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Derivation of a clinical prediction rule to identify both chronic moderate/severe disability and full recovery following whiplash injury

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ABSTRACT

Recovery following a whiplash injury is varied: approximately 50% of individuals fully recover, 25% develop persistent moderate/severe pain and disability, and 25% experience milder levels of disability. Identification of individuals likely to develop moderate/severe disability or to fully recover may help direct therapeutic resources and optimise treatment. A clinical prediction rule (CPR) is a research-generated tool used to predict outcomes such as likelihood of developing moderate/severe disability or experiencing full recovery from whiplash injury. The purpose of this study was to assess the plausibility of developing a CPR. Participants from 2 prospective, longitudinal studies that examined prognostic factors for poor functional recovery following whiplash injury were used to derive this tool. Eight factors, previously identified as predictor variables of poor recovery, were included in the analyses: initial neck disability index (NDI), initial neck pain (visual analogue scale), cold pain threshold, range of neck movement, age, gender, presence of headache, and posttraumatic stress symptoms (Posttraumatic Diagnostic Scale [PDS]). An increased probability of developing chronic moderate/severe disability was predicted in the presence of older age and initially higher levels of NDI and hyperarousal symptoms (PDS) (positive predictive value [PPV] = 71%). The probability of full recovery was increased in younger individuals with initially lower levels of neck disability (PPV = 71%). This study provides initial evidence for a CPR to predict both chronic moderate/severe disability and full recovery following a whiplash injury. Further research is needed to validate the tool, determine the acceptability of the proposed CPR by practitioners, and assess the impact of inclusion in practice.

1. Introduction

Whiplash-associated disorders (WAD) are the most common nonhospitalised injury resulting from a road traffic crash [11]. The consequent pain and disability experienced incur substantial socioeconomic costs [11,23]. Recent research indicates that improvements in pain and disability are likely to occur within the first 3 months [21]. However, only 50% of individuals with WAD experience full recovery; approximately 25% continue to experience persistent moderate/severe pain and disability, and 25% have milder levels of pain and disability [15,21,32,36,37]. It is the moderate/severe disability group that incurs the majority of associated costs [26]. Identification of individuals likely to develop moderate/severe disability or experience full recovery may help direct therapeutic resources and optimise treatment. Clinical prediction rules (CPRs) are one type of research-generated tool used to predict outcomes such as the likelihood of developing chronic moderate/severe disability or full recovery from whiplash injury.

CPRs use quantitative methods to analyse the contributions of specific patient characteristics and subsequently create pathways to assist clinicians in making predictions about patient outcomes [25,29]. CPRs are most useful when decision-making is complex [25] or uncertain [27], or there are possibilities for cost savings without compromising patient care [25]. Patients with WAD present with a complex profile, the recovery pathway is not homogenous [32], and outcomes following treatment are unclear [12,28]. Accumulating evidence indicates a biopsychosocial model of recovery, with numerous factors suggested to influence recovery [4,33,35]. Furthermore, although improvement in prognosis has been shown for some individuals following exercise and mobilisation therapy [41], emerging evidence suggests that early intensive health care may delay recovery [12,28]. It may be that specific subsets of patients benefit from specific treatment strategies, whereas the same therapies may be detrimental to others. Hence, given the

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plethora of possible predictors of recovery, development of a dual-pathway CPR to predict both moderate/severe symptoms and full recovery may help consolidate current evidence and facilitate the design of treatment strategies to target specific subsets of patients.

Proposing to link the design of treatment strategies with probability of outcome necessitates a CPR with: factors amenable to change; a high specificity; and one that provides an enhanced probability of the outcome (positive predictive value [PPV]). To our knowledge, only one CPR has been published for prediction of chronicity from WAD [18], and no publications exist for the prediction of full recovery. The published tool underwent a derivation study only, was unique to the locality of the study, and did not consider the biopsychosocial factors amenable to change that are thought to contribute to chronicity [18,30,33].

The aim of the present study was to investigate the plausibility of developing a CPR for WAD. Specifically, this study was designed to: analyse previously identified predictor variables of poor recovery for inclusion within a CPR and to derive a dual-pathway CPR for whiplash injury that ensured an acceptable revised percentage (PPV) of those predicted to develop chronic moderate/severe symptoms or to recover fully.

2. Methods

A secondary analysis of data from 2 prospective, longitudinal studies was performed to develop a dual-pathway CPR. The designs of both studies adhered to Strobe criteria for cohort studies [43].

2.1. Participants

Participants were from 2 prospective, longitudinal studies that examined prognostic factors for poor functional recovery following whiplash injury, and these studies were conducted in 2006–2010 [32, unpublished data]. Participants for both studies were recruited via hospital accident and emergency departments, primary care practices, and via general advertisement. Eligibility for both studies was the same and included individuals with acute whiplash injury (ie, symptoms < 1 month in duration) following a motor vehicle crash with Quebec Task Force Classification of WAD I, II, or III [31]. Participants were excluded if they were WAD IV (fracture or dislocation), experienced concussion 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. They were also excluded if they reported being diagnosed with or receiving treatment for a psychiatric or psychological condition either currently or in the past.

Participants were assessed at < 1 month (ie, baseline), 3, 6, and 12 months post injury at a university laboratory. Predictor variable data were measured at inception, and identification of final outcome (eg, moderate/severe pain and disability, mild pain and disability, or full recovery) was made from data collected at 12 months. No usual treatment was withheld or modified. Different treatments received by the participants were not expected to confound this study for 2 reasons. Firstly, data from our initial studies demonstrated that there were no differences in the types and numbers of treatments received between recovered and nonrecovered subjects [34]. Secondly, no current treatment has yet demonstrated a capability to lessen the transition to chronic symptoms. Participant sample details are shown in Fig. 1. Ethical approval was gained from the institutional Medical Research Ethics Committee, and all participants provided signed informed consent.

2.2. Dependent variable

The neck disability index (NDI) is a valid, reliable, and responsive measure [24,45]. An overall score (out of 100) is calculated by totalling responses to 10 questions, each with 6 potential Likert-type responses (eg, 0 = no disability to 5 = total disability) and multiplying the sum by 2 to yield a percentage. Previous research has suggested that an NDI $\geqslant$ 30% is indicative of moderate to severe levels of pain-related disability and an NDI $\leqslant$ 10% indicates full recovery [24,36,44].

2.3. Predictor variables

Although previous research has suggested numerous predictors of recovery following a whiplash injury [4,6,30,33,35,46], recent conclusions indicate that possible predictors are likely to include those that encompass a biopsychosocial model of recovery [4,33,35]. Given the complexity and plethora of possible variables, the following 8 previously identified biopsychosocial variables were selected for inclusion.

The recent validation of a prognostic model to predict chronic moderate/severe disability following whiplash injury confirmed the association of initial NDI, cold pain threshold, age, and post-traumatic stress symptoms with delayed recovery [34]. Hence, these 4 factors were included in the analyses for the present study. Additional factors included in the present study were: initial neck pain (visual analogue scale [VAS]), the only factor to consistently predict poor functional recovery from WAD in previously published cohort studies [20,21,30,32,36]; and factors proposed to predict recovery in previous reviews: gender [21], presence of headache [21,46] and range of neck movement (ROM) [46].

2.4. Measurement of predictor variables

Predictor variables were measured at baseline. Measurement of NDI is discussed in an earlier paragraph and the PDS is described in the following paragraph. Cold pain thresholds were measured over the mid-cervical spine using the Thermotest system (Somedic AB, Farsta, Sweden). Triplicate recordings were taken at each site and the mean values used for analysis, a process shown to be valid and reliable [33,36]. Age at last birthday was measured in years, and presence of headache at the time of assessment was measured as a yes/no response. Initial pain level over the past 24 hours was measured using an 11-point VAS with anchors of 0 = no pain and 10 = worst pain imaginable, a valid and reliable measure of pain [5]. Cervical ROM was measured using an electromagnetic, motion-tracking device (FASTRAK; Polhemus, Colchester, VT, USA) according to previously established methods shown to be reliable and valid [13,42]. Although the previous validation study [34] suggested inclusion of left neck rotation only, to ensure acceptance by clinicians, total neck rotation (ROM) (eg, sum of left and right neck rotation, flexion and extension) was included in the present study.

2.5. Posttraumatic diagnostic scale

Previous research with WAD has reported posttraumatic stress symptoms using 2 different self-reported scales: the Impact of Events Scale and the Posttraumatic Diagnostic Scale (PDS) [16,19]. Both scales have been shown to be reliable and valid [16,19], however, only the PDS scale includes a measure of hyperarousal [16]. Hyperarousal symptoms form 1 of the 3 necessary clusters of symptoms in the diagnosis and presentation of posttraumatic stress disorder (PTSD) [2]. The PDS maps the symptoms of PTSD onto the *Diagnostic and Statistical Manual of Mental Disorders* diagnosis of PTSD [16]. Hence, the PDS was deemed to be the more inclusive scale to measure posttraumatic stress symptoms.

The PDS comprises 49 items and is scored to provide a measure of total symptom severity in addition to 3 scale measures: re-experiencing, avoidance, and hyperarousal. A single scale containing 49 items was deemed to be too lengthy for a CPR. Hence, standard