



Physical and psychological factors maintain long-term predictive capacity post-whiplash injury

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Abstract

Higher initial levels of pain and disability, older age, cold hyperalgesia, impaired sympathetic vasoconstriction and moderate post-traumatic stress symptoms have been shown to be associated with poor outcome 6 months following whiplash injury. This study prospectively investigated the predictive capacity of these variables at a long-term follow-up. Sixty-five of an initial cohort of 76 acutely injured whiplash participants were followed to 2–3 years post-accident. Motor function (ROM; kinaesthetic sense; activity of the superficial neck flexors (EMG) during cranio-cervical flexion), quantitative sensory testing (pressure, thermal pain thresholds and brachial plexus provocation test), sympathetic vasoconstrictor responses and psychological distress (GHQ-28, TSK and IES) were measured. The outcome measure was Neck Disability Index (NDI) scores. Participants with ongoing moderate/severe symptoms at 2–3 years continued to manifest decreased ROM, increased EMG during cranio-cervical flexion, sensory hypersensitivity and elevated levels of psychological distress when compared to recovered participants and those with milder symptoms. The latter two groups showed only persistent deficits in cervical muscle recruitment patterns. Higher initial NDI scores (OR 1.00–1.1), older age (OR 1.00–1.13), cold hyperalgesia (OR 1.1–1.13) and post-traumatic stress symptoms (OR 1.03–1.2) remained significant predictors of poor outcome at long-term follow-up ($r^2 = 0.56$). The robustness of these physical and psychological factors suggests that their assessment in the acute stage following whiplash injury will be important.

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1. Introduction

The development of chronic pain and disability following whiplash injury is not uncommon and results in substantial social and economic costs (Barnsley et al., 1994; MAIC, 2002). The capacity to predict outcome following whiplash injury is important because of the need to institute appropriate early intervention for those deemed at risk of a poorer outcome and in the possible curtailment of costs.

Many studies have investigated the prognostic capability of various factors such as sociodemographic status; crash related variables; compensation/litigation, psychosocial and physical factors (Radanov et al., 1995; Cassidy et al., 2000; Kasch et al., 2001). However, 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). Whilst knowledge of this factor may offer some assistance in identifying patients who may develop persistent symptoms, we have shown that pain and disability levels alone whilst having high specificity had relatively low sensitivity to predict those with ongoing moderate to severe symptoms at 6 months post-accident

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(Sterling et al., 2005). Furthermore, measurement of pain and disability levels alone is unlikely to assist in the direction of secondary and tertiary management stages of this condition.

We have recently reported that a combination of physical and psychological factors including the early presence of cold hyperalgesia, cervical movement loss, impaired sympathetic vasoconstriction and post-traumatic stress symptoms in addition to high pain and disability levels and older age were strong predictors of poor outcome at 6 months (20–25% of this cohort) (Sterling et al., 2005). It appears that some whiplash injured individuals demonstrate a complex presentation from soon after injury that includes augmented central pain processing mechanisms, movement loss and a post-traumatic stress reaction (Sterling et al., 2005). Some support for these findings can be found in another independent prospective study where reduced cold pain tolerance was also associated with non-recovery one year post-injury (Kasch et al., 2004).

Knowledge of whether or not these factors persist and maintain their predictive capacity at a longer term follow-up time point is not known. This study sought to follow up the initial cohort of 76 whiplash injured persons between 2 and 3 years post-motor vehicle crash to determine whether or not the original model maintained its predictive capacity at a long-term follow-up post-whiplash injury. The secondary aim was to compare the current status of physical and psychological features in relation to reported pain and disability levels with those documented at earlier time frames (Sterling et al., 2003a,b,c).

2. Methods

2.1. Study design

A prospective longitudinal design was used to follow and assess whiplash subjects from the acute stage (less than one month post-injury), to 2, 3 and 6 months post-injury (Sterling et al., 2003a,b,c) and 2–3 years post-injury (current study). Participants attended a university research unit to complete all questionnaires and assessments.

2.2. Subjects

The participants who took part in the earlier study consisted of 80 individuals (56 females, mean age 36.27 ± 12.69 years) reporting neck pain as a result of a motor vehicle crash and 76 participants were followed to 6 months post-injury (Sterling et al., 2005). Participants were recruited to the study via hospital accident and emergency departments, primary care practices and from advertisement and 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 treat-

ment. For the present study, the 76 participants who were assessed at 6 months were contacted by telephone, letter or email and invited to participate in the present study. All participants provided written informed consent and the study was approved by the Institutional Ethics Committee.

2.3. Physical and psychological measures

The physical and psychological measures employed in the current study were those used at the earlier time points. These have been previously outlined in detail (Sterling et al., 2003a,b,c). In brief they are as follows.

2.3.1. Physical measures of motor function

Range of active cervical movement (ROM) and joint position error (JPE) were measured using an electromagnetic, motion-tracking device (Fastrak, Polhemus, USA) according to previously established methodology (Sterling et al., 2005). ROM was measured in the directions of flexion, extension and left and right rotation. For JPE, the participant's 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 test of cranio-cervical flexion (Jull et al., 2004).

2.3.2. Measures of sensory function

Pressure pain thresholds (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), bilaterally over the articular pillars of C2/3 and C5/6; over the median nerve trunk at the elbow and at a remote site (tibialis anterior). 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 Thermostest 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. 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).

2.3.3. Sympathetic nervous system function

The sympathetic vasoconstrictor response (SVR) was measured using laser Doppler flowmetry (floLAB Monitor, Moor Instruments, Devon, England) by recording skin blood flow in the fingertips of both hands. A provocation manoeuvre (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.

2.3.4. Questionnaires

The Neck Disability Index (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. There are six potential responses for each item ranging from no disability (0) to total disability (5). The overall score (out of 100) is calculated by totalling the responses of each individual item and multiplying by 2. A higher score indicates greater pain and disability (Vernon and Mior, 1991).

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

The TAMPA Scale of Kinesophobia (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).

2.4. Procedure

All testing was performed in a laboratory setting and by the same examiner (MS). Participants first completed the questionnaires (NDI, GHQ-28, TSK and IES). Testing was then conducted in the following order: SVR, ROM, JPE, CCFT, PPT, thermal pain thresholds and BPPT. This procedure has been previously described in detail (Sterling et al., 2003a,b,c).

2.5. Data analysis

The whiplash participants were classified into one of three groups based on NDI scores at 2–3 years post-accident. These groups were recovered (<8 NDI), mild pain and disability (10–28 NDI) and moderate/severe pain and disability (>30 NDI) (Vernon, 1996). We have previously demonstrated the validity of this classification using cluster analysis (*K*-means algorithm), which showed no significant difference between the analytical clustering and the NDI groups as proposed by Vernon (1996) (Sterling et al., 2003a). A repeated measures mixed model analysis of variance with a between-subjects factor of Group (3 levels: recovered, mild and moderate/severe) and a within subjects factor of Time (2 levels: 6 months and 2–3 years post-injury) was performed to determine changes in motor, sensory and psychological function since the 6-month follow-up point. Age and gender were used as covariates in this analysis. Differences between the groups were analysed with a priori contrasts. Significance for analysis of variance was set at $p < 0.05$.

Regression analyses were used to evaluate the predictive function of the initial model at the longer-term follow-up. A multivariate regression analysis predicted NDI score at the endpoint of the study (2–3 years post-injury). In this analysis, the independent variables were initial NDI score, age, ROM (left rotation), cold pain threshold, SVR quotients and IES score as these were the significant predictors of outcome at 6 months. The compensation status of participants (compensation claim made or not made) was also included as an independent variable in the analysis.

Binomial logistic regression analyses were used to evaluate group assignment based on previous studies (Sterling et al., 2003a,b). The first logistic regression predicted membership

to the moderate/severe group versus all other participants with the independent variables being initial NDI score, age, cold pain threshold and IES score. The second logistic regression predicted membership to the milder pain and disability group versus recovered participants with the independent variables being initial NDI score, GHQ-28 scores, QI of the SVR and extension ROM. In both analyses, the independent variables were those that showed significant predictive capacity at 6 months post-injury. In addition, compensation status was included as an independent variable in both logistic regression analyses.

For all regression analyses significance was set at $p < 0.05$.

3. Results

3.1. Participants

Sixty-five of the 76 participants assessed at 6 months agreed to enter the present study. Eight subjects could not be contacted, one developed cancer since the 6-month follow-up and 2 declined to participate. Of the 65 participants who completed the 2–3 year follow-up, 71% were female. The mean (SD) intensity of neck pain was 3.2 (3.4) on a 10 cm VAS scale, the mean (SD) score of the NDI was 15.57 (14.1) and the mean (SD) duration of symptoms was 2.4 (0.2) years.

Fifty-six percent of the 65 participants continued to report symptoms of varying degrees. Of these participants with ongoing symptoms, all reported neck pain, 40% reported headaches and 20% reported shoulder/arm pain. Of the total sample in this study (65 participants), 14 (22%) participants' conditions improved and 2 (3%) reported a worsening of their neck pain and disability. With respect to the classification of the participants into the 3 groups (recovered, milder or moderate/severe pain) the status of 78.5% remained the same as that at the 6-month point. Seven participants who were classified as having mild pain and disability at 6 months were now recovered and 3 participants with moderate/severe symptoms at 6 months improved and now reported only mild levels of pain and disability. Four participants reported worsening symptoms, with 2 participants who were originally classified as having milder symptoms now reporting moderate/severe symptoms and 2 recovered participants at 6 months now reporting milder levels of pain and disability as per the NDI. Details of the 3 groups at 2–3 years post-injury are depicted in Table 1.

It was not an aim of this study to investigate the effects of treatment and participants were allowed to pursue any form of treatment. Due to the potential for recall bias of participants with regard to the long time frame between the 6 month and 2–3 year follow-up time points and that there was little difference between the groups for treatment received to 6 months (Sterling et al., 2005), we did not record in detail the treatments received during this 18 month period. Thirty-eight

Table 1

The age, gender and classification of subject groups at two years according to the NDI scores

Group	Number	Age (years) (mean \pm SD)	Gender % Female	NDI classification	NDI (mean \pm SD)
Recovered group	26	30.5 \pm 8.4	57.6	<8	2.9 \pm 3.1
Mild pain and disability group	25	36.4 \pm 14.8	76	10–28	16.7 \pm 6
Moderate/severe pain and disability group	14	45.6 \pm 13	85.7	>30	37.1 \pm 8

(58%) of the 65 participants assessed at this long-term follow-up had filed a claim for compensation. With respect to the sub-groupings based on NDI scores, 50% of the recovered group; 56% of the group with milder symptoms and 78% of the moderate/severe group filed a compensation claim.

3.2. Physical and psychological changes from 6 months to 2 years

3.2.1. Motor measures

There was a significant Group effect for all directions of ROM and EMG with cranio-cervical flexion ($p < 0.01$) and no interaction between Group and Time. There was no effect of Group or any interaction effect for the measure of joint position error in any direction. The group with persistent moderate/severe symptoms at 2–3 years post-injury showed less cervical ROM in all directions and higher levels of EMG with cranio-cervical flexion compared to the other 2 groups ($p < 0.01$). There was no difference between recovered participants and those with persistent milder symptoms at 2–3 years. Mean (SD) values of the three groups are shown in Tables 2 and 3. There was no effect of gender on any measure but a significant effect of age on ROM ($p < 0.04$) but not for JPE or EMG.

3.2.2. Sensory measures

There was a significant Group effect for PPT at all sites, heat and cold pain thresholds and BPPT responses (elbow extension, VAS) ($p < 0.01$) but no interaction between Group and Time for any measure, indicating that these measures remained stable from the 6 months to 2–3 year time points. There was no difference between

the groups for either quotient of the SVR or any interaction between Group and Time for this measure. The group with moderate/severe symptoms at 2–3 years had lower PPT at all sites, lower heat and cold pain thresholds and heightened responses to the BPPT (decreased elbow extension, increased pain levels) compared to those who had recovered or reported milder symptoms at this time point ($p < 0.01$) with no difference between the latter two groups. Mean (SD) values of the three groups are shown in Tables 2 and 3. There was no effect of age on any sensory measure but a significant effect of gender on PPT and thermal pain thresholds ($p > 0.05$).

3.2.3. Psychological measures

There was a significant Group effect for TSK, IES and GHQ-28 ($p < 0.01$) but no interaction between Group and Time for any measure. The group with moderate/severe symptoms at 2–3 years showed higher scores on all three questionnaires when compared to the other groups ($p < 0.01$) with no difference between recovered participants and those with milder symptoms. Mean (SD) values of the three groups are shown in Tables 2 and 3. There was no effect of age or gender on any of the psychological measures.

3.3. Prediction of outcome

The results of the multivariate regression analysis score revealed that the independent variables of initial NDI score, age, cold pain threshold and IES score contributed significantly to the prediction of NDI score at 2–3 years and together accounted for 56% of the variability in NDI scores at long-term follow-up (Table 4).

Table 2

Group means and SD for best predictors of group (recovered, mild pain and disability and 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	2 years	>1 month	6 months	2 years	>1 month	6 months	2 years
Initial NDI ^{a,b,c}	19.2 (12.5)	2.9 (2.9)	2.8 (3.0)	37.2 (19.8)	16.5 (5.6)	15.7 (6)	54.7 (13.6) ^{a,b}	42.8 (12.2)	37.1 (8.0)
Age ^{a,c}	29.3 (11.7)			34.3 (12.5)			43.7 (14.5)		
Cold pain threshold ^{a,c}	12.7 (6.7)	9.5 (4.5)	9.2 (3.6)	12.0 (6.8)	11.7 (6)	8.4 (3.4)	17.4 (7.7) ^a	18.1 (7.7)	18.2 (6.1)
IES ^{a,c}	9.8 (12.2)	1.8 (5.3)	2 (7.5)	16.1 (16.8)	6.8 (11.2)	5.2 (11)	26.2 (18.6) ^a	18.9 (18.2)	14.4 (16.2)

^a Significant predictors to distinguish between moderate/severe symptoms at 2 years from the other two groups.

^b Significant predictors to distinguish between those with persistent mild symptoms from those who were recovered by 2 years post-injury.

^c Significant predictors in stepwise regression analysis.

Table 3

Group means and SD, at 2–3 years post-injury for independent variables that were not significant predictors of group (recovered, mild pain and disability and moderate/severe pain and disability) membership based on logistic regression analysis

Variable	Recovered	Mild pain and disability	Moderate/severe
Extension	45 (12)	57 (10)	36 (13) ^a
Flexion	47 (8.9)	46 (8.5)	37 (4) ^a
Right rotation	53.8 (10)	58 (9)	40 (15) ^a
Left rotation	60 (16.6)	60 (7.4)	50.4 (10) ^a
JPE	3.3 (2.6)	2.4 (1.5)	4.3 (3)
% EMG	20.6 (18)	22.7 (14)	48 (21) ^a
PPT (neck)	198 (75)	187 (67)	132 (73) ^a
PPT (median nerve)	235 (71)	267 (99)	193 (62) ^a
PPT (Tib ant)	407 (160)	403 (154)	304 (139) ^a
Heat pain threshold	44 (2.3)	44.3 (3)	41.7 (3.5) ^a
BBPT – ext	–18 (12)	–19 (10)	–28 (16) ^a
SVR – QI	53 (13)	58 (14)	64 (15)
SVR – SRF	0.77 (0.14)	0.75 (0.10)	0.66 (0.14)
TSK	28.4 (5.6)	33 (8.8)	38.4 (7) ^a
GHQ-28	11.5 (6)	17 (8.2)	30.8 (18) ^a

^a Significant group differences at 2–3 years post-injury.

These results indicate that a higher NDI score at 2–3 years post-injury is associated with a higher initial NDI score, older age, cold hyperalgesia and higher post-traumatic stress symptoms. The previously significant prognostic variables of ROM and QI of the sympathetic vasoconstrictor response or the compensation status of participants were not significant predictors of NDI score at 2–3 years.

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 group with persistent moderate severe symptoms at 2–3 years ($p < 0.05$) (Table 5). Participants' compensation status was not a significant predictor of membership to this group. This model correctly predicted 60% of those with persistent moderate/severe symptoms and 84% of those without moderate/severe symptoms at 2–3 years post-injury with an overall success rate of 84.6%. A logistic regression analysis was also

Table 4

Results of multivariate regression analysis with NDI score at 2 years as the dependent variable

	Estimate	Standard error	<i>t</i> -value	<i>p</i> -value
(Intercept)	11.32	8.66	1.3	0.196
Initial NDI	0.275	0.07	3.78	0.001
Age	0.263	0.098	2.75	0.008
Left rotation	–0.008	–0.107	–0.27	0.78
CPT	0.416	0.18	2.28	0.026
QI	–0.02	–0.07	–0.25	0.8
IES (total)	0.242	0.1	2.3	0.018
Compensation status	–0.07	–0.01	–0.78	0.44

Residual standard error: 9.35 on 62 degrees of freedom. Multiple *R*-squared: 0.588. Adjusted *R*-squared: 0.56. *F*-statistic: 20.69 on 4 and 58 DF, *p*-value: 0.001.

Table 5

Results of logistic regression analysis showing factors associated with membership to the whiplash group with persistent moderate/severe symptoms at 2 years post-injury

Variables	<i>B</i>	SE	Wald test (<i>z</i> -ratio)	<i>p</i> -value	OR	95%CI OR	
						Lower	Upper
Initial NDI	0.049	0.024	4.25	0.04	1.05	1.00	1.10
Age	0.06	0.032	3.85	0.05	1.1	1.0	1.13
Cold pain threshold	0.05	0.022	4.88	0.04	1.1	1.0	1.13
IES score	0.065	0.032	5.32	0.02	1.11	1.03	1.2

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

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 83% of those without moderate/severe symptoms at 6 months and 35% of those with moderate/severe symptoms, with an overall success rate of 71%.

The results of the logistic regression analysis used to predict those subjects with residual milder symptoms at 2–3 years from those who had recovered showed that initial NDI score was the only significant predictor of membership to this group ($p < 0.05$) (Table 6). This model correctly predicted 73.1% of recovered subjects and 80% of those with persistent milder symptoms with an overall success rate of 76.5%. The variables GHQ-28 scores, QI of the SVR, extension ROM and compensation status were not significant predictors.

Table 2 depicts the mean (SD) values of the variables that significantly predicted membership to each of the three whiplash groups. Table 3 depicts the mean (SD) values at 2–3 years post-injury of the variables that were not significant predictors of membership to the whiplash groups.

4. Discussion

In this long-term follow-up of 65 of an original cohort of 80 acutely injured whiplash participants, the conditions of most remained stable over an extended period of time. Pain and disability levels (NDI) of 80% of those assessed at 6 months post-injury remained unchanged at 2–3 years. Of the 13 participants whose NDI scores changed, the majority (11 participants,

Table 6

Results of logistic regression analysis showing factors associated with membership to the whiplash group with persistent milder symptoms versus recovery at 2 years post-injury

Variables	<i>B</i>	SE	Wald test (<i>z</i> -ratio)	<i>p</i> -value	OR	95%CI OR	
						Lower	Upper
Initial NDI	0.12	0.042	8.09	0.005	1.13	1.04	1.21

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

17% of total cohort) improved with only 2 participants (3% of cohort) reporting a worsening of their symptoms. Fifty-five percent of those who attended the 2–3 year assessment point continued to report symptoms to varying degrees compared to 62% at six months post-injury. The mean (SD) of NDI score of the total cohort at 2–3 years (15 ± 14.1) was no different from the mean NDI at six months after the accident (17.67 ± 16.5).

The physical and psychological profiles of the previously identified sub-groupings of the whiplash participants also remained stable. In the earlier assessments (<1 month, 2, 3 and 6 months) of these sub-groupings, it was shown that those with persistent moderate/severe symptoms at 6 months could be characterised by a complex presentation involving widespread sensory hypersensitivity (mechanical and thermal); post-traumatic stress symptoms (IES); generalised psychological distress (GHQ-28) and disturbed motor function (movement loss, altered muscle recruitment and kinaesthetic deficits) (Sterling, 2004). At 2–3 years post-accident, the majority of these phenomena persisted in those with ongoing moderate/severe symptoms. The long-term persistence of this complex presentation in this group who fail to recover has implications for the early management of whiplash. The physical and psychological disturbances were apparent within one month of injury and remained unchanged to 6 months and now 2–3 years post-injury. We have previously suggested that this group of whiplash injured people may require early rather than later multiprofessional management including adequate control of pain (pharmacological intervention), rehabilitation of motor deficits (physical therapy) and cognitive behavioural management of psychological distress in an attempt to prevent the transition to chronicity (Sterling et al., 2005). Although speculative at present, our findings that these changes persist well after the initial injury suggest that appropriate and effective early interventions specifically directed toward these deficits may be required in an attempt to prevent the chronicity associated with this condition.

At earlier follow-up times the presentation of recovered participants and those with ongoing milder symptoms was less complex than that of the moderate/severe group. The former two groups showed early neck movement loss, altered muscle recruitment patterns, local cervical hyperalgesia and psychological distress but did not demonstrate features of widespread sensory hypersensitivity or post-traumatic stress symptoms (Sterling et al., 2003a,b,c). Whilst most of these features resolved by 2–3 months, altered muscle recruitment patterns in the cervical spine persisted in these groups at both 3 and 6 months post-injury (Sterling et al., 2003b). The present study has shown that these changes in motor function continued to 2–3 years post-injury. Whilst the EMG activity of the neck flexor muscles was less than that of the moderate/severe group, it

remained outside the 95% confidence intervals for control data that we have previously reported (Sterling et al., 2003b). These findings appear consistent with those of other musculoskeletal pain syndromes (for example low back pain) where altered patterns muscle recruitment persist despite patient recovery and may be a factor involved in the high rate of recurrence associated with this condition (Hides et al., 2001). In light of this, we examined the recovered whiplash injured participants in this study for symptom recurrence. Of the recovered participants at 6 months, 2 participants' whiplash condition worsened such that they were now classified as being in the group with milder symptoms ($NDI > 10$). Eleven of the 26 recovered participants (at 2–3 years post-injury) reported intermittent neck pain that they did not experience prior to the motor vehicle crash, although the NDI scores of this group remained low 8/100. As disturbed cervical muscle recruitment patterns were the only persistent deficit that could be detected in this group at this time point suggests that this factor cannot be ruled out as a possible contributor to recurrent symptoms. This may indicate that early rehabilitation of motor deficits is necessary even in those who appear to be recovering quickly and well from the injury.

We have recently shown that a combination of physical (cervical movement loss, cold hyperalgesia and sympathetic disturbances) and psychological factors as well as higher initial levels of pain and disability and older age are important prognostic indicators of outcome 6 months following whiplash injury (Sterling et al., 2005). The results of the current study demonstrate the robustness of most of these factors in predicting long-term outcome of whiplash injury. Initial NDI scores, older age, cold hyperalgesia and post-traumatic stress symptoms were predictive of higher NDI scores at 2–3 years post-injury and were also predictive of membership to the group with moderate/severe symptoms at this time frame. However, from 6 months to 2–3 years, the model's predictive capacity had decreased with r^2 decreasing from 0.67 to 0.56 in the multivariate regression and the classification rate for this group decreasing from 68.8% to 60%. The consistency of the model's predictive capacity over an extended time frame suggests that the presence of these factors should at least be assessed for in the acutely injured whiplash patient. As we have previously mentioned, it is not clear if the results of this study in a limited sample of whiplash injured people can be extrapolated to other whiplash populations and further validation of this predictive model is required in a larger independent cohort. Two variables that were significant prognostic indicators at 6 months were not predictive of 2–3 year outcome, namely cervical range of movement and impaired sympathetic vasoconstriction. The reason for this is not clear and these factors require further investigation to support or negate their predictive capacity.

We have also attempted to differentiate those with persistent milder symptoms from participants who reported recovery. At 6 months post-injury, higher initial pain and disability levels, cervical extension loss, greater psychological distress (GHQ-28) and decreased sympathetic vasoconstriction were associated with ongoing but milder symptoms (Sterling et al., 2005). At 2–3 years post-injury, only initial NDI scores remained as significant predictors of membership to this group. Further investigation of these factors is also required as differentiation of these groups may allow cost curtailment through earlier claim settlement.

The compensation status of the participants (whether or not a claim was filed) was not a significant predictor of outcome in any analysis. This finding supports those of a recent systematic review where strong evidence was found for this factor not to influence outcome following whiplash injury (Scholten-Peeters et al., 2003).

At this long-term follow-up point, we used initial NDI score as a measure of pain and disability levels. We had previously shown that this measure was a superior predictor of outcome at 6 months than a measure of pain severity alone (Sterling et al., 2005). It would appear from our data at both time points that a measure of pain and disability as opposed to pain intensity alone be used in the assessment of whiplash injury, although further investigation of the relative roles of these factors is required.

In summary, we have shown that those with a poorer outcome following whiplash injury manifest disturbances in motor, sensory and psychological function that are present soon after injury and persist well into the period of chronicity. These features suggest complex underlying mechanisms as contributing to ongoing moderate/severe symptoms following whiplash injury that include augmented central pain processing, post-traumatic stress and motor deficits. The early presence of high levels of pain and disability, older age, cold hyperalgesia and moderate post-traumatic stress symptoms remain robust predictors of a poor outcome following whiplash injury at 2–3 years post-injury. These factors should be assessed for in the acutely injured whiplash person and treatment directed toward these factors may help to lessen the transition to chronicity.

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