI has established validity and reliability (McCarthy et al, 2007).
- The S-LANSS is a short, self-completed tool that identifies pain of predominantly neuropathic origin (Bennett et al, 2005). It comprises 5 symptom items and 2 self-examination items and has a maximum possible score of 24. S-LANSS has demonstrated good internal consistency (0.74) and reliability (0.76 to 0.81) (Bennett et al, 2005). Sensitivity and specificity of 82–91% and 80–94% respectively have been reported (Bennett et al, 2005). A score of >12 is indicative of pain of predominantly neuropathic origin (Sterling and Pedler, 2009).
- HADS evaluates existing psychological factors, in particular, psychosocial issues that affect behavior or performance (Bjelland et al, 2002). Scores of 0–7 represent normal; 8–10 mild; 11–14 moderate and 15–21 severe anxiety/depression. HADS has demonstrated 'good to very good' concurrent validity (correlations 0.60 to 0.80) (Bjelland et al, 2002).

Outcome measures

VT was evaluated using a portable vibrameter type IV (Somedic AB, Stockholm, Sweden), by applying mechanical stimulation with a frequency of 100–120Hz (Greening et al, 2003). Inter-rater reliability of the vibrameter is good (intraclass correlation coefficients (ICC 2.1); 0.798) (O'Conaire et al, 2011). VT was calculated as the mean of vibration perception threshold (VPT) and vibration disappearance threshold (VDT). Two local sites of the palmar surface thenar eminence (median nerve distribution) (Chien et al, 2008), and the palmar surface hypothenar eminence (ulnar nerve distribution) were tested. To ensure consistency of site location, tests were made mid-way between the carpo-metacarpal and metacarpo-phalangeal joints from the thenar and hypothenar eminences.

CPT was determined using the method of limits (Palmer et al, 2000), using Somedic Thermotest apparatus combined with SenseLab software (Somedic AB, Sweden). Thermal stimuli were delivered directly to the participant's skin through a metal 25x50 mm Peltier thermode. Thresholds were measured over local (thenar eminence, dorsal aspect of fifth metacarpal (5thMCP)) and remote sites (mid cervical spine). Stimuli were delivered at a rate of 1^{o}C/sec, starting from a baseline temperature of 30^{o}C. Three successive measurements were taken at each site, with an interval of 10 seconds between measurements. To identify CPT, participants were asked to press a button as soon as the sensation of cold first became uncomfortable (Palmer et al, 2000).

Cervical JPE assesses the ability to relocate the head to a neutral position after performing movements of the cervical spine. A helmet with mounted laser was positioned on the participant's head to track its position. Lines representing the vertical (Y) and horizontal (X) planes were marked as a cross on A3 paper, separating it into four quadrants (Rix and Bagust, 2001). The paper was positioned on the wall, in front of the participant, so that the centre of the cross represented the neutral starting position of the head. The repositioning error, for each of six consecutive trials was recorded (mm), for four movements (flexion, extension, left and right rotation) (Swait et al, 2007).

Procedures

All screening and data collection were conducted in a laboratory where temperature and environmental conditions were controlled. Following informed consent, participants were allocated an identification number. Each participant had their height (cm) and weight (kg) recorded and was familiarised with the testing procedure before testing, using a standardised set of instructions. No verbal feedback was provided on performance. For VT and CPT, participants were comfortably positioned in the supine position and were unable to view readings from equipment. The sequence of testing outcomes was randomised, regarding site and equipment across participants, to address potential order effects. The vibrameter was calibrated and the sensation of vibration demonstrated by applying the horizontally positioned and balanced probe to the sternum. Three readings of VPT and VDT were recorded at each testing site. The probe was removed between measurements. The thermotest was calibrated and a demonstration of CPT measurement was conducted on the opposite side to testing. Three successive recordings of CPT were taken at each site. All VT and CPT measurements were taken unilaterally on the dominant side for control participants (as there was no difference in temperature thresholds between sides (Chien et al, 2008) and the most symptomatic side for CWADII participants.

To measure JPE, participants sat on a chair, with tape on the floor, which constituted a reference line to maintain a constant distance between the chair and wall. The laser beam made a dot on the A3 sheet and this was taken as the location of the perceived, neutral (O) head position (Treleaven et al, 2006). The laser beam was maintained horizontal to the floor and perpendicular to the wall throughout. A training protocol (Swait et al, 2007) familiarised participants with the procedure (one measurement of head repositioning for cervical flexion, extension, right rotation and left rotation). Participants were then blindfolded (sleeping mask), and were asked to move within comfortable limits, returning as precisely as possible to the preliminary (perceived, neutral) position (Treleaven et al, 2006), which they indicated verbally. A second researcher marked this position on the paper. The participant's head was passively repositioned to the neutral starting position before each trial. Six consecutive trials were performed for each direction of movement.

Ethical approval

Ethical approval was provided by a UK university. All procedures were in accordance with the Helsinki Declaration of 2000. Anonymity and confidentiality were assured. A participant information sheet and the opportunity to ask questions enabled written informed consent.

Data analysis

Means of the three readings taken per participant for each of VPT, VDT and CPT, and of the six trials for each movement direction (flexion, extension, right and left rotation), were used for analyses. For JPE, X and Y errors were defined as the horizontal and vertical distances, respectively, between the starting position (O) and final neutral positions. The normal convention was followed for signs (-ve or +ve) of X and Y with respect to O. A global repositioning accuracy (G), defined as the distance between O and final neutral position (Hill et al, 2009), was calculated using the square root of $(X^2 + Y^2)$.

Table 1. Summary of participant characteristics

	CWADII group (*n*=20; 13 female)		Control group (*n*=22; 9 female)	
Characteristic	**Minimum, maximum**	**Median (IQR)**	**Minimum, maximum**	**Median (IQR)**
Age (years)	20.0, 55.0	28.5 (12.8)	20.0, 39.0	26.0 (4.00)
Height (cm)	159.0, 190.0	170.0 (11.3)	154.0, 199.0	174.0 (11.3)
Weight (kg)	54.0; 120.0	73.5 (19.5)	47.0, 94.0	74.0 (18.3)
Time since injury (months)	12, 66	46.5 (25.8)	N.A.	N.A.
HADS score (range 0–21)	7, 10	8.0 (0)	N.A.	N.A.
NDI score (range 0–50)	2, 20	10.5 (6)	N.A.	N.A.
S-LANSS score (range 0–24)	0, 3	0 (2)	N.A.	N.A.
Classification of WADII group				
Presence of neck pain	*n*=12 (60%)			
Decreased ROM of Cx	*n*=18 (90%)			
Point tenderness (yes)	*n*=20 (100%)			
No neurological signs	*n*=20 (100%)			
Neck pain intensity (0–4 score from NDI)	Median IQR=2 (3%)			

Cx: cervical spine; CWADII: chronic whiplash-associated disorder II; HADS: Hospital Anxiety and Depression Scale; IQR: interquartile range; NDI: neck disability scale; ROM: range of movement; S-LANSS: Leeds Assessment of Neuropathic Symptoms and Signs

All statistical analyses were performed using IBM SPSS Statistics version 19. Summaries of participant characteristics and outcome measures were computed for each group using median, inter-quartile range, and minimum and maximum values (Sim and Wright, 2000). Statistical difference in the proportion of females per group was tested using a continuity corrected Chi-squared test and group differences on other participant characteristics through Mann Whitney and Wilcoxon tests (Sim and Wright, 2000). Associations across the components within each of the three outcome measures were assessed using Kendall's tau (Arndt et al, 1999). Non-parametric tests were conducted because they require no assumption to be made about the distribution of the underlying population values. In this study, no prior knowledge was available to support an assumption about the distributions and the small sample size precluded the conduct of statistical tests on assumptions underlying the use of parametric tests. Potential use of VT, CPT or G components of JPE to dis-

Table 2. Summary statistics of sensory outcomes

	Control group (*n*=22; 9 female)		CWADII group (*n*=20; 13 female)	
Sensory outcome	Median (IQR)	Minimum, maximum	Median (IQR)	Minimum, maximum
VT (μm)				
Thenar	0.99 (0.47)	0.41, 2.36	0.78 (0.49)	0.39, 1.88
Hypothenar	0.87 (0.36)	0.44, 1.36	0.78 (0.48)	0.39, 1.43
CPT (ºC)				
Thenar	7.30 (12.27)	3.91, 25.13	6.67 (12.62)	3.90, 26.83
5thMCP	5.23 (8.21)	3.90, 26.90	8.49 (12.36)	3.90, 27.80
Mid cervical spine	9.70 (18.41)	4.00, 29.17	15.67 (17.40)	3.60, 28.43
JPE (mm)				
G error				
Flexion	43.21 (29.23)	26.67, 81.88	40.14 (32.52)	20.12, 100.95
Extension	49.08 (31.64)	19.8, 88.0	42.66 (25.64)	30.72, 115.71
Right rotation	45.31 (29.53)	24.68, 115.01	54.76 (23.22)	17.15, 126.89
Left rotation	42.16 (30.59)	20.58, 77.77	49.42 (18.28)	21.18, 131.95
Horizontal errors (X error)				
Flexion	-2.50 (35.25)	-52.67,19.00	-3.58 (26.58)	-62.33, 76.33
Extension	-7.33 (25.17)	-36.83, 45.67	-1.00 (36.67)	-61.83, 36.67
Right rotation	14.33 (47.75)	-42.33, 70.17	-3.00 (52.92)	-50.67, 126.00
Left rotation	0.33 (44.17)	-71.67, 56.67	-3.67 (44.75)	-118.17, 33.50
Vertical errors (Y error)				
Flexion	15.00 (47.33)	-63.67, 76.33	-14.17 (20.21)	-76.83, 67.00
Extension	0.50 (63.73)	-85.50, 73.50	-16.75 (60.83)	-82.67, 70.17
Right rotation	-15.33 (32.67)	-82.00, 40.17	-15.50 (33.79)	-77.50, 23.83
Left rotation	-15.67 (30.25)	-64.00, 31.33	-6.83 (33.71)	-58.00, 26.50
G error	42.16 (30.59)	20.58, 77.77	49.42 (18.28)	21.18, 131.95

CWAD: chronic whiplash-associated disorder; G error: global positioning error=$\sqrt{(X\ error^2+Y\ error^2)}$; IQR: interquartile range; 5thMCP: 5th metacarpal; X error: positioning error in the horizontal plane; Y error: positioning error in the vertical plane

criminate between CWADII and control groups was assessed using separate logistic regressions (Cohen et al, 2003). Non-significantly correlated components were used as highly correlated predictors can cause problems for the estimation of parameters (Berwick et al, 2005). Goodness of fit of each model was assessed using Hosmer-Lemeshow test (Jewell, 2004; Berwick et al, 2005). In this preliminary study, all statistical hypothesis tests were conducted using a two-tailed significance level of 0.01 owing to repeated testing.

FINDINGS

Participant characteristics

Participant characteristics are detailed in *Table 1*. There were no statistically significant differences in median age, height or weight across the two groups (p>0.05 for all parameters) or in percentage female participants (p>0.05). Characteristics of CWADII participants are presented in Table 1. CWADII participants presented with mild anxiety/depression based on HADS scores (Bjelland et al, 2002), low levels of disability and no evidence of neuropathic pain, with no participants reporting S-LANSS scores ≥12 (Bennett et al, 2005). Eight of the 20 CWADII participants had received physiotherapy for management of whiplash in the past.

Sensory outcomes

Summary statistics for sensory outcomes are reported in *Table 2*. One 'control' participant was excluded from JPE testing because of their inability to complete the tests (dizziness due to hypotension).

Associations between sensory outcomes are reported in *Table 3*. No association was found between VTs at the thenar and hypothenar eminences for participants in the control group (p>0.01), contrasting a moderate, positive correlation in the CWADII group.

Table 3. Kendall's Tau correlations between components of sensory measures

	Group					
Sensory outcome and components	Control *n*=22 (21 for JPE)			CWADII *n*=20		
	τ (p)	τ (p)	τ (p)	τ (p)	τ (p)	τ (p)
VT (μm)	Thenar			Thenar		
Hypothenar	.392 (.011)			.596**(.000)		
CPT (°C)	Thenar	5thMCP		Thenar	5th MCP	
5thMCP	.429**(.007)	–		.833***(.000)	–	
Mid cervical spine	.640***(.000)	.491**(.002)		.525***(.001)	.529***(.001)	
JPE (mm)						
G error	Flexion	Extension	Right rotation	Flexion	Extension	Right rotation
Extension	.190 (.227)	–	–	.189 (.243)	–	–
Right rotation	.057 (.717)	.181 (.251)	–	.316 (.052)	.263 (.105)	–
Left rotation	.229 (.147)	.314 (.046)	.371 (.019)	.368 (.023)	.421* (.009)	.421* (.009)
Horizontal errors (X error)	Flexion	Extension	Right rotation	Flexion	Extension	Right rotation
Extension	.272 (.085)	–	–	.274 (.092)	–	–
Right rotation	.301 (.057)	.248 (.116)	–	.042 (.795)	-.158 (.330)	–
Left rotation	.287 (.070)	.329 (.037)	.148 (.349)	.179 (.270)	.211 (.194)	-.084 (.604)
Vertical errors (Y error)	Flexion	Extension	Right rotation	Flexion	Extension	Right rotation
Extension	.014 (.928)	–	–	.242 (.136)	–	–
Right rotation	.133 (.398)	.320 (.043)	–	.186 (.255)	.090 (.581)	–
Left rotation	-.048 (.783)	.196 (.215)	.419**(.008)	.100 (.537)	.322 (.048)	.606***(.000)

CWAD: chronic whiplash-associated disorder; G error: global positioning error=√(X error²+Y error²); JPE: joint position error, 5thMCP: 5th metacarpal; n: number; τ: Kendall's tau; X error: positioning error in the horizontal plane; Y error: positioning error in the vertical plane; **: statistically significant at .01 level; ***: statistically significant at the .001 level

Moderate-to very-high positive associations were found between CPTs at the thenar, 5th metacarpal and mid cervical spine within both groups. No significant associations were found between global JPEs for participants in the control group (p<.01), compared with highly significant associations in the CWADII group, following left rotation and extension (p<0.01) and following left and right rotation (p<0.01). Significant associations were also found between joint positioning errors in the vertical direction following left and right rotation, in both the control and CWADII groups (both p<0.01).

Neither VT nor CPT at the thenar eminence discriminated between control and CWADII participants (Hosmer-Lemeshow p>0.01), respectively (see *Table 4*). Neither did a model including the three global positioning errors for flexion, extension and right rotation (selected because of their non-significant inter-correlations, see *Table 3*) discriminate between the two groups (Hosmer-Lemeshow p>0.01).

DISCUSSION

This preliminary study does not support the use of vibration, cold pain threshold or JPE to discriminate individuals with chronic WAD with relatively mild levels of self-report disability from control participants.

Participants

Although comparable with respect to age, height or weight and gender, the median NDI scores illustrated CWADII participants with low neck pain-related disability (Vernon and Mior, 1991). The S-LANSS findings identified no participants presenting with pain of predominantly neuropathic origin (Sterling and Pedlar, 2009). The median HADs score reflected mild levels of psychological factors. This population could have presented as a consequence of recruiting a convenience sample from staff and students, but were all classified as WADII with physical findings on examination (*Table 1*).

Table 4. Results from logistic regression analyses							
Sensory component	**Hosmer- Lemeshow χ^2 (df, p)**	**B**	**SE**	**Wald**	**df**	**Sig**	**Exp(B)**
VT thenar eminence	4.311 (8, .828)	-0.365	.772	.223	1	.637	.694
CPT thenar eminence	3.432 (8, .904)	0.010	.045	.053	1	.817	1.010
G error:	9.280 (8, .319)						
Flexion		-0.666	.018	.125	1	.727	.994
Extension		-0.009	.018	.218	1	.641	.991
Right rotation		0.017	.016	1.170	1	.279	1.017

B: coefficient in the logistic model; df: degrees of freedom for Wald test; Exp(B): odds ratio; Sig: significance level; SE: standard error; Wald: Wald statistic, tests significance of coefficient B

Sensory outcomes

For VT at the thenar and hypothenar eminences the findings suggested that VT might discriminate the CWADII participants. For CPT at the thenar, 5th metacarpal and mid cervical spine the findings suggested that CPT would not discriminate the CWADII participants.

For global positioning errors of JPE for left rotation and extension, the findings suggested that JPE might discriminate the CWADII participants. However, for global positioning errors of JPE in the vertical direction for right and left rotation the findings suggested that JPE would not discriminate the CWADII participants.

From the logistic regression, a model including VT and CPT at the thenar eminence did not discriminate between the two groups of participants. A second model of three global positioning errors for flexion, extension, and right rotation was created as each had demonstrated non-significant inter-correlations. However, the model did not discriminate between the two groups of participants. Therefore, the results do not support the use of vibration, CPT or JPE to discriminate individuals with low levels of disability in CWADII from control participants.

For VT, this study has not replicated the findings from Chien et al (2008) that demonstrated significantly elevated VTs in CWAD participants compared to controls. However different measurement sites were used as Chien et al (2008) used 1st, 2nd palmar surface and 5th doral surface of the hand, reflecting dermatomal distribution rather than the current study where peripheral nerve cutaneous innervation sites were tested. Additionally, vibration attenuation times vary according to the underlying tissue and may account for differences is findings between Chien et al (2008) and the current study. Furthermore, the demographics and characteristics of the participants differed, with Chien et al (2008) having a slightly older (mean age 37.2±10.4 years) CWAD sample with relatively higher levels of disability (NDI 47.4±16.4).

For CPT, this study has not replicated previous findings of significantly elevated CPTs in CWAD participants compared to controls (Sterling et al, 2003a; Scott et al, 2005; Raak and Wallin, 2006; Chien et al, 2008; Wallin and Raak, 2008) at head/neck/upper thoracic and upper limb sites. Again, this may be attributable to time point post injury, disability levels and sample characteristics used in the different studies. For example, Sterling et al (2003a) included a slightly older sample (mean age 34.3±12.5 years) of participants at 6 months post injury and with a relatively higher level of disability (NDI 16.5±5.6). For JPE, this study has found evidence of differences between the groups, with extension and both rotations exceeding the reported mean global relocation error of 3.84 cm (Heikkila and Wenngren, 1998). However, this study did not replicate previous findings of significantly greater errors in CWAD participants compared to controls (Sterling et al, 2003a; Sterling, 2004; Hill et al, 2009) following movement in the sagittal and transverse planes.

There are two key considerations that could have impacted upon why this study did not replicate the findings of previous studies. First, as most previous studies had evaluated several classifications of WAD beyond the WADII classification, more severe presentations might have contributed to the significant differences. Second, the convenience sample was of low disability without group evidence of a neuropathic component to the presentation and this might have contributed to the lack of differentiation.

CONCLUSIONS

This preliminary study does not support the use of vibration, CPT or JPE to distinguish individuals with CWADII with relatively mild levels of self-report disability from control participants.

The reported associations between measures, however, do suggest that further work in this area would be valuable, with an adequate sample size and use of participants presenting for management within a practice environment. IJTR

Conflict of interest: None declared.

Arndt S, Turvey C, Andreasen NC (1999) Correlating and predicting psychiatric symptom ratings, Spearman's r versus Kendall's tau correlation. *J Pyschiatr Res* **33**(2): 97–104

Bennett MI, Smith BH, Torrance N, Potter J (2005) The S-LANSS score for identifying pain of predominantly neuropathic origin: validation for use in clinic and postal research. *Pain* **6**(3): 149–58

Berwick V, Cheek L, Ball J (2005) Statistics review 14: Logistic regression. *Critical Care* **9**(1): 112–18

Bjelland I, Dahl AA, Haug TT, Neckelmann D (2002) The validity of the Hospital Anxiety and Depression Scale: an updated literature review. *J Psychosom Res* **52**(2): 69–77

Burton K (2003) *Treatment guidelines: is there a need?* In: Proceedings of Whiplash conference 2003, Bath, England, 6–8 May. Lyons Davidson Solicitors, Bristol

Carroll LJ, Hurwitz EL, Cote P et al (2008) Research priorities and methodological implications. The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and its Associated Disorders. *Spine* **33**(4S): S214–20

Chien A, Eliav E, Sterling M (2008) Whiplash (grade II) and cervical radiculopathy share a similar sensory presentation: an investigation using quantitative sensory testing. *Clin J Pain* **24**(7): 759–66

Chien A, Eliav E, Sterling M (2009) Hypoesthesia occurs with sensory hypersensitivity in chronic whiplash- further evidence of a neuropathic condition. *Manual Therapy* **14**(2): 138–46

Chien A, Sterling M (2010) Sensory hypoesthesia is a feature of chronic whiplash but not chronic idiopathic neck pain. *Manual Therapy* **15**(1): 48–53

Cohen J, Cohen P, West SG, Aiken LS (2003) *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences, 3rd edn*. Lawrence Erlbaum Associates, New Jersey

Curatolo M, Banic B, Petersen F et al (2002) *Preliminary electrophysiological evidence for central hypersensitivity in whiplash pain and fibromyalgia.* 10th World Congress on Pain. International Association for the Study of Pain, San Diego, CA

Goldsmith R, Wright C, Bell SF, Rushton A (2012) Cold hyperalgesia as a prognostic factor in whiplash associated disorders: A systematic review. *Manual Therapy* **17**(5): 402–10

Greening J, Lynn B (1998) Minor peripheral nerve injuries: an underestimated source of pain? *Manual Therapy* **3**(4): 187–94

Greening J, Lynn B, Leary R (2003) Sensory and autonomic function in the hands of patients with non-specific arm pain (NSAP) and asymptomatic office workers. *Pain* **104**(1–2): 275–81

Heikkila HV, Wenngren BI (1998) Cervicocephalic kinesthetic sensibility, active range of cervical motion, and oculomotor function in patients with whiplash injury. *Arch Phys Med Rehabil* **79**(9): 1089–94

Hill R, Jensen P, Baardsen T, Kulvik K, Jull G, Treleaven J (2009) Head repositioning accuracy to neutral: a comparative study of error calculation. *Man Ther* **14**(1): 110–4

Jansen GB, Edlund C, Grane P et al (2008) The Swedish Society of Medicine and the Whiplash Commission Medical Task Force. Whiplash injuries: diagnosis and early management. *European Spine Journal* **17**(Suppl3): S359–418

Jewell NP (2004) *Statistics for Epidemiology.* Chapman and Hall/CRC, New York

Jull G, Sterling M, Kenardy J, Beller E (2007) Does the presence of sensory hypersensitivity influence outcomes of physical rehabilitation for chronic whiplash? A preliminary RCT. *Pain* **129**(1–2): 28–34

Kampner SJ, Rebbeck TJ, Maher CG, McAuley JH, Sterling M (2008) Course and prognostic factors of whiplash: a systematic review and analysis. *Pain* **138**(3): 617–29

Kasch H, Qerama E, Bach F, Jensen TS (2005) Reduced cold pressor pain tolerance in non-recovered whiplash patients: a 1 year prospective study. *Eur J Pain* **9**(5): 561–9

Lundborg G (1988) *Nerve Injury and Repair.* Churchill-Livingstone, Edinburgh

Martina I, van Koningsveld R, Schmitz PI, Meche FG, Doorn PA (1998) Measuring vibration threshold with a graduated tuning fork in normal aging and in patients with polyneuropathy. *J Neurol Neurosurg Psychiatry* **65**(5): 743–7

McCarthy MJ, Grevitt MP, Silcocks P, Hobbs G (2007) The reliability of the Vernon and Mior neck disability index, and its validity compared with the short form-36 health survey questionnaire. *Eur Spine J* **16**(12): 2111–17

Moore A, Jackson A, Jordan J et al (2005) *Clinical Guidelines for the Physiotherapy Management of Whiplash Associated Disorder (WAD).* Chartered Society of Physiotherapy, London

O'Conaire E, Rushton A, Wright C (2011) The assessment of vibration sense in the musculoskeletal examination: Moving towards a valid and reliable quantitative approach to vibration testing in clinical practice. *Manual Therapy* **16**(3): 296–300

Palmer ST, Martin DJ, Steedman WM, Ravey J (2000) C- and Aδ-fibre mediated thermal perception: response to rate of temperature change using method of limits. *Somatosens Mot Res* **17**(4): 325–33

Raak R, Wallin M (2006) Thermal thresholds and catastrophizing in individuals with chronic pain after whiplash injury. *Biol Res Nurs* **8**(2): 138–46

Rix GD, Bagust J (2001) Cervicocephalic kinesthetic sensibility in patients with chronic, nontraumatic cervical spine pain. *Arch Phys Med Rehabil* **82**(7): 911–9

Rushton A, Wright C, Heneghan N, Eveleigh G, Calvert M, Freemantle N (2011) Physiotherapy rehabilitation for Whiplash Associated Disorder II: a systematic review and meta-analysis of randomised controlled trials. *BMJ Open* **1**(2): e000265

Scott D, Jull G, Sterling M (2005) Widespread sensory hypersensitivity is a feature of chronic whiplash associated disorders but not chronic idiopathic neck pain. *Clin J Pain* **21**(2): 175–81

Sim J, Wright C (2000) *Research in Health Care: Concepts, Designs and Methods*. Nelson Thornes, Oxford

Spitzer WO, Skovron ML, Salmi LR et al (1995) Scientific monograph of the Quebec task force on whiplash-associated disorders: redefining "whiplash" and its management. *Spine* **20**(8): 1S–73S

Sterling M, Jull G, Vicenzino B, Kenardy J (2003a) Sensory hypersensitivity occurs soon after whiplash injury and is associated with poor recovery. *Pain* **104**(3): 509–17

Sterling M, Jull G, Vizenzino B, Kenardy J, Darnell R (2003b) Development of motor system dysfunction following whiplash injury. *Pain* **103**(1–2): 65–73

Sterling M (2004) A proposed new classification system for whiplash associated disorders – implications for assessment and management. *Man Ther* **9**(2): 60–70

Sterling M, Pedler A (2009) A neuropathic pain component is common in acute whiplash and associated with a more complex clinical presentation. *Manual Therapy* **14**(2): 173–9

Sterling M (2010) Differential development of sensory hypersensitivity and a measure of spinal cord hyperexcitability following whiplash injury. *Pain* **150**(3): 501e6

Sterling M, Hendrikz J, Kenardy J (2011) Similar factors predict disability and posttraumatic stress disorder trajectories after whiplash injury. *Pain* **152**(6): 1272e8

Sterling M (2014) Physiotherapy management of whiplash-associated disorders (WAD). *Journal of Physiotherapy* **60**(1): 5–12

Stone AM, Vicenzino B, Lim ECW, Sterling M (2012) Measures of central hyperexcitability in chronic whiplash associated disorder – A systematic review and meta-analysis. *Manual Therapy* **18**(2): 111–7

Swait G, Rushton BA, Miall CR, Newell D (2007) Evaluation of cervical proprioceptive function. *Spine* **32:** E692–701

Tabachnick BG, Fidell L (2013) *Using Multivariate Statistics, 6th edn*. Allyn and Bacon, Boston

Treleaven J, Jull G, LowChoy N (2006) The relationship of cervical joint position error to balance and eye movement disturbances in persistent whiplash. *Man Ther* **11**(2): 99–106

Vernon H, Mior S (1991) The neck disability index: a study of reliability and validity. *J Manipulative Physiol Ther* **14**(7): 409–15

Wallin MK, Raak RI (2008) Quality of life in subgroups of individuals with whiplash associated disorders. *Eur J Pain* **12**(7): 842–49

Wallin M, Liedberg G, Borsbo B, Gerdle B (2012) Thermal detection and pain thresholds but not pressure pain thresholds are correlated with psychological factors in women with chronic whiplash-associated pain. *Clin J Pain* **28**(3): 211–21