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Review

Evidence for cervical muscle morphometric changes on magnetic resonance images after whiplash: A systematic review and meta-analysis

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ABSTRACT

Introduction: Morphometric changes to cervical musculature in whiplash associated disorder have been reported in several studies with varying results. However, the evidence is not clear because only a limited number of cohorts have been studied and one cohort has been reported in multiple publications. The aim of this study was to assess the evidence for cervical muscle morphometric changes on magnetic resonance (MR) images after whiplash using a systematic review with meta-analysis.

Materials and methods: PubMed, MEDLINE and Cochrane Library were searched without language restriction using combinations of the MeSH terms “muscles”, “whiplash injuries”, and “magnetic resonance imaging”. Studies of acute and chronic whiplash were included if they compared whiplash and control cervical spine muscle morphometry measurements from MR images. The search identified 380 studies. After screening, eight studies describing five cohorts (one acute, three chronic, one both acute and chronic) met the inclusion criteria. Participant characteristics and outcome measures were extracted using a standard extraction format. Quality of eligible studies was assessed using the Newcastle-Ottawa Scale. Muscle cross-sectional area (CSA) and fat infiltrate (MFI) for acute and chronic whiplash cohorts were compared using mean difference and 95% confidence intervals. Meta-analysis models were created when data from more than two eligible cohorts was available, using inverse-variance random-effects models (RevMan5 version 5.3.5).

Results: Quality assessment was uniformly good but only two studies blinded the assessor. Analysis of the acute cohorts revealed no consensus with respect to CSA. MFI was not measured in the acute cohorts. Analysis of the chronic cohorts revealed CSA is probably increased in some muscles after whiplash but there is insufficient evidence to confirm whether MFI is also increased. Because the available data were limited, meta-analyses of only multifidus were performed. In chronic whiplash multifidus CSA was significantly increased at C5 ($Z = 3.51, p < 0.01$) and C6 ($Z = 2.66, p < 0.01$); and MFI was significantly increased at C7 only ($Z = 2.52, p < 0.01$) but the heterogeneity was unacceptably high ($I^2 = 83\%$).

Conclusions: The strength of the evidence for cervical muscle morphometric changes on MR images after whiplash is inconsistent for CSA and MFI. Future study designs should be standardised with quantification of three-dimensional muscle morphometry.

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Introduction

Neck pain and disability from whiplash following motor vehicle trauma (MVT) is one of the most common debilitating injuries in the developed world [1,2]. The reported incidence of whiplash associated disorders (WAD) after MVT is at least 300 per 100,000 in western countries with a consistent rising trend [3–6]. In the United States (US) alone, it is estimated that 3 million new cases of whiplash are reported every year [7]. Whilst the majority of cases recover, up to 50% develop chronic symptoms for which the efficacy of rehabilitation is variable [2,8]. Whiplash imposes a significant economic burden on health-care systems with estimated annual costs totalling more than \$29 billion spent on injuries and litigation in the US and €1.6 billion in the United Kingdom [9–11].

There has been continued debate about whether WAD is attributable to a defined pathoanatomical entity or to psychological or cultural factors [12–15]. It has been suggested that compensation seeking is associated with complaints of persistent pain after MVT and that some patients amplify their symptoms for financial gain [16]. The introduction of a no-fault insurance system in Canada which removed payments for pain and suffering resulted in a 43 percent reduction in claims by men and 15 percent for women [17]. In addition, a similar analysis in Australia found that outcome scores improved significantly when no-fault insurance was introduced [18]. However, more recent studies have proposed that adverse pain outcomes following MVT are not unique to litigious individuals and in fact are common among non-litigious individuals who are not engaged in compensation seeking [19–21]. Although no single pathognomonic entity has been identified in the cervical spine following whiplash, advances in imaging technologies have led to reports of structural changes affecting the ligaments and muscles of the neck [22–24]. The evidence for signs of ligamentous damage on magnetic resonance (MR) imaging has been investigated in a systematic review with meta-analysis [25]. The results suggested that no significant differences exist between whiplash and control subjects for either alar or transverse ligaments. The evidence for changes in muscle morphology on MR images is not clear.

The MR measures that have been used to quantify the morphology of the cervical spine musculature after whiplash include cross-sectional area and muscle fat infiltrate [26–32]. An increase in cross-sectional area is thought to be due to an increase

in injury-induced muscle fat infiltrate, making muscle fat infiltrate a potentially more robust marker for WAD than cross-sectional area [33,34]. However, the cross-sectional area data is conflicting [28–32] and there is very little muscle fat infiltrate data [26,27,29,30] at this point in time. Further, the cohorts are small but by combining them it is possible to ascertain whether the evidence supports the use of muscle fat infiltrate and/or cross-sectional area as a marker for WAD. If sensitive, these markers could potentially enable more precise rehabilitation strategies.

There has been one recent systematic review of muscle morphologic changes in chronic neck pain patients including WAD [35]. The authors concluded that there is some evidence for morphological changes in deep and higher cervical level muscles in chronic WAD with larger cross-sectional area measurements because of increased fatty infiltrate. In contrast, they concluded that idiopathic neck pain patients have decreased cross-sectional area in most muscles because of disuse atrophy. However, this review had several limitations. First, rather than dissecting and comparing the actual study data, the review simply summarized the overall message from each of the studies. Second, both controlled and uncontrolled studies were included thereby allowing non-normalised results to be incorporated. Third, both MR and ultrasound imaging modalities were included. Finally, five studies by Elliott et al. [27–29,34,36] which reported data from the same cohort were presented as discrete studies thereby inflating their influence on the overall review. Therefore, the results of this review may not provide a clear picture of whether MR measurements of cervical muscle morphology are different in WAD compared to controls.

Therefore, the aim of this systematic review and meta-analysis was to rigorously assess the evidence for the presence of MR morphological changes (cross-sectional area and muscle fat infiltrate) in muscle after whiplash, and whether they represent a consistent marker which discriminates between WAD and control participants. The ability to be able to confidently identify WAD will have significant impact on diagnosis and the recognition of effective and non-effective management strategies. The study question was: in MR muscle measurement studies of acute and chronic WAD, does a systematic review and meta-analysis demonstrate evidence for increased cross-sectional area and/or muscle fat infiltrate in the cervical spine compared to non-WAD controls?

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