Pain 138 (2008) 617–629

PAIN

www.elsevier.com/locate/pain

Course and prognostic factors of whiplash: A systematic review and meta-analysis ☆

Steven J. Kamper [a,*], Trudy J. Rebbeck [b], Christopher G. Maher [a], James H. McAuley [a], Michele Sterling [c]

[a] The George Institute, University of Sydney, NSW, Australia
[b] Back Pain Research Group, University of Sydney, NSW, Australia
[c] Centre for National Research on Disability and Rehabilitation Medicine (CONROD), University of Queensland, Australia

Received 19 October 2007; received in revised form 23 January 2008; accepted 20 February 2008

Abstract

We conducted a systematic review and meta-analysis of prospective cohort studies of subjects with acute whiplash injuries. The aim was to describe the course of recovery, pain and disability symptoms and also to assess the influence of different prognostic factors on outcome. Studies were selected for inclusion if they enrolled subjects with neck pain within six weeks of a car accident and measured pain and/or disability outcomes. Studies were located via a sensitive search of electronic databases; Medline, Embase, CINAHL, Cochrane database, ACP Journal club, DARE and Psychinfo and through hand-searches of relevant previous reviews. Methodological quality of all studies was assessed using a six item checklist. Sixty-seven articles, describing 38 separate cohorts were included. Recovery rates were extremely variable across studies but homogeneity was improved when only data from studies of more robust methodological quality were considered. These data suggest that recovery occurs for a substantial proportion of subjects in the initial 3 months after the accident but after this time recovery rates level off. Pain and disability symptoms also reduce rapidly in the initial months after the accident but show little improvement after 3 months have elapsed. Data regarding the prognostic factors associated with poor recovery were difficult to interpret due to heterogeneity of the techniques used to assess such associations and the way in which they are reported. There was also wide variation in the measurement of outcome and the use of validated measures would improve interpretability and comparability of future studies.

Keywords: Whiplash; Course; Prognosis; Systematic review; Meta-analysis

1. Introduction

Whiplash injuries occur due to an acceleration–deceleration energy transfer to the neck, usually resulting from a motor vehicle collision [68]. The accident may precipitate a number of clinical symptoms most notable of which are pain and disability. These injuries are a common and costly problem in most parts of the world. Incidence rates vary across different studies and countries but may be as high as 677 per 100,000 inhabitants [11] with some evidence to suggest that incidence is rising [79]. Costs associated with the condition are substantial, for example in Europe these are estimated to be €10 billion per

☆ *Funding:* S.J.K.'s scholarship is funded by an Australian Research Council Discovery Grant and the National Health and Medical Research Council of Australia, and part of the production of this paper was funded by The Trauma Injury and Recovery Council of South Australia (TRACsa). C.G.M.'s fellowship is funded by the National Health and Medical Research Council of Australia. T.J.R. performs paid contract work for TRACsa, which is an initiative of the South Australian government.

* Corresponding author. The George Institute for International Health, University of Sydney, PO Box M201, Missenden Road, Sydney NSW 2050, Australia. Tel.: +61 2 8238 2413; fax: +61 2 9657 0301.

E-mail address: skamper@george.org.au (S.J. Kamper).

0304-3959/$34.00 © 2008 International Association for the Study of Pain. Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.pain.2008.02.019

annum, [17] with chronic cases responsible for the bulk of these costs.

The Quebec Taskforce conducted a landmark review of the whiplash literature in 1995 [68] and among their recommendations highlighted the need to conduct good quality research into the prognosis of the condition. While a large number of prognostic studies have been undertaken, there remains considerable uncertainty regarding the course of the condition. Some studies report a benign and self-limiting course wherein pain and symptoms resolve quickly and completely [41,45] whereas others report ongoing, and often debilitating symptoms, in a large proportion of subjects. [33,42] Similar confusion also remains regarding the prognostic factors associated with poor recovery. The magnitude of personal and societal impacts makes understanding of the course of the condition vital in order to allow policy-makers to direct appropriate resources to health care, research and compensation.

No previous reviews [12,63] provide a quantitative synthesis of the course of symptoms following whiplash injury. Instead they report descriptive information from individual studies and focus on identifying prognostic factors associated with poor recovery. As such, there exists no summary of the data from the many prognostic studies that describes the course of patients following a whiplash injury, without this information it is difficult for the clinicians to provide accurate advice to patients regarding this issue.

To address this deficit we performed a meta-analysis of inception cohort studies that followed the course of pain and disability in whiplash. The aims of the review were to; chart the course of acute whiplash in terms of recovery, pain and disability, identify prognostic factors that are associated with poor outcome, and assess the methodological quality of prognosis studies of whiplash.

2. Methods

We conducted a systematic review and meta-analysis of inception cohort studies that enrolled subjects following a whiplash injury and measured pain, or disability or recovery outcomes over time.

2.1. Inclusion criteria

Articles were included if they satisfied the following criteria; enrolled adults with neck pain following a motor vehicle accident within six weeks of their accident, prospective design, the aim was to chart course or assess the influence of prognostic factors on recovery, outcomes were pain or disability or recovery and were published as full papers in English or a translation available. Studies that included subjects with neck fractures or dislocations were excluded.

2.2. Identification of studies and assessment of methodological quality

Experienced investigators identified articles through sensitive searches of Medline, Cochrane Database of Systematic Reviews, ACP Journal club, DARE, PSYCINFO and EMBASE from their inception to April 2007. Search terms used to identify the study population included whiplash, whiplash-associated disorder, neck pain and neck sprain. Terms used to identify prognosis studies included prognostic, observational, prospective and follow-up studies. Complete search strategies are included in Appendix 1. Articles were initially screened on the basis of title and abstract, full text copies were then retrieved of articles that met all inclusion criteria or in cases where inclusion was uncertain. The reference lists of previous reviews [12,63] were searched by hand and the list of included studies was reviewed by experts in the field to identify important articles that may have been missed. Articles were screened by two reviewers to determine eligibility and methodological quality was assessed via the six criteria used by Pengel et al. [46]. Disagreements were resolved by consensus. Where multiple articles reported on the same cohort, an individual quality item was coded as 'Yes' if any of the articles satisfied the criterion. Articles were not excluded on the basis of the methodological quality. The authors acknowledge that there is little consensus regarding the optimal method for assessing the methodological quality and determining the likelihood of bias associated with the findings of prognostic studies. Of note the use of quality 'scales', where criteria are added to give a final score appears to be particularly uninformative and potentially misleading. Table 1 presents the results of quality assessment for all criteria for all included studies, from this information some determination of the risk of bias associated with the results of individual studies can be drawn.

2.3. Data extraction and analysis

2.3.1. Recovery, pain and disability

Data extracted were sample source, sample size, inception time, prognostic outcomes (pain, disability, recovery), prognostic factors and association of prognostic factors with outcome. These data were selected to provide a description of the cohort and satisfy the aims of the review. Recovery rates were extracted according to the definition used in the individual articles. This was generally the absence, or minimal levels of pain or disability. Where articles reported pain scores for only the symptomatic subjects in a cohort, a score of 10/100 was allocated to each asymptomatic subject in order to calculate a mean pain score for the whole cohort. This score was chosen to approximate the definition of pain-related recovery used in several studies [33,62,66]. Following conversion to a common 0–100 scale, pain and disability scores were pooled and variance-weighted means and 95% confidence intervals were calculated at each follow-up time point using a random effects model using comprehensive meta-analysis software v2.2.

We conducted a series of subgroup analyses to explore the influence of various sources of heterogeneity on prognostic estimates. These features were chosen on the basis that their presence or absence could logically affect the estimates of recovery. We stratified cohorts according to whether they met the individual quality criteria, to the source of the sample, whether they used a validated measure for recovery and their time of inception (dichotomised at three weeks). We also tested combinations of these factors.

Table 1
Methodological quality items for included cohorts

Cohort	Representative sample	Defined sample	Follow-up rate >80%	Blinded outcome assessment	Outcome data reported	Statistical adjustment	Inception time <3/52
Atherton [1]	N	Y	N	N	Y	Y	Y
Berglund [2]	N	Y	N	N	Y	Y	Y
Borchgrevink [3–5]	N	Y	Y	N	Y	N	Y
Buitenhuis [7]	N	N	N	N	Y	Y	N
Carroll [9], Cassidy [11]	Y	Y	Y	Y	Y	Y	N
Cassidy [10]	Y	Y	N	N	Y	Y	N
Crouch [13]	Y	Y	Y	N	Y	N	N
Drottning [14,15]	Y	Y	Y	N	Y	N	Y
Ettlin [16]	Y	N	Y	N	Y	N	Y
Gargan [18,20]	Y	N	Y	Y	Y	N	Y
Greenfield [21]	Y	N	N	N	Y	N	Y
Gun [22]	Y	Y	Y	N	Y	Y	N
Hendriks [23]	N	Y	Y	Y	Y	Y	Y
Hildingsson [24]	Y	N	Y	N	Y	N	Y
Jakobsson [25]	N	N	Y	N	Y	N	Y
Jonsson [27]	Y	N	Y	N	Y	N	Y
Karlsborg [28], Smed [65]	Y	Y	Y	N	Y	N	Y
Kasch [29–31]	Y	Y	Y	N	Y	N	Y
Kivioja [32]	Y	Y	Y	N	Y	Y	Y
Kyhlback [33]	Y	Y	Y	N	Y	Y	N
Mayou [34,35]	Y	N	Y	N	Y	Y	N
Mayou [36]	Y	N	N	N	Y	Y	Y
Minton [37]	Y	Y	N	N	Y	N	Y
Nederhand [38,39]	N	Y	Y	N	Y	N	Y
Norris [40], Gargan [19], Squires [69]	Y	N	N	N	Y	N	Y
Olsson [42]	N	Y	Y	N	Y	Y	Y
Ottosson [44]	N	Y	N	N	Y	N	Y
Partheni [45]	Y	Y	Y	N	Y	N	Y
Pennie [47]	N	N	Y	N	Y	N	N
Pettersson [48,49]	Y	Y	Y	Y	Y	N	Y
Petterson [50]	Y	Y	Y	Y	Y	N	Y
Radanov [51–60], Sturzenegger [77]	Y	Y	Y	N	Y	Y	Y
Richter [61]	Y	Y	N	N	Y	Y	Y
Ryan [62], Voyvodic [80]	N	Y	Y	N	Y	N	N
Scott [64]	N	Y	Y	N	Y	N	Y
Soderlund [66,67]	N	Y	Y	N	Y	Y	N
Sterling [70–74]	N	Y	Y	N	Y	Y	N
Sterner [75]	Y	Y	Y	N	Y	Y	N
No. Y	24	27	28	5	38	17	26
% Y	63%	71%	74%	13%	100%	45%	68%

- Representative sample: participants were selected as consecutive or random cases.
- Defined sample: description of participant source and inclusion and exclusion criteria.
- Follow-up >80%: outcome data were available for at least 80% of participants at one follow-up point.
- Blinded outcome assessment: assessor was unaware of prognostic factors at the time of outcome assessment.
- Outcome data: reporting of outcome data at follow-up.
- Statistical adjustment: multivariate analyses conducted with adjustment for potentially confounding factors.
- <3/52 inception time less than 3 weeks after accident.

2.3.2. Prognostic factors

Prognostic factors associated with outcome were extracted from all cohorts. A prognostic association was considered significant if the reported *p*-value was less than 0.05, if the article reported that an association was significant, or if the 95% confidence intervals around a rate ratio or similar statistic did not cross 1. Where a prognostic factor was assessed with respect to the outcome at a number of time-points in one cohort, data were extracted for short term follow-up (less than 6 months) and for long term follow-up (the longest follow-up point greater than or equal to 6 months). Only prognostic factors that were assessed via univariate analyses are presented, this decision was taken due to the different statistical techniques and choice of covariates used in the individual multivariate models. We decided that the collective interpretation of factors drawn from different multivariate models may be potentially misleading.

Psychological factors were grouped according to the underlying construct which they purported to measure. While this process inevitably involves some degree of subjective judgement, it was undertaken to facilitate collective interpretation of factors from different cohorts that used different measurement instruments.

3. Results

The search retrieved 6433 titles. Of these, 67 articles reporting on 38 unique cohorts met all criteria and were included in the review (Fig. 1). Brief summaries of included cohorts are given in Table 2 and excluded articles are listed in Appendix 1. Included cohorts were recruited from emergency departments (26 cohorts), primary care practices (two), insurance companies (five) and other or mixed sources (five). Twenty-six (68%) of the cohorts reported an inception time of three weeks or less, the remaining 12 did not explicitly report an inception time of less than three weeks, all cohorts enrolled subjects within six weeks of their accident. Note that all emergency department cohorts were coded as less than three weeks even if they did not explicitly report inception time (eight cohorts).

3.1. Methodological quality

With respect to the quality criteria (Table 1), 28 cohorts (74%) had adequate follow-up rate of at least 80%, 24 (63%) described methods to assemble a representative sample, 27 (71%) provided sufficient description of inclusion and exclusion criteria, 17 (45%) reported statistical adjustment for the quantification of prognostic associations and five cohorts (13%) used blinded assessment of outcome. It is noted however, given that the outcomes of interest here were self-reported, that none of the studies can be considered to have a truly blinded outcome assessment.

3.2. Recovery from acute whiplash

Recovery rate was measured in 33 of the cohorts (87%), from which 67 data points were extracted. Definitions of recovery included standardised disability (e.g., Neck Disability Index (NDI) [13,70–74]) or pain measures (e.g., Numerical rating Scale (NRS) [27,33]) and self-reported recovery questions (e.g., Do you feel recovered? [44]). A total of 21 different measures of recovery were used, only four of which (used in nine cohorts) were validated instruments. Recovery rates reported by the included studies showed considerable variability at all time-points (Fig. 2), the degree of variability is such that pooling would seem unwise.

In an attempt to explain this variability, a number of different study features were investigated, these included all the methodological quality items, subject source and use of a validated outcome measure. [76] Stratifying cohorts by each of these factors in isolation did not sub-

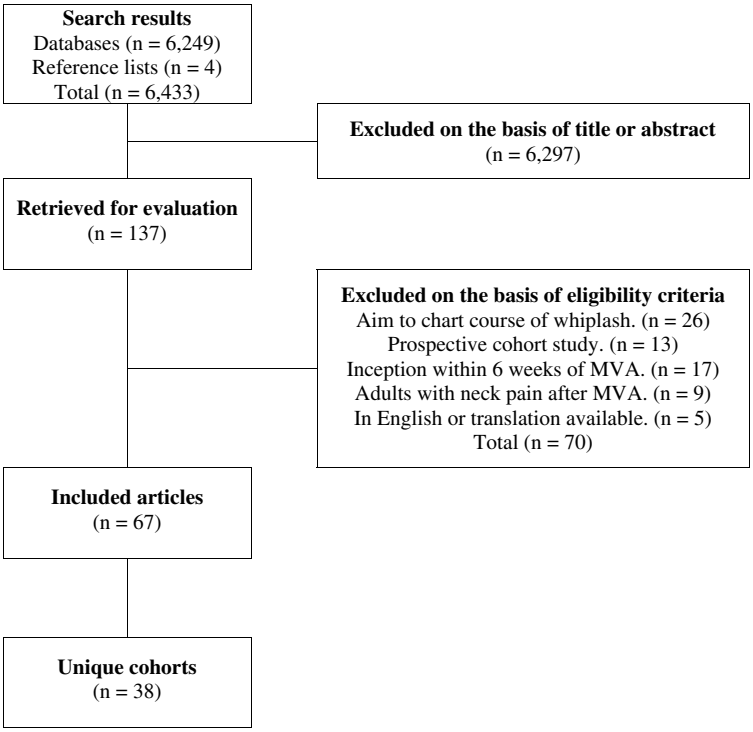

Fig. 1. Retrieval of studies for the review. MVA: motor vehicle accident.

Table 2
Descriptive information for included cohorts

Cohort	Source	Area	Sample	Inception time	Definition of whiplash	Outcomes extracted 1. Recovery 2. Pain 3. Disability	Follow-up[a]
Atherton [1]	Emergency	Manchester	765	1 day	Neck pain after MVA	1. No persistent neck pain	1, 3, **12** months
Berglund [2]	Insurance	Sweden	2280	A few days	Soft tissue injury to the neck	1. Pain <30 on 100 mm VAS Disability 0–5 on DRI 2. 100 mm VAS 3. DRI	1, 6, 12, 24 months
Borchgrevink [3–5]	Emergency	Trondheim	52	4 days	Hyperextension-flexion injury	1. Neck pain never or sometimes	6, **12**, 24 months
Buitenhuis [7]	Insurance	Netherlands	240	4 weeks	Neck pain following MVA	1. No persistent neck pain 2. 0–10 NRS	6, 12 months
Carroll [9], Cassidy [11]	Insurance	Saskatchewan	6021	6 weeks	Neck or shoulder pain due to traffic accident	1. <3 on 6-point recovery scale 2. 0–10 NRS	3, 6, 9, 12 months
Cassidy [10]	Insurance	Saskatchewan	7462	4 weeks	Neck or shoulder pain due to traffic accident		12 months
Crouch [13]	Emergency	Southampton	170	6 weeks	Neck pain following MVA	1. 0–4 on NDI 3. NDI	**4–6** weeks
Drottning [14,15]	Emergency	Oslo	587	2 days	Whiplash injury following MVA	1. Low symptom group 2. 1–9 VAS	**1**, 6, 12 months
Ettlin [16]	Emergency	Basel	26	3 days	Acute whiplash injury	1. No neck pain	3, 12 months
Gargan [18,20]	Emergency	Swindon	50	1 week	Attended emergency following rear-end collision	1. Mild symptoms	3, **24** months
Greenfield [21]	Insurance	Los Angeles	179	1 week	Neck symptoms following MVA	1. Asymptomatic	Variable
Gun [22]	Mixed	Sth Australia	135	6 weeks	Neck soft tissue injury following MVA		12 months
Hendriks [23]	Mixed	Netherlands	141	2 weeks	QTF grade I–II	1. Pain <30 on 100 mm VAS and Disability >78 on 100 mm VAS 2. 100 mm VAS 3. 0–100 level of activities VAS	1, **3**, **12** months
Hildingsson [24]	Emergency	Umea	93	3 days	Non-contact injury to C/S from MVA		Variable
Jakobsson [25]	Emergency	Goteborg	24	3 weeks	Neck symptoms after frontal crash	1. No symptoms	3, 12 months
Jonsson [27]	Emergency	Uppsala	50	Emergency	Whiplash-type C/S distortions in MVA	1. Pain <1 on 0–9 VAS 2. 0–9 VAS	6 weeks, 12, 60 months
Karlsborg [28], Smed [65]	Emergency	Copenhagen	39	2 weeks	QTF grade III	1. No neck pain	1, **7** months
Kasch [29–31]	Emergency	Aarhus	141	1 week	Neck pain or headache after MVA	1. Pre-injury work hours 2. 100 mm VAS	1, 3, 6, **12** months
Kivioja [32]	Emergency	Huddinge	91	1 week	Whiplash injury following MVA	1. No neck pain now	**12** months
Kyhlback [33]	Mixed	Sweden	83	3 weeks	QTF I-III	1. Pain <10 on 100 mm VAS 2. 100 mm VAS 3. PDI	3, 12 months
Mayou [34,35]	Emergency	Oxford	74	3–4 weeks	Neck pain or discomfort after MVA	1. No physical problems	3, 12, 60 months
Mayou [36]	Emergency	Oxford	278	Emergency	Neck pain or discomfort	1. Back to normal	1, 3, **12**, 36 months
Minton [37]	Emergency	Manchester	96	A few days	Whiplash injury following MVA	3. 0–9 Disability scale	6, **12** months
Nederhand [38,39]	Emergency	Netherlands	90	1 week	Pain in neck or head following MVA	1. 0–8 on NDI 3 NDI	**6** months
Norris [40], Gargan [19], Squires [69]	Emergency	Bristol	61	Emergency	Soft-tissue neck injury following MVA	1. Mild symptoms	Variable, 10 years, 15 years
Olsson [42]	Emergency	Goteborg	130	2 weeks	QTF I–III	1. No residual pain	**12** months
Ottosson [44]	Emergency	Stockholm	176	Emergency	Neck pain after a car accident	1. Feel recovered	1, 6 months
Partheni [45]	Emergency	Patras	180	2 days	QTF I–II	1. No neck pain	1, 3, 6 months
Pennie [47]	Emergency	Wirral	144	4 weeks	Whiplash injuries	1. Settled	5 months
Pettersson [48,49]	Emergency	Umea	48	Emergency	Whiplash trauma in car accidents	1. Asymptomatic	12, 24 months

(*continued on next page*)

Table 2 (*continued*)

Cohort	Source	Area	Sample	Inception time	Definition of whiplash	Outcomes extracted 1. Recovery 2. Pain 3. Disability	Follow-up[a]
Petterson [50]	Emergency	Nth Sweden	40	1 day	QTF II–III	1. No symptoms 2. 0–10 VAS	**24** month
Radanov [50–60], Sturzenegger [77]	Primary Care	Switzerland	117	1 week	Musculoligamental strain due to hyperflexion/extension	1. Asymptomatic 2. 0–10 NRS	3, 6, 12, **24** months
Richter [61]	Emergency	Hannover	43	Emergency	QTF I–II	1. No disturbance to daily life 2. 0–10 VAS 3. 0–10 limitations to daily life VAS	6 months
Ryan [62], Voyvodic [80]	Primary Care	Adelaide	29	3–4 weeks	Soft-tissue neck strain following MVA	1. Pain <1 on 0–10 NRS 2. 0–10 Injury severity NRS	**6** months
Scott [64]	Emergency	Newcastle	25	Emergency	Whiplash-type injury following MVA	1. Nil neck pain	3 months
Soderlund [66,67]	Emergency	Uppsala	66	3 weeks	Pain in the neck after MVA	1. Pain <1 on 0–10 VAS 2. 0–10 VAS 3. PDI	3, **6**, 12 months
Sterling [70–74]	Mixed	Brisbane	80	4 weeks	QTF II–III	1. 0–8 on NDI	2, 3, **6**, 24 months
Sterner [75]	Mixed	Umea	281	4 weeks	Whiplash trauma following MVA	1. Disability 0–1 on 4 pt scale	**16** months

MVA, motor vehicle accident; QTF, Quebec Taskforce; VAS, visual analogue scale; NRS, numerical rating scale; DRI, disability rating index; NDI, neck disability index; PDI, pain disability index.
[a] Bold and underlined figure is the follow-up time-point used to extract prognostic associations.

stantially increase homogeneity of the data, as assessed by visual inspection of the resultant plots. Of the features, three were considered to be of greatest significance in providing an accurate estimate of recovery. A more strict definition of inception time (less than three weeks after the accident) to distinguish between true inception and survival cohorts, a validated recovery measure to ensure the reliability and comparability of estimates and adequate follow-up rate to guard against bias due to systematic reasons for drop-outs. Stratifying by the presence of all three factors did increase homogeneity, three cohorts [23,27,38,39] passed through this filter and results are plotted in Fig. 2b.

3.3. Course of pain and disability symptoms in whiplash

Fourteen cohorts report pain scores from at least one follow-up time point (Fig. 3), a total of 44 data points were extracted. Pain was measured on 10 cm Visual Analogue Scales (VAS) or 0–10 NRS in all studies and converted to 0–100 scale. At baseline, variance-weighted mean pain scores were 40.4 (95% CI 29.0–51.9), at 1 month; 38.0 (21.8–54.1), at 2 months; 35.7 (14.7–56.8), at 3 months; 24.4 (9.6–39.2), at 6 months; 23.9 (11.1–36.8), at 12 months; 25.3 (11.7–39.0) and 24 months; 21.5 (3.4–39.6). Scores of 10/100 were assigned for asymptomatic subjects in two cohorts, removal of these cohorts from the analysis did not materially change the shape of the plot.

Nine cohorts report disability scores from at least one follow-up time point (Fig. 4), a total of 25 data points were extracted. Disability was measured using a number of instruments including; NDI, Pain Disability Index (PDI), and subjective VAS scores related to limitations in function, all scores were converted to 0–100 scale. At baseline, variance-weighted mean disability scores were 35.6 (95% CI 30.5–40.7), at 1 month; 28.6 (20.4–36.7), at 2 months; 23.9 (15.5–32.2), at 3 months; 24.7 (19.3–30.2), at 6 months; 19.8 (14.8–24.8) and at 12 months; 19.0 (13.0–25.0).

3.4. Prognostic factors

There were 42 prognostic factors that were assessed in univariate analyses in at least two cohorts at long term follow-up and 10 at short term follow-up (less than 6 months). For the purposes of clarity factors were divided into eight categories based on NSW Motor Accidents Authority Guidelines [8] (Tables 3 and 4). The most commonly assessed factors at long term follow-up were gender (17 cohorts), age (15), initial neck pain intensity (10), direction of impact (10), prior neck pain or headaches (seven) and a measure of general psychological distress, such as anxiety or depression (seven). All but three of the cohorts reported a significant association between high initial neck pain intensity

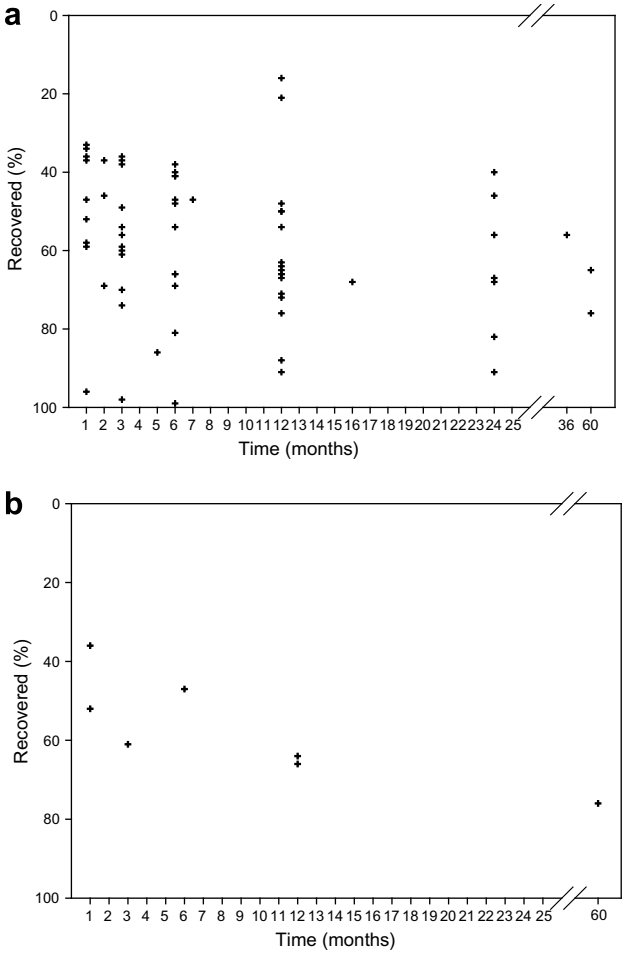

Fig. 2. (a) Percentage of subjects reported as recovered versus time in all cohorts (includes 67 data points from 33 cohorts). NB: Individual cohorts used varying definitions of recovery. (b) Percentage of subjects reported as recovered versus time in those cohorts with less than 3 weeks inception time, greater than 80% follow-up and a validated outcome measure (includes 7 data points from 3 cohorts).

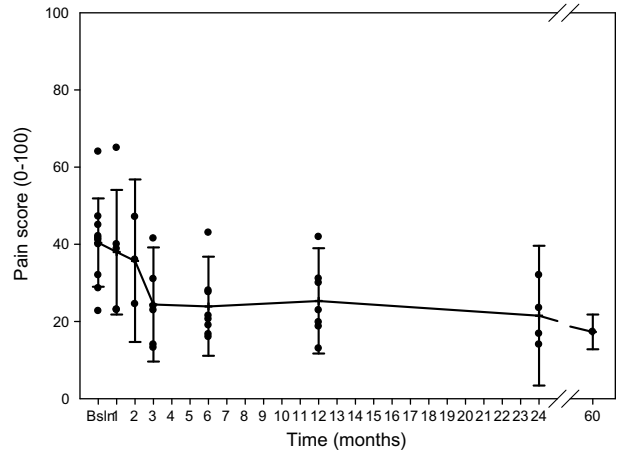

Fig. 3. Variance-weighted mean pain score out of 100 with 95% confidence intervals versus time for all cohorts (includes 44 data points from 14 cohorts). NB: 60 month mean and confidence interval from a single cohort.

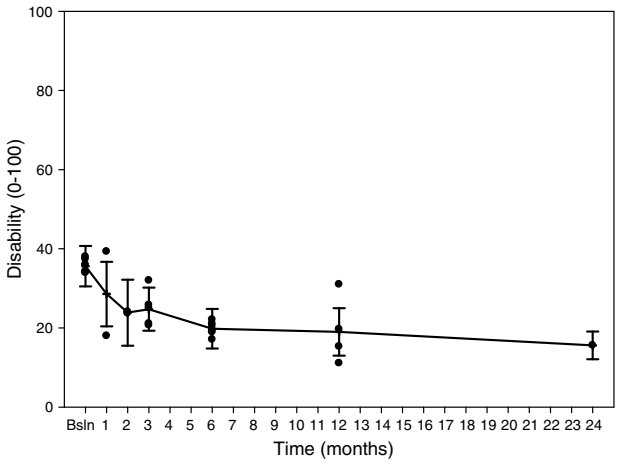

Fig. 4. Variance-weighted mean disability score out of 100 with 95% confidence intervals versus time for all cohorts (includes 25 data points from 9 cohorts). NB: 24 month mean and confidence interval from a single cohort.

and poor outcome and five of seven cohort reported significant associations between general psychological distress and poor outcome. However, in the case of the other factors the vast majority of cohorts reported non-significant associations between the factor and outcome. The results for short term follow-up are not substantially different to those for long term, Table 4. Dividing studies according to whether they measured outcome in terms of pain or disability did not change the proportion of significant associations for individual factors. Where reported, the strength of association between prognostic factors and outcome was also extracted as shown in Tables 3 and 4.

Due to the way in which strengths of association were reported in different studies no pooling was conducted. Included cohorts reported 407 univariate associations, of which 132 were statistically significant. Of the 407 associations, 72 (18%) were reported in a way such that the magnitude of the association could be interpreted (e.g., odds ratio, hazard rate ratios, beta-coefficients, etc.), the rest were reported as *p*-values, area under a receiver operating characteristic (ROC) curve or described as 'significant/non significant' in the text.

4. Discussion

4.1. Course of pain and disability

Our review was the first meta-analysis of the course of recovery, pain and disability following acute whiplash injury, 38 separate cohorts were included in the analysis. The results indicate rapid improvement in pain and disability in the first 3 months but beyond this there is little, if any, improvement. It would appear that a significant proportion of people experience ongoing low to moderate levels of pain and disability. Clinically, this finding

highlights the critical nature of the period immediately after onset and also suggests that current management strategies for patients in the chronic stage of the condition are not optimal.

4.2. Recovery rate

Recovery rates across the cohorts were highly variable, in all likelihood this inconsistency is due to the number and variety of measures used to measure recovery. The included cohorts used 21 different definitions of recovery and less than a quarter (nine cohorts) used a validated instrument, this is a notable finding and represents a substantial barrier to the interpretation of the literature. It is concerning that this problem persists even though the Quebec Task Force [68] highlighted this deficiency in 1995 and recommended the use of measurement methods whose reliability and validity had been established (p 41S). It recommended that the authors of future studies use validated instruments in measurement of recovery.

We attempted to account for the heterogeneity of the recovery data by investigating a number of study quality and design features. It was only when the subset of studies that satisfied three important criteria (less than three-weeks inception, adequate follow-up rate, validated recovery measure) were considered that there was homogeneity of the data. The fact that only three cohorts satisfied all methodological features dictates that findings should interpreted with caution, but the data suggest that recovery rates follow a path that is somewhat similar to the pain and disability course (Fig. 2) i.e., most patients recover within the initial few months but a significant proportion do not and continue to suffer from ongoing symptoms years later. These ongoing problems are typically mild to moderate pain and disability.

It is notable that the pooled recovery rates and course of symptoms observed in this study are broadly similar to those reported for other musculoskeletal conditions such as shoulder pain [78] and acute lumbar spine pain [46]. Also in common with these conditions is the uncertainty regarding prognostic factors and pathological processes involved. Although somewhat speculative, this may provide indirect evidence that factors specific to the crash are not responsible for the modest recovery rates.

4.3. Prognostic factors

Previous research provides inconsistent findings as to the prognostic significance of various factors. While two reviews agreed regarding the significance of high initial neck pain [12,63] one found that age, gender, headache intensity and neurological symptoms were also associated with poor recovery. [12] Individual cohorts have reported the importance of crash-related factors, [57] psychological factors, [42] and previous headache [5] among other things. While variation in the way that the authors of individual studies build prognostic models may explain part of this variation, it would seem likely that the differences in the way recovery is measured contribute to the inconsistencies in the literature.

We decided not to consider the results of multivariate analyses because the different statistical techniques and choices of covariates made meaningful comparison between cohorts impossible. We extracted all the factors that were assessed via univariate analysis and counted the number of times a significant association was reported. Of note, we found that associations were reported only in terms of *p*-values or described as 'significant/non significant' in the text in the vast majority of cases (82% of associations). However, statistical significance does not give any indication as to the magnitude of an association and is also heavily reliant on the size of the sample. This means that associations reported only in terms of *p*-values are of limited clinical utility, furthermore the fact that the size of the association is not reported makes meta-analysis impossible. Where available we extracted this information regarding the strength of association, and have presented it in Tables 3 and 4. It is recommended that future studies reporting prognostic associations do so in a manner that enables readers to determine the size of the association.

It must be noted that there are some limitations to the data that caution against definitive interpretation, firstly there are the limitations associated with the vote-counting approach [26], the major weakness is that this technique takes no account of the strength of associations and hence significant association may be more reflective of a large sample size than a clinically meaningful relationship. This approach therefore may lead to an overestimation of the significance of a prognostic factor. Second, it is probable that many of the cohorts had insufficient subject numbers [6] to detect important prognostic associations. Finally, the possibility of reporting bias cannot be ruled out, which may have resulted in non-significant associations going unreported. It should also be noted that a significant univariate association does not imply that there is a causal relationship between the factor and the outcome, this fact must be considered when interpreting these results.

These reservations aside, our findings are broadly consistent with the previous reviews [12,63] in reporting high initial pain and disability as an indicator of poor prognosis. Some psychological factors may be important, in particular indicators of generalised psychological distress such as anxiety and depression have been investigated in a number of cohorts with relatively consistent findings. Socio-demographic factors notably female gender and older age and crash-related factors including direction and estimated speed of impact do not appear to be related to poor outcome.

Table 3
Prognostic factors for which univariate analyses were reported in at least two cohorts and strength of prognostic association where available Long term follow-up (greater than or equal to 6 months)

Factor	Number/significant[a]	Strength of association	Explanation of strength of association value (for significant associations only)
Symptoms			
High neck pain intensity	10/7 [23,32,39,42,57,61,72]	(Exp $B = 1.03$, $p = 0.006$) [23]	The risk of not recovering by 12 months increases 3% for every mm increase on the 100 mm pain VAS
		(Exp $B = 1.78$, $p = 0.14$) [31]	NS
High disability	4/3 [23,39,66]	(Exp $B = 1.01$, $p = 0.009$) [23]	The risk of not recovering in 12 months increases 1% for every mm decrease on the 100 mm activity VAS
High WAD grade	4/2 [40,75]	(OR 2.17; 95% CI: 1.23,3.83) [75]	Subjects with QTF grade 2 or 3 are 2.17 times more likely to have disability affecting work or leisure at 16 months than those with QTF grade 1
Greater No complaints	4/2 [23,57]	(Exp $B = 2.59$, $p = 0.043$) [23]	The risk of not recovering in 12 months for subjects with 9 or more physical complaints is 2.59 times greater than for those with less than 9
		(Exp $B = 1.48$, $p = 0.13$) [31]	NS
Neurological symptoms	3/2 [23,57]	(Exp $B = 2.58$) [23]	NS
Shoulder/arm/hand pain	4/1 [21]	–	–
Headache	3/1 [57]	–	–
Back pain	2/1 [21]	–	–
Visual disturbance	2/1 [57]	–	–
Neck stiffness	2/0	–	–
Auditory disturbance	2/0	–	–
Dizziness	2/0	–	–
Radiological			
Degenerative changes	5/1 [3]	–	–
Flattened cervical lordosis	4/0	–	–
Psychological			
Psychological distress (e.g., depression, anxiety)	7/5 [23,39,42,57,72]	(Exp $B = 1.21$, $p = 0.009$) [23]	The risk of not recovering in 12 months increases by 21% for every increase of 1pt on the 48 pt somatisation subscale of the SCL-90
Personality factors	6/1 [23]	(Exp $B = 1.18$) [23]	NS
Social function	5/3 [42,61,72]	–	–
Coping strategies	4/3 [9,31,42]	(active: HRR 1.02; 95% CI: 1.00,1.03) [9]	For each additional point on the 5–25 point active coping scale, time to self-assessed recovery decreased by 2%
		(Passive: HRR 0.95; 95% CI: 0.93,0.96) [9]	For each additional point on the 0–30 point passive coping scale, time to self-assessed recovery increased by 5%
Quality of life	3/3 [57,61,72]	–	–
PTSD symptoms	3/2 [61,72]	–	–
Insomnia	3/2 [23,57]	(Exp $B = 1.32$) [23]	NS
Catastrophizing	3/2 [31,39]	–	–
Stress	2/1 [28]	–	–
Fear avoidance	2/1 [39]	–	–

(*continued on next page*)

Table 3 (*continued*)

Factor	Number/significant[a]	Strength of association	Explanation of strength of association value (for significant associations only)
Socio-demographic			
Female gender	17/2 [23,32]	(Exp $B = 4.73$, $p = 0.001$)[23]	Females are 4.73 times more likely to be unrecovered at 12 months
		(OR 2.32; 95% CI: 1.36,3.91) [75]	Females are 2.32 times more likely to have major disability at 16 months
Older age	15/4 [37,57,72]	(Exp $B = 1.03$, $p = 0.89$) [31]	NS
		(Exp $B = 1.00$, $p = 0.99$) [31]	NS
		(OR 0.99; 95% CI: 0.97, 1.01) [75]	NS
Lower education	4/2 [23,75]	(OR 1.87; 95% CI: 1.05, 3.30) [75] [23]	Subjects without university education are 1.87 times more likely to have major disability at 16 months than those with university education
		(Exp $B = 4.02$, $p = 0.007$)	Subjects with low education levels were 4.02 times more likely to be unrecovered at 12 months
Crash-related			
Direction of impact, rear	10/0	(OR 1.5; 95% CI: 0.2, 11.7) [1]	NS
		(OR 0.77; 95% CI: 0.45, 1.92) [75]	NS
Higher speed of vehicles	6/0	(Exp $B = 1.21$, $p = 0.45$) [31]	NS
		(OR 2.9; 95% CI: 0.3, 27.2) [1]	NS
Aware of impending collision	4/1 [62]	(OR 15.0; 95% CI: 1.83, 177.6) [62]	Subjects unaware of the impending impact are 15 times more likely to have signs and symptoms of neck injury at 6 months
Head rest in place	4/0	–	–
Seating position, driver	3/0	–	–
Rotated head position	2/1 [57]	(OR 1.3; 95% CI: 0.2, 10.4) [1]	NS
No seatbelt used	2/0	(Exp $B = 2.28$, $p = 0.078$) [23]	NS
Stationary or moving	2/0	–	–
Impairment			
Reduced cervical ROM	5/2 [23,31]	(Exp $B = 1.01$, $p = 0.037$) [23]	The risk of not recovering in 12 months increases by 1% for every decrease of 1 degree of total C/S ROM
		(Exp $B = 2.53$, $p = 0.01$) [31]	The risk of not returning to pre-injury work duties at 12 months for subjects with total C/S ROM 2 SD below mean for normal is 2.53 times greater than that for subjects with normal ROM
Cold sensitivity	2/2 [31,70]	–	–
Altered muscle recruitment	2/2 [39,71]	–	–
Joint position error	2/1 [71]	–	–
Prior condition			
Prior neck pain or headache	7/3 [3,57,75]	(OR 2.63; 95% CI: 1.42, 4.88) [75]	Subjects with prior neck pain or headaches are 2.63 times more likely to have major disability at 16 months
Other			
BMI	2/1 [39]	(Exp $B = 1.36$, $p = 0.33$) [31]	NS
Height	2/0	–	–

NDI, neck disability index; QTF, Quebec Task Force; PTSD, post traumatic stress disorder; ROM, range of motion; BMI, body mass index; Exp *B*, Exponent of the beta coefficient (transformed to assist interpretation); NS, non-significant; *r*, Pearson's correlation coefficient; OR, odds ratio; CI, confidence interval; HRR, hazard rate ratio; C/S, cervical spine; SD, standard deviation.

[a] Number of cohorts in which the factor was reported/Number of cohorts in which a significant association with poor outcome was reported.

Table 4
Prognostic factors for which univariate analyses were reported in at least two cohorts and strength of prognostic association where available Short-term follow-up (less than 6 months)

Factor	Number/significant[a]	Strength of association	Explanation of strength of association value (for significant associations only)
Symptoms			
High neck pain intensity	3/3 [13,14,23]	(Exp $B = 1.03$, $p = 0.04$) [23]	The risk of not recovering by 3 months increases 3% for every mm increase on the 100 mm pain VAS
		($r = 0.31$, $p < 0.01$) [13]	9.3% of variance in NDI score at 4–6 weeks is explained by baseline pain score
Neurological symptoms	2/0	–	–
Radiological			
X-ray taken	2/1 [13]	–	–
Socio-demographic			
Female gender	3/1 [23]	(Exp $B = 2.66$, $p = 0.02$) [23]	Females are 2.66 times likely to be unrecovered at 3 months
Older age	3/1 [13]	($r = 0.25$, $p < 0.01$) [13]	6.3% of variance in NDI score at 4–6 weeks is explained by baseline age
Crash-related			
No seatbelt used	2/1 [13]	–	–
Direction of impact, rear	2/0	–	–
Higher speed of vehicles	2/0	($r = 0.15$, $p = 0.08$) [13]	NS
Impairment			
Reduced cervical ROM	2/0	(Exp $B = 0.99$)	NS
Prior condition			
Prior neck pain or headache	3/0	–	–

NDI, neck disability index; ROM, range of motion Exp *B*, Exponent of the beta coefficient (transformed to assist interpretation); NS, non-significant; *r*, Pearson's correlation coefficient.
[a] Number of cohorts in which the factor was reported/Number of cohorts in which a significant association with poor outcome was reported.

We have not attempted to investigate the association of compensation factors with outcome despite the apparent controversy in this area. [43,63] In this review, only prognostic factors that were measured at baseline were extracted, factors collected at some point through the course of the condition will inevitably be influenced by the course of the condition itself. Thereby their association with outcome represents a different and more complex relationship to that of factors present at inception. This being the case, we contend that there are other methodologies for example case-control studies, better suited to determine the influence of compensation factors, e.g., Cassidy [10].

5. Conclusions

The data presented here demonstrate that people with a whiplash injury often experience ongoing pain and disability for an extended period after their car accident. While there is a large volume of research investigating prognostic factors, the manner of measuring and in particular reporting prognostic associations represent a major barrier to meaningful interpretation of the literature as a whole. As such we are unable to definitively establish which factors are important in predicting poor outcome. In order to provide more precise and interpretable data, it is recommended that the authors of future studies pay attention to methodological quality criteria, use validated measures to determine all outcomes and report the magnitude of all prognostic associations, significant or otherwise.

Acknowledgement

The authors acknowledge the assistance of Professor Ian Cameron, Dr Jim Stewart and Dr Mark Stewart in preparation of the manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.pain.2008.02.019.

References

[1] Atherton K, Wiles NJ, Lecky FE, Hawes SJ, Silman AJ, Macfarlane GJ, et al. Predictors of persistent neck pain after whiplash injury. Emerg Med J 2006;23:195–201.
[2] Berglund A, Bodin L, Jensen I, Wiklund A, Alfredsson L. The influence of prognostic factors on neck pain intensity, disability, anxiety and depression over a 2-year period in subjects with acute whiplash injury. Pain 2006;125:244–56.

[3] Borchgrevink G, Smevik O, Haave I, Haraldseth O, Nordby A, Lereim I. MRI of cerebrum and cervical columna within two days after whiplash neck sprain injury. Injury 1997;28:331–5.
[4] Borchgrevink GE, Smevik O, Nordby A, Rinck PA, Stiles TC, Lereim I. MR imaging and radiography of patients with cervical hyperextension-flexion injuries after car accidents. Acta Radiol 1995;36:425–8.
[5] Borchgrevink GE, Stiles TC, Borchgrevink PC, Lereim I. Personality profile among symptomatic and recovered patients with neck sprain injury, measured by MCMI-I acutely and 6 months after car accidents. Journal of Psychosomatic Research 1997;42:357–67.
[6] Borghouts JA, Koes BW, Bouter LM. The clinical course and prognostic factors of non-specific neck pain: a systematic review. Pain 1998;77:1–13.
[7] Buitenhuis J, de Jong PJ, Jaspers JP, Groothoff JW. Relationship between posttraumatic stress disorder symptoms and the course of whiplash complaints. Journal of Psychosomatic Research 2006;61:681–9.
[8] Cameron ID, Stewart J, Stewart M, Rebbeck T, Trevena L. Motor Accidents Authority Multidisciplinary Working Party. Guidelines for the Management of Acute Whiplash-Associated Disorders: Technical Report 2nd ed., 2007. © Motor Accidents Authority of NSW wwwmaanswgovau. 2007.
[9] Carroll LJ, Cassidy JD, Cote P. The role of pain coping strategies in prognosis after whiplash injury: passive coping predicts slowed recovery. Pain 2006;124:18–26.
[10] Cassidy JD, Carroll LJ, Cote P, Lemstra M, Berglund A, Nygren A. Effect of eliminating compensation for pain and suffering on the outcome of insurance claims for whiplash injury. N Engl J Med 2000;342:1179–86.
[11] Cassidy JD, Carroll LJ, Cote P, Frank J. Does multidisciplinary rehabilitation benefit whiplash recovery?: results of a population-based incidence cohort study. Spine 2007;32:126–31.
[12] Cote P, Cassidy JD, Carroll L, Frank JW, Bombardier C. A systematic review of the prognosis of acute whiplash and a new conceptual framework to synthesize the literature. Spine 2001;26:E445–58.
[13] Crouch R, Whitewick R, Clancy M, Wright P, Thomas P. Whiplash associated disorder: incidence and natural history over the first month for patients presenting to a UK emergency department. Emerg Med J 2006;23:114–8.
[14] Drottning M, Staff PH, Levin L, Malt UF. Acute emotional response to common whiplash predicts subsequent pain complaints: a prospective of 107 subjects sustaining whiplash injury. Nordic Journal of Psychiatry 1995;49:293–9.
[15] Drottning M, Staff PH, Sjaastad O. Cervicogenic headache (CEH) after whiplash injury. Cephalalgia 2002;22:165–71.
[16] Ettlin TM, Kischka U, Reichmann S, Radii EW, Heim S, Wengen D, et al. Cerebral symptoms after whiplash injury of the neck: a prospective clinical and neuropsychological study of whiplash injury. J Neurol Neurosurg Psychiatry 1992;55:943–8.
[17] Galasko CSB, Murray P, Stephenson W. Incidence of whiplash-associated disorder. BC Med J 2002;44:237–40.
[18] Gargan M, Bannister G, Main C, Hollis S. The behavioural response to whiplash injury. J Bone Joint Surg Br 1997;79:523–6.
[19] Gargan MF, Bannister GC. Long-term prognosis of soft-tissue injuries of the neck. J Bone Joint Surg Br 1990;72:901–3.
[20] Gargan MF, Bannister GC. The rate of recovery following whiplash injury. Eur Spine J 1994;3:162–4.
[21] Greenfield J, Ilfield FW. Acute cervical strain. Clinical Orthopaedics and Related Research 1977;122:196–200.
[22] Gun RT, Osti OL, O'Riordan A, Mpelasoka F, Eckerwall CG, Smyth JF. Risk factors for prolonged disability after whiplash injury: a prospective study. Spine 2005;30:386–91.
[23] Hendriks EJ, Scholten-Peeters GG, van der Windt DA, Neeleman-van der Steen CW, Oostendorp RA, Verhagen AP. Prognostic factors for poor recovery in acute whiplash patients. Pain 2005;114:408–16.
[24] Hildingsson C, Toolanen G. Outcome after soft-tissue injury of the cervical spine. A prospective study of 93 car-accident victims. Acta Orthop Scand 1990;61:357–9.
[25] Jakobsson L, Norin H, Bunketorp O. Whiplash-associated disorders in frontal impacts: influencing factors and consequences. Traffic Inj Prev 2003;4:153–61.
[26] Jones DR. Meta-analysis: weighing the evidence. Statistics in Medicine 1995;14:137–49.
[27] Jonsson Jr H, Cesarini K, Sahlstedt B, Rauschning W. Findings and outcome in whiplash-type neck distortions. Spine 1994;19:2733–43.
[28] Karlsborg M, Smed A, Jespersen H, Stephensen S, Cortsen M, Jennum P, et al. A prospective study of 39 patients with whiplash injury. Acta Neurol Scand 1997;95:65–72.
[29] Kasch H, Bach FW, Jensen TS. Handicap after acute whiplash injury: a 1-year prospective study of risk factors. Neurology 2001;56:1637–43.
[30] Kasch H, Bach FW, Stengaard-Pedersen K, Jensen TS. Development in pain and neurologic complaints after whiplash: a 1-year prospective study. Neurology 2003;60:743–9.
[31] Kasch H, Qerama E, Bach FW, Jensen TS. Reduced cold pressor pain tolerance in non-recovered whiplash patients: a 1-year prospective study. European Journal of Pain 2005;9:561–9.
[32] Kivioja J, Jensen I, Lindgren U. Early coping strategies do not influence the prognosis after whiplash injuries. Injury 2005;36:935–40.
[33] Kyhlback M, Thierfelder T, Soderlund A. Prognostic factors in whiplash-associated disorders. Int J Rehabil Res 2002;25:181–7.
[34] Mayou R, Bryant B. Outcome of'whiplash' neck injury. Injury 1996;27:617–23.
[35] Mayou R, Tyndel S, Bryant B. Long-term outcome of motor vehicle accident injury. Psychosom Med 1997;59:578–84.
[36] Mayou R, Bryant B. Psychiatry of whiplash neck injury. British Journal of Psychiatry 2002;180:441–8.
[37] Minton R, Murray P, Stephenson W, Galasko CS. Whiplash injury – are current head restraints doing their job? Acid Anal Prev 2000;32:177–85.
[38] Nederhand MJ, Hermens HJ, Ijzerman MJ, Turk DC, Zilvold G. Chronic neck pain disability due to an acute whiplash injury. Pain 2003;102:63–71.
[39] Nederhand MJ, MJ IJ, Hermens HJ, Turk DC, Zilvold G. Predictive value of fear avoidance in developing chronic neck pain disability: consequences for clinical decision making. Arch Phys Med Rehabil 2004;85:496–501.
[40] Norris SH, Watt I. The prognosis of neck injuries resulting from rear-end vehicle collisions. J Bone Joint Surg Br 1983;65:608–11.
[41] Obelieniene D, Schrader H, Bovim G, Miseviciene I, Sand T. Pain after whiplash: a prospective controlled inception cohort study. J Neurol Neurosurg Psychiatry 1999;66:279–83.
[42] Olsson I, Bunketorp O, Carlsson SG, Styf J. Prediction of outcome in whiplash-associated disorders using West Haven-Yale Multidimensional Pain Inventory. Clin J Pain 2002;18:238–44.
[43] Osti OL, Gun RT, Abraham G, Pratt NL, Eckerwall G, Nakamura H. Potential risk factors for prolonged recovery following whiplash injury. Eur Spine J 2005;14:90–4.
[44] Ottosson C, Nyren O, Johansson SE, Ponzer S. Outcome after minor traffic accidents: a follow-up study of orthopedic patients in an inner-city area emergency room. J Trauma 2005;58:553–60.
[45] Partheni M, Constantoyannis C, Ferrari R, Nikiforidis G, Voulgaris S, Papadakis N. A prospective cohort study of the outcome of acute whiplash injury in Greece. Clin Exp Rheumatol 2000;18:67–70.
[46] Pengel LH, Herbert RD, Maher CG, Refshauge KM. Acute low back pain: systematic review of its prognosis 2003;327:323.

[47] Pennie B, Agambar L. Patterns of injury and recovery in whiplash. Injury 1991;22:57–9.
[48] Pettersson K, Karrholm J, Toolanen G, Hildingsson C. Decreased width of the spinal canal in patients with chronic symptoms after whiplash injury. Spine 1995;20:1664–7.
[49] Pettersson K, Hildingsson C, Toolanen G, Fagerlund M, Bjornebrink J. Disc pathology after whiplash injury: a prospective magnetic resonance imaging and clinical investigation. Spine 1997;22:283–8.
[50] Pettersson K, Brandstrom S, Toolanen G, Hildingsson C, Nylander PO. Temperament and character: prognostic factors in whiplash patients? Eur Spine J 2004;13:408–14.
[51] Radanov BP, di Stefano G, Schnidrig A, Ballinari P. Role of psychosocial stress in recovery from common whiplash. Lancet 1991;338:712–5.
[52] Radanov BP, di Stefano G, Schnidrig A, Sturzenegger M. Psychosocial stress, cognitive performance and disability after common whiplash. Journal of Psychosomatic Research 1993;37:1–10.
[53] Radanov BP, di Stefano G, Schnidrig A, Sturzenegger M, Augustiny KF. Cognitive functioning after common whiplash. A controlled follow-up study. Arch Neurol 1993;50:87–91.
[54] Radanov BP, Sturzenegger M, di Stefano G, Schnidrig A, Aljinovic M. Factors influencing recovery from headache after common whiplash. BMJ 1993;307:652–5.
[55] Radanov BP, di Stefano G, Schnidrig A, Sturzenegger M. Common whiplash: psychosomatic or somatopsychic? J Neurol Neurosurg Psychiatry 1994;57:486–90.
[56] Radanov BP, Sturzenegger M, di Stefano G, Schnidrig A. Relationship between early somatic, radiological, cognitive and psychosocial findings and outcome during a one-year follow-up in 117 patients suffering from common whiplash. Br J Rheumatol 1994;33:442–8.
[57] Radanov BP, Sturzenegger M, Di Stefano G. Long-term outcome after whiplash injury. A 2-year follow-up considering features of injury mechanism and somatic, radiologic, and psychosocial findings. Medicine 1995;74:281–97.
[58] Radanov BP, Begre S, Sturzenegger M, Augustiny KF. Course of psychological variables in whiplash injury – a 2-year follow-up with age, gender and education pair-matched patients. Pain 1996;64:429–34.
[59] Radanov BP, Sturzenegger M. The effect of accident mechanisms and initial findings on the long-term outcome of whiplash injury. J Musculoskeletal Pain 1996;4:47–59.
[60] Radanov BP, Sturzenegger M. Predicting recovery from common whiplash. Eur Neurol 1996;36:48–51.
[61] Richter M, Ferrari R, Otte D, Kuensebeck HW, Blauth M, Krettek C. Correlation of clinical findings, collision parameters, and psychological factors in the outcome of whiplash associated disorders. J Neurol Neurosurg Psychiatry 2004;75:758–64.
[62] Ryan GA, Taylor GW, Moore VM, Dolinis J. Neck strain in car occupants: injury status after 6 months and crash-related factors. Injury 1994;25:533–7.
[63] Scholten-Peeters GGM, Verhagen AP, Bekkering GE, van der Windt DAWM, Barnsley L, Oostendorp RAB, et al. Prognostic factors of whiplash-associated disorders: a systematic review of prospective cohort studies. Pain 2003;104:303–22.
[64] Scott S, Sanderson PL. Whiplash: a biochemical study of muscle injury. Eur Spine J 2002;11:389–92.
[65] Smed A. Cognitive function and distress after common whiplash injury. Acta Neurol Scand 1997;95:73–80.
[66] Soderlund A, Olerud C, Lindberg P. Acute whiplash-associated disorders (WAD): the effects of early mobilization and prognostic factors in long-term symptomatology. Clin Rehabil 2000;14:457–67.
[67] Soderlund A, Lindberg P. Whiplash-associated disorders – predicting disability from a process-oriented perspective of coping. Clin Rehabil 2003;17:101–7.
[68] Spitzer WO, Skovron ML, Salmi LR, Cassidy JD, Duranceau J, Suissa S, et al. Scientific monograph of the Quebec Task Force on whiplash-associated disorders: redefining "whiplash" and its management. Spine 1995;20:1S–73S.
[69] Squires B, Gargan MF, Bannister GC. Soft-tissue injuries of the cervical spine. 15-year follow-up. J Bone Joint Surg Br 1996;78:955–7.
[70] Sterling M, Jull G, Vicenzino B, Kenardy J. Sensory hypersensitivity occurs soon after whiplash injury and is associated with poor recovery. Pain 2003;104:509–17.
[71] Sterling M, Jull G, Vicenzino B, Kenardy J, Darnell R. Development of motor system dysfunction following whiplash injury. Pain 2003;103:65–73.
[72] Sterling M, Kenardy J, Jull G, Vicenzino B. The development of psychological changes following whiplash injury. Pain 2003;106:481–9.
[73] Sterling M, Jull G, Vicenzino B, Kenardy J, Darnell R. Physical and psychological factors predict outcome following whiplash injury. Pain 2005;114:141–8.
[74] Sterling M, Jull G, Kenardy J. Physical and psychological factors maintain long-term predictive capacity post-whiplash injury. Pain 2006;122:10–108.
[75] Sterner Y, Toolanen G, Gerdle B, Hildingsson C. The incidence of whiplash trauma and the effects of different factors on recovery. Journal of Spinal Disorders and Techniques 2003;16:195–9.
[76] Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA 2000;283:2008–12.
[77] Sturzenegger M, Radanov BP, Di Stefano G. The effect of accident mechanisms and initial findings on the long-term course of whiplash injury. J Neurol 1995;242:443–9.
[78] van der Windt DA, Koes BW, Boeke AJ, Deville W, De Jong BA, Bouter LM. Shoulder disorders in general practice: prognostic indicators of outcome. British Journal of General Practice 1996;46:519–23.
[79] Versteegen GJ, Kingma J, Meijler WJ, ten Duis HJ. Neck sprain in patients injured in car accidents: a retrospective study covering the period 1970–1994. Eur Spine J 1998;7:195–200.
[80] Voyvodic F, Dolinis J, Moore VM, Ryan GA, Slavotinek JP, Whyte AM, et al. MRI of car occupants with whiplash injury. Neuroradiology 1997;39:35–40.