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Physical and psychological factors predict outcome following whiplash injury

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Abstract

Predictors of outcome following whiplash injury are limited to socio-demographic and symptomatic factors, which are not readily amenable to secondary and tertiary intervention. This prospective study investigated the predictive capacity of early measures of physical and psychological impairment on pain and disability 6 months following whiplash injury. Motor function (ROM; kinaesthetic sense; activity of the superficial neck flexors (EMG) during cranio-cervical flexion), quantitative sensory testing (pressure, thermal pain thresholds, brachial plexus provocation test), sympathetic vasoconstrictor responses and psychological distress (GHQ-28, TSK, IES) were measured in 76 acute whiplash participants. The outcome measure was Neck Disability Index scores at 6 months. Stepwise regression analysis was used to predict the final NDI score. Logistic regression analyses predicted membership to one of the three groups based on final NDI scores (<8 recovered, 10–28 mild pain and disability, >30 moderate/severe pain and disability). Higher initial NDI score (1.007–1.12), older age (1.03–1.23), cold hyperalgesia (1.05–1.58), and acute post-traumatic stress (1.03–1.2) predicted membership to the moderate/severe group. Additional variables associated with higher NDI scores at 6 months on stepwise regression analysis were: ROM loss and diminished sympathetic reactivity. Higher initial NDI score (1.03–1.28), greater psychological distress (GHQ-28) (1.04–1.28) and decreased ROM (1.03–1.25) predicted subjects with persistent milder symptoms from those who fully recovered. These results demonstrate that both physical and psychological factors play a role in recovery or non-recovery from whiplash injury. This may assist in the development of more relevant treatment methods for acute whiplash.

Keywords: Whiplash injury; Physical and psychological factors; NDI scores; Prediction

1. Introduction

Most individuals recover within a few weeks of whiplash injury from motor vehicle crashes but a significant proportion (14–42%) develop persistent pain with 10% reporting constant severe pain (Barnsley et al., 1994).

The ability to predict which patients will develop chronic symptoms following whiplash injury is important so that appropriate early management can be targeted to these patients. Since the Quebec Task Force's recommendation in 1995 (Spitzer et al., 1995) that a greater number of prognostic studies on whiplash were necessary, many factors such as socio-demographic status, crash-related, compensation/litigation, psychosocial and physical factors have been studied for their predictive capacity (Cassidy et al., 2000; Kasch et al., 2001; Radanov et al., 1995; Schrader et al., 1996). Despite these investigations, two recent systematic reviews of prospective cohort studies on whiplash could agree on only high initial pain intensity as showing strong evidence for delayed functional recovery (Cote et al., 2001; Scholten-Peeters et al., 2003).

It is apparent from these systematic reviews that it is still very unclear which patients are at risk of delayed recovery

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following whiplash injury. Furthermore, few factors have been identified that can assist in directing the secondary and tertiary management of this condition such that the transition to persistent pain and disability may be averted.

In light of the current biopsychosocial model of musculoskeletal pain and recent findings of more complex changes in both the motor and sensory function of persons with chronic whiplash associated disorders (WAD) (Koelbaek-Johansen et al., 1999; Nederhand et al., 2002), investigation of the predictive capacity of a more complete set of measures reflecting such changes is long overdue. Chronic WAD have been shown to be associated with motor dysfunction, generalised sensory hypersensitivity suggestive of changes in central nociceptive pathways and psychological distress (Dall'Alba et al., 2001; Koelbaek-Johansen et al., 1999; Radanov et al., 1996). We and others have previously demonstrated that some of these changes occur soon after injury and persist into the period of chronicity in certain patients (Nederhand et al., 2002; Sterling et al., 2003a,b.) It is not known whether the early presence of disturbances in motor and sensory function as well as psychological distress is predictive of poor outcome following whiplash injury.

We have previously reported the development of changes in these systems from soon after injury until the development of chronicity in this whiplash cohort (Sterling et al., 2003a,b,c, 2004). The aim of this study was to determine the predictive capacity of the combined comprehensive set of measures (motor, sensory and psychological), encompassing the broad biopsychosocial model of musculoskeletal pain, on outcome (persistent pain and disability) at 6 months post-whiplash injury.

2. Methods

2.1. Study design

A prospective longitudinal design was used to assess the whiplash subjects at less than 1 month post-injury and then at 6 months post-injury. Participants attended the research unit to complete all questionnaires and assessments.

2.2. Subjects

Eighty individuals (56 females, mean age 36.27 ± 12.69 years) reporting neck pain as a result of a motor vehicle crash participated in the study. The whiplash subjects were recruited via hospital accident and emergency departments, primary care practices and from advertisement. They were eligible if they met the Quebec Task Force Classification of WAD II or III (Spitzer et al., 1995). Subjects were excluded if they were WAD IV, experienced concussion, loss of consciousness or head injury as a result of the accident and if they reported a previous history of whiplash, neck pain or headaches that required treatment.

2.3. Dependent variable

The outcome measure (dependent variable) was persistent pain and disability at 6 months post-injury as measured with the Neck Disability Index (NDI) (Vernon and Mior, 1991). The NDI consists of 10 items addressing functional activities such as personal care, lifting, reading, work, driving, sleeping and recreational activities as well as pain intensity, concentration and headache (Vernon and Mior, 1991). There are six potential responses for each item ranging from no disability (0) to total disability (10). The overall score (out of 100) is calculated by totalling the responses of each individual item and multiplying by two. A higher score indicates greater pain and disability (Vernon and Mior, 1991). The NDI is a valid, reliable and responsive measure of neck pain and disability (Pietrobon et al., 2002) and is in line with calls for the focus on such instruments as outcome measures of functional recovery following whiplash injury (Scholten-Peeters et al., 2003). Participants returned to the research unit to complete this questionnaire at 6 months post-injury.

2.4. Independent variables

The independent variables were measures of both physical (motor and sensory function) and psychological impairment as outlined below. Three additional variables were also included since these have been consistently shown in previous studies to be predictors of poor outcome (Cote et al., 2001). These were age, gender and the initial intensity of symptoms based on both NDI score measured within 1 month of injury and the participants' initial pain intensity (10 point VAS scale; 0, no pain; 10, worst pain imaginable).

2.5. Physical measures of motor function

Range of active cervical movement (ROM) was measured in three dimensions using an electromagnetic, motion-tracking device (Fastrak, Polhemius, USA) according to previously established methodology (Dall'Alba et al., 2001).

Joint position error (JPE) was measured according to Revel et al. (1994) by using the Fastrak system and set-up described for ROM. The subjects' ability, whilst blindfolded, to relocate the head to a natural head posture was measured following active cervical left and right rotation and extension.

Surface electromyography (EMG) was used to measure the activity of the superficial neck flexor muscles during the established 5-staged clinical test of cranio-cervical flexion· (Jull et al., 2004; Sterling et al., 2003b).

2.6. Measures of sensory function

PPTs were measured using a pressure algometer with a probe size of 1 cm^2 and application rate of 40 kPa/s (Somedic AB, Farsta, Sweden). PPTs were measured bilaterally over the articular pillars of C2/3 and C5/6; over the three main peripheral upper limb nerve trunks and at a remote site (tibialis anterior). These sites have been previously used in investigation of WAD (Sterling et al., 2003a). Triplicate recordings were taken at each site and the mean values used for analysis.

Thermal (heat and cold) pain thresholds were measured bilaterally over the cervical spine using the Thermotest system

(Somedic AB, Farsta, Sweden). Triplicate recordings were taken at each site and the mean values used for analysis.

The brachial plexus provocation test (BPPT) was performed as described previously (Sterling et al., 2003a). The range of elbow extension was measured at the subjects' pain threshold using a standard goniometer (Clarkson and Gilewich, 1989). If the subject did not experience pain, the test was continued until end of available range. At the completion of this test, the subjects were asked to record their pain on a 10 cm visual analogue scale (VAS).

2.7. Sympathetic nervous system function

The sympathetic vasoconstrictor response (SVR) was used as an indication of sympathetic nervous system (SNS) activity (Schurmann et al., 1999). Using laser Doppler flowmetry (floLAB Monitor, Moor Instruments, Devon, England), the skin blood flow in the fingertips of both hands was measured. A provocation maneuver (inspiratory gasp), which is known to cause a short sympathetic reaction and cutaneous vasoconstriction, was performed (Schurmann et al., 1999). Two quotients were calculated: the SRF parameter (sympathetic reflex) that represents the relative drop in the curve after provocation and the QI (quotient of integrals) that also takes into account the duration of perfusion decrease (Schurmann et al., 1999). A high QI and low SRF are indicative of an impaired vasoconstrictor response.

2.8. Psychological questionnaires

The General Health Questionnaire 28 (GHQ-28) is a 28-item measure of emotional distress in medical settings (Goldberg, 1978).

The TAMPA Scale of Kinesphobia (TSK) is a 17-item questionnaire that measures the fear of reinjury due to movement (Kori et al., 1990).

The Impact of Events Scale (IES) is a 15-item questionnaire that measures current subjective stress related to a specific life event (Horowitz et al., 1979).

2.9. Data analysis

Regression analyses were used to evaluate the predictive function of the variable set. A stepwise regression analysis predicted NDI score at the endpoint of the study (6 months post-injury). Binomial logistic regression was used to evaluate group assignment based on previous studies (Sterling et al., 2003a,b). These groups were formed based on NDI scores at the endpoint of the study (6 months post-injury) and included: recovered (<8 NDI), milder pain and disability (10–28 NDI) and moderate/severe pain and disability (>30 NDI) (Vernon, 1996). This grouping was validated by a cluster analysis (K-means algorithm), which showed no significant difference between the analytical clustering and the NDI groups as proposed by Vernon (1996). The logistic regression analyses were then subjected to cross-validation analysis (leave one out) to assess the error rate of the classification rates and to assess the reliability and generalisability of the findings.

For all analyses significance was set at $P<0.05$.

3. Results

Seventy-six subjects completed the 6-month follow-up. Five volunteers were excluded from the study. Reasons for exclusion included a whiplash injury of greater than 4 weeks duration (3 subjects) and a history of previous whiplash injury (2 subjects). Four subjects withdrew after the first assessment point. The reasons for withdrawal included relocation to another city (two subjects), a head injury several weeks following the whiplash injury (one subject) and no reason given (one subject).

Seventy percent of participants were female and the mean age was 36.27 ± 12.69 years. The mean intensity of neck pain was 3.5 (1.2) on a 10 cm VAS scale and the mean score on the NDI was 34.15 (2.37). Three participants (3.9%) could be classified as WAD III with the remainder being WAD II. All participants reported neck pain with headaches (55%), shoulder/arm pain (30%), thoracic (54%), and lumbar spine (30%) also being reported.

The results of the stepwise regression analysis score revealed that the independent variables of initial NDI score, age, left rotation ROM, cold pain threshold, QI, and IES score contributed significantly to the prediction of NDI score at 6 months and together accounted for 67% of the variability in NDI scores at 6 months post-injury (Table 1). These results indicate that a higher NDI score at 6 months post-injury is associated with a higher initial NDI score, older age, female gender, decreased active range of left rotation, decreased cold pain thresholds, less vasoconstriction with the SVR test and higher levels of acute emotional distress.

Details of the whiplash groups used for the logistic regression analyses are provided in Table 2. This study did not aim to investigate the effect of treatment and subjects were free to pursue any form of treatment. The types and numbers of treatments received (including medication) were similar between the three whiplash groups (Table 3).

The results of the logistic regression analysis showed that initial NDI score, age, cold pain threshold and IES score were significant predictors of membership to the whiplash

Table 1
Results of stepwise regression analysis with NDI score at six months as the dependent variable

	Estimate	Standard error	t-value	P
(Intercept)	11.74	10.89	1.08	0.285
Initial NDI	0.387	0.083	4.67	0.00002
Age	0.387	0.108	3.42	0.001
Left rotation	−0.178	0.106	−1.902	0.05
CPT	0.505	0.199	2.53	0.01
QI	−0.147	0.07	−2.098	0.04
IES (total)	0.338	0.094	3.608	0.006

Residual standard error, 10.07 on 65 degrees of freedom; multiple R-squared, 0.6742; adjusted R-squared, 0.6291; F-statistic, 14.95 on 9 and 65 DF; P-value, 8.33×10^{-13}.

Table 2
The age, gender and classification of subject groups at 6 months according to the NDI scores

Group	Number	Age (years) (mean±SD)	Gender % female	NDI classification	NDI (mean±SD)
Recovered group	29	29.3±11.72	50	<8	2.9±2.9
Mild pain and disability group	30	34.3±12.5	77	10–28	16.5±5.6
Moderate/severe pain and disability group	17	43.7±14.5	94	>30	42.8±12.2

Table 3
The numbers and types of treatment and medication received by the three whiplash groups

Group	*N* (%) who received treatment	No. of treatments (average/study period)	Treatment type *N* (%)			*N* (%) on medication	Medication type					
			PT	CH	AC		SA	NS	Cod	AD	St	Op
Recovered (*N*=29)	14 (48.3)	10.6	29 (100)	0	0	7 (24)	3	4	1	0	1	0
Mild symptoms (*N*=30)	19 (63)	14.4	14 (46.7)	4 (13.3)	1 (3)	13 (43.3)	2	10	2	1	0	1
Mod/severe symptoms (*N*=17)	9 (52.9)	18.4	8 (47)	1 (5.8)	0	12 (70.5)	2	7	2	2	0	1

Treatment: PT, physiotherapy; CH, chiropractic; AC, acupuncture. Medication: SA, simple analgesics; NS, non-steroidal anti-inflammatory; Cod, codeine; AD, anti-depressants; St, steroids; Op, opioids.

group with persistent moderate severe symptoms at 6 months ($P<0.05$) (Table 4). This model correctly predicted 68.8% of those with persistent moderate/severe symptoms and 93.2% of those without moderate/severe symptoms at 6 months post-injury with an overall success rate of 88%. Following cross-validation analysis the prediction rate of the moderate/severe group remained at 68.8% with the prediction rate of non-moderate/severe cases decreasing slightly to 88.5% with an overall success rate of 86.7%.

A logistic regression analysis was also performed using only the variables of age and initial NDI score to compare the classification rate of these variables to the more complete set (initial NDI score, age, cold pain threshold and IES score). This model correctly predicted 93.2% of those without moderate/severe symptoms at 6 months and 37% of those with moderate/severe symptoms, with an overall success rate of 81%.

Table 4
Results of logistic regression analysis showing factors associated with membership to the whiplash group with persistent moderate/severe symptoms at six months post-injury

Variables	*B*	SE	Wald test (*z*-ratio)	*P*-value	OR	95%CI OR	
						Lower	Upper
Initial NDI	0.06	0.027	4.84	0.028	1.06	1.007	1.12
Age	0.13	0.05	6.41	0.01	1.13	1.03	1.23
Cold pain threshold	0.26	0.10	6.09	0.01	1.29	1.05	1.58
IES score	0.11	0.04	7.71	0.005	1.11	1.03	1.2

OR, odds ratio; CI OR, confidence interval for odds ratio.

The results of the logistic regression analysis used to predict those subjects with residual milder symptoms at 6 months from those who had recovered showed that initial NDI score, QI quotient of the SVR test, GHQ-28 scores and decreased range of cervical extension were significant predictors of membership to this group ($P<0.05$) (Table 5). This model correctly predicted 89.3% of recovered subjects and 90.3% of those with persistent milder symptoms with an overall success rate of 89.8%. Following cross-validation analysis the successful prediction rates decreased, with 78.6% of recovered subjects predicted and 83.9% of those with persistent milder symptoms. The overall success rate was 81.4%.

The following variables demonstrated no significant predictive capacity in either the stepwise or logistic regression analyses: Joint position error, EMG activity of the superficial neck flexor muscles during the cranio-cervical flexion test, PPT (all sites), heat pain threshold, responses to the brachial plexus test and scores of the TSK.

Table 5
Results of logistic regression analysis showing factors associated with membership to the whiplash group with persistent milder symptoms versus recovery at six months post-injury

Variables	*B*	SE	Wald test (*z*-ratio)	*P*-value	OR	95%CI OR	
						Lower	Upper
Initial NDI	0.18	0.077	5.75	0.017	1.15	1.03	1.28
GHQ-28	0.23	0.1	4.84	0.028	1.15	1.04	1.28
Extension	−0.15	0.07	4.89	0.027	1.1	1.03	1.25

OR, odds ratio; CI OR, confidence interval for odds ratio.

Table 6
Group means and SD for best predictors of group (recovered, mild pain and disability, moderate/severe pain and disability) membership based on logistic regression analysis

Measure	Recovered: mean (SD)		Mild pain and disability: mean (SD)		Moderate/severe: mean (SD)	
	> 1 month	6 months	> 1 month	6 months	> 1 month	6 months
Initial NDI[a,b,c]	19.2 (12.5)	2.9 (2.9)	37.2 (19.8)	16.5 (5.6)	54.7 (13.6)[a,b]	42.8 (12.2)
Age[a]	29.3 (11.7)		34.3 (12.5)		43.7 (14.5)[a]	
Left rotation[a,c]	55.5 (11.0)	59.4 (11.2)	51.4 (11.9)	55.4 (11.2)	44.8 (12.4)[a]	47.5 (12.6)
Extension[b]	45.29 (13.3)	48.8 (13.9)	38.75 (13.6)	48.3 (13.2)	32.14 (13.4)[b]	31.1 1(3)
Cold pain threshold[a,c]	11.02 (5.7)	10 (5.1)	10.37 (6.1)	11 (6.1)	20.27 (6.4)[a]	19.89 (6.4)
QI[c]	58.4 (17.2)	55.7 (16.9)	52.19 (16.9)	56.1 (15)	69.68 (18.2)[b]	69.44 (17)
SRF[c]	0.75 (0.17)	0.75 (0.2)	0.76 (0.18)	0.76 (0.17)	0.61 (0.15)	0.63 (0.14)
IES[a,c]	9.5 (7.3)	0.38 (7.4)	13.5 (14.2)	4.7 (14.3)	28.1 (15.1)[a]	21.4 (13.1)
GHQ-28 total[b]	19.6 (7.3)	12. (7.3)	32.4 (14.3)[b]	21.4 (14.5)	41.9 (16.2)[b]	34 (16.5)
Flexion	*39.2 (9.5)*	*41.7 (9.2)*	*33.2 (11.5)*	*39.6 (11.4)*	*30.63 (12.2)*	*34.5 (12.9)*
Right rotation	*50.7 (9.9)*	*56.5 (10.8)*	*47.4 (11.8)*	*51.6 (11.8)*	*43.5 (12.8)*	*47.2 (12.6)*
JPE	*3.7 (2)*	*3.5 (2)*	*3.2 (2.4)*	*3.4 (2.2)*	*4.3 (2.6)*	*4.5 (2.8)*
% EMG	*23.3 (3.22)*	*19.5 (3.34)*	*25.43 (3.16)*	*19.19 (3.11)*	*34.55 (4.8)*	*28.65 (4.47)*
PPT (neck)	*167.3 (75.1)*	*202 (65.4)*	*152.5 (75.1)*	*199.4 (85)*	*91 (62)*	*135 (60.7)*
PPT (median nerve)	*197.6 (70.6)*	*231.8 (65.1)*	*210.5 (74.7)*	*244 (64.6)*	*140.9 (50.5)*	*169.9 (54.7)*
PPT (Tib ant)	*333 (75)*	*416.3 (76.3)*	*380.3 (84.3)*	*415.1 (76.4)*	*241 (48.7)*	*256.1 (55.3)*
Heat pain threshold	*41.9 (3.2)*	*43.1 (3.3)*	*42.8 (3.5)*	*43.4 (3.6)*	*38.6 (3.2)*	*39.5 (3.4)*
TSK	*34.4 (6.3)*	*28.4 (5.6)*	*38.4 (6.4)*	*34.3 (6.2)*	*42.3 (8.3)*	*39.7 (8.1)*

Variables that failed to reach significance are shown in italics.
[a] Significant predictors to distinguish between moderate/severe symptoms at 6 months from the other two groups.
[b] Significant predictors to distinguish between those with persistent mild symptoms from those who were recovered by six months post-injury.
[c] Significant predictors in stepwise regression analysis.

Table 6 depicts the mean (SD) values of the variables that significantly predicted membership to each of the three whiplash groups.

4. Discussion

This study is the first to show that a combination of physical (motor and sensory) and psychological factors, in addition to previously recognised indicators of age and initial symptom intensity are important in the determination of outcome following whiplash injury. Initial NDI score was the measure of symptom intensity that reached significance with VAS scores of pain intensity failing to demonstrate a significant predictive capacity. The high correlation ($r = 0.8$, $P < 0.01$) between these measures in this study may explain these findings, but it also suggests that a measure of pain and disability as opposed to pain intensity alone be used in the early assessment of whiplash.

Both a multiple regression analysis using final NDI score as the independent variable and logistic regression using a classification system based on final NDI score as criterion variables showed similar results with a combination of variables providing the best prediction of outcome. Higher initial levels of pain and disability, older age, cold hyperalgesia and acute post-traumatic stress were associated with a higher NDI score and membership to the group with persistent moderate/severe symptoms at 6 months. The odds ratios for these variables ranged from 1.1 to 1.3. It should be noted that this applies to increased odds for a one-unit change in the predictor variable. For example if cold pain threshold decreases by 1 °C the odds of developing persistent moderate/severe symptoms increases by a factor of 1.3. With reference to Table 6, it can be seen that the difference between mean values of cold pain threshold of recovered subjects compared to those with persistent moderate/severe symptoms was 9 °C. In this case the odds ratio would increase to 10.6.

Diminished vasoconstrictive responses, whilst predictors of higher NDI scores at 6 months in the multiple regression analysis were not strong predictors of membership to the group with moderate/severe symptoms. The reasons for this are unclear. However, the results of the two analyses together, suggest that all the above mentioned variables be included in further evaluation of outcome following whiplash injury. Gender was not predictive of poor outcome in either analysis supporting the findings of a recent systematic review (Scholten-Peeters et al., 2003). The predictive capacity of this variable requires further clarification.

The combination of variables identified in this study was superior in predicting a poor outcome when compared to previous models. A combination of age, gender, psychological factors or age, gender, accident features have accounted for approximately 35% of the variation in pain and disability at 1 year post-accident (Kyhlback et al., 2002;

Mayou and Bryant, 1996), well short of the 67% R^2 demonstrated by our variables. Using logistic regression analysis we correctly classified 68.8% of those with persistent moderate/severe symptoms post-injury. This figure is similar or superior to that determined either by psychological tests, a combination of symptoms and ROM and a combination of accident features and pain (Hartling et al., 2002; Kasch et al., 2001; Olsson et al., 2002). These studies utilised a dichotomous outcome (recovery or non-recovery) based on unvalidated questionnaires. In line with recent calls for prognostic studies of whiplash to use reliable and valid outcomes of functional recovery (Scholten-Peeters et al., 2003), we employed the NDI as our outcome measure. This allowed discrimination to be made between subjects reporting recovery at 6 months, those with milder symptoms and those with moderate/severe symptoms at this time frame. This differentiation is important since those with more severe symptoms account for a much greater proportion of the costs (MAIC, 2002) and their early identification is of interest to all stakeholders. The logistic regression analysis also showed that higher initial NDI and GHQ-28 scores, and less cervical extension differentiated participants reporting milder symptoms at 6 months from those who recovered. Understanding of differences between these two groups is important for both the development of appropriate interventions as well as for stakeholders interested in curtailing costs through early claim settlement.

The classification rates of our set of predictor variables (initial NDI, age, cold pain threshold, IES score) were superior to those based on initial NDI score and age alone (previously recognised predictors). Whilst both predictor sets classified 93% of those without moderate/severe symptoms at 6 months, the latter two variables predicted only 37% of those with persistent moderate/severe symptoms compared to the 68.8% rate of the complete predictor set. This provides strong argument for the inclusion of additional measures of cold hyperalgesia and post-traumatic stress reaction in the assessment of acute whiplash.

The classification rates of our study decreased when subjected to cross-validation analysis suggesting that the results need to be viewed as preliminary until further validation in other whiplash populations is undertaken. It is notable that previous studies (Hartling et al., 2001; Mayou and Bryant, 1996; Olsson et al., 2002) did not report the use of cross-validation analysis on their classification rates and thus the utility of their results is unknown.

Whilst it was a combination of levels of pain and disability, physical and psychosocial factors that were predictive of a poor outcome following whiplash injury, not all measures showed significant predictive capacity. Post-traumatic stress reaction was the only psychological predictor of poor outcome with both fear of movement and general psychological distress failing to reach significance. This may be at odds with investigation of the development of chronicity in low back pain where fear avoidance beliefs play a prognostic role (Vlaeyen and Linton, 2000) and more recently in whiplash injury where Nederhand et al. (2004) found TSK scores to be predictive of persistent symptoms at 6 months post-trauma. It should be noted that the latter study investigated only two variables (NDI, TSK) as possible prognostic factors. The inclusion of a measure of post-traumatic stress may have provided different results. Our findings also highlight potentially important differences between other musculoskeletal conditions such as low back pain and whiplash injury. The traumatic event (MVC) that precipitates the onset of whiplash may have different psychological consequences that influence recovery than those involved in the onset of low back pain, indicating further research investigating such differences is warranted. Our findings of specific psychological factors related to delayed recovery following whiplash injury suggest that specific treatments provided to those with an early post-traumatic stress reaction may be more efficacious than a broadly applied cognitive behavioural approach.

Cervical ROM loss was the only measure of motor function predictive of higher pain and disability at 6 months and supports findings of previous studies (Kasch et al., 2001; Radanov et al., 1995). Neither joint position error nor EMG activity during cranio-cervical flexion showed significant predictive capacity. These motor deficits are present in both idiopathic neck pain (Jull et al., 2004; Kristjansson et al., 2003) and in whiplash injured persons with lesser symptoms (Sterling et al., 2003b). The uniformity of these deficits across neck pain conditions is the likely reason for their poor predictive capacity of those with persistent moderate to severe symptoms.

Cold hyperalgesia and impaired sympathetic vasoconstriction were the strongest sensory predictive variables. Whilst we have shown previously in this cohort that mechanical, heat hyperalgesia and responses to brachial plexus provocation are present from soon after injury and persist in those with poor recovery (Sterling et al., 2003a), these variables were not predictors of outcome. The reasons for this are not clear but some possible explanations can be explored. The sensory hypersensitivity seen in patients with whiplash injury is proposed as being due to the augmentation of central pain processing mechanisms (Moog et al., 2002; Sterling et al., 2003a). Cold hyperalgesia and SNS disturbances have not been previously investigated in patients with whiplash injury, with most studies using some form of mechanical or electrical stimulation (Banic et al., 2003; Moog et al., 2002). It is possible that the two former measures are better clinical indicators of central nervous system hyperexcitability and this requires further investigation. Additionally cold hyperalgesia and SNS disturbances could be an indication of peripheral nerve tissue damage (Djouhri et al., 2004), a potential consequence of whiplash injury (Ide et al., 2001; Taylor and Taylor, 1996).

The findings of this study show that in a proportion of people (20–25% of the cohort), whiplash injury induces concomitant sensory changes reflective of underlying disturbances in pain processing, a post-traumatic stress reaction, movement loss and higher levels of pain and disability. The casual relationship between these factors is yet to be determined and cannot be inferred from this study. The reason for such changes in some participants but not others in this cohort is not known. Whilst the rest of the cohort showed evidence of muscle impairment and general psychological distress post-accident, they did not demonstrate post-traumatic stress or widespread sensory changes (Sterling et al., 2003a). It appears that those with poor recovery have experienced a more complex injury that leads to the development of profound physical and psychological changes.

These findings have implications for management of acute whiplash injury. Concomitant high levels of pain and disability, movement loss, sensory disturbance and a post-traumatic stress reaction indicate that a multiprofessional approach is required for these patients in the acute stage of injury. This approach may need to include psychological intervention to address the post-traumatic stress reaction, physical therapy to restore movement loss as well as adequate pain management (medication) in view of the sensory disturbances and high pain levels seen in this subgroup of the whiplash injured.

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