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Loud preimpact tones reduce the cervical multifidus muscle response during rear-end collisions: a potential method for reducing whiplash injuries

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Abstract

BACKGROUND CONTEXT: Neck muscle responses after unexpected rear-end collisions consist of a stereotypical combination of postural and startle responses. Prior work using surface electromyography (EMG) has shown that the superficial neck muscle responses can be attenuated when a loud tone (105 dB) is presented 250 milliseconds before impact, but the accompanying response of the deeper multifidus muscles remains unknown. Quantifying this response in multifidus is important because this muscle attaches directly to the cervical facet capsule and can potentially increase the strain in the capsule during an impact and contribute to whiplash injury.

PURPOSE: To investigate if a loud preimpact tone decreases the cervical multifidus muscle response during rear-end perturbations.

STUDY DESIGN: After approval by the University Clinical Ethics Review Board, human volunteers experienced a series of three whiplash-like perturbations.

PATIENT SAMPLE: Twelve subjects with no history of neurologic disorders or whiplash injury were recruited to participate in this experiment.

OUTCOME MEASURES: Bilateral indwelling EMG of multifidus at the C4 and C6 levels, surface EMG of sternocleidomastoid (SCM) and C4 paraspinals (PARAs), and kinematics of the head/neck were measured.

METHODS: Subjects experienced three whiplash-like perturbations (peak acceleration of 19.5 m/s^2) preceded by either no tone or a loud tone (105 dB) presented 250 milliseconds before sled acceleration onset.

RESULTS: The loud tone decreased the muscle activity of C6 multifidus (42%) and C4 PARAs (30%), but did not affect the C4 multifidus or SCM activity. Peak head kinematic responses (extension angle: 6%, retraction: 9%, linear forward acceleration: 9%, and angular acceleration in extension: 13%) were also decreased by the loud preimpact tone.

FDA device/drug status: Not applicable.

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CONCLUSIONS: The attenuation of peak C6 multifidus activity and head kinematic responses suggests that a loud preimpact tone may reduce the strain in the cervical facet capsule, which may reduce the risk of whiplash injury during rear-end collisions.

Keywords: Neck muscles; Whiplash; Head-neck control; Perturbation; Prestimulus inhibition; Neuromuscular response

Introduction

Whiplash injuries are the most common injuries caused by automobile collisions, and rear-end collisions pose the greatest risk of a whiplash injury [1]. Although the exact etiology of whiplash injuries remains unclear, the cervical facet joint has been implicated as a common source of pain in 40% to 68% of chronic whiplash patients [2]. Sudden flexion/extension of the neck during a rear-end impact causes abnormal intervertebral kinematics in the neck and can generate injurious levels of strain in the facet capsular ligaments [3–5]. Based on the cadaver neck studies, these capsular ligament strains are largest in the lower cervical spine (C6–C7: 40%, C5–C6: 39%, C4–C5: 27%, C3–C4: 30%, C2–C3: 17%; [5]). Because of their direct attachments onto the capsular ligaments of C4–C5, C5–C6, and C6–C7 [6,7], early activation of the cervical multifidus muscles during a rear-end impact could increase the capsular ligament strain already induced by the intervertebral kinematics [8]. The maximum force applied to the facet capsule unilaterally by the cervical multifidus muscle has been estimated to be about 29±14 N, which is 64% of the quasistatic load (45±21 N) required to cause subcatastrophic failure in the ligament [8,9]. Thus, reducing cervical multifidus muscle activity during a period when the neck structures are vulnerable to injury may decrease the capsular ligaments strain and, potentially, the risk of whiplash injury.

The neuromuscular response evoked by a low-speed whiplash-like perturbation comprises both postural and startle responses [10]. The perturbation-induced startle response has been shown to increase neck muscle activity, increase peak head/neck kinematics, and elicit autonomic responses during whiplash-like perturbations [11–13]. Startle also activates the cervical multifidus muscle [8] and, consequently, could exacerbate whiplash injury by increasing capsular ligament strain when the ligament is already vulnerable. Exploiting the inhibitory effect of a prestimulus on the startle response [14–16], Mang et al. (2012) [17] showed that a loud (sound pressure level: 105 dB) preimpact tone presented 250 milliseconds before a whiplash-like perturbation decreased neck muscle activity by 16% to 29% and peak head kinematics by 17% to 23%. These findings suggested that a loud preimpact tone might be a novel method of reducing whiplash injury risk by inhibiting the whiplash-evoked startle response in vehicle occupants. This previous study, however, used only surface electromyographic (EMG) electrodes and thus, it remains unclear whether its findings extend to the deep cervical multifidus muscles. This distinction between the present and previous studies is important because only the neck multifidus muscles attach to the capsular ligament and the activity in these muscles can only be measured with indwelling wire electrodes.

The goal of this study was to determine if a loud acoustic tone presented 250 milliseconds before a rear-end impact can inhibit the startle response of the cervical multifidus muscles evoked by the rear-end impact. Superficial neck muscles were recorded to allow for comparison with our previous results. If a loud acoustic preimpact tone can inhibit the cervical multifidus muscle response, then we may be able to reduce the strain on the cervical facet joints during a rear-end collision and potentially reduce the risk of a whiplash injury.

Methods

Subjects

Twelve subjects with no history of neurologic disorders or whiplash injury participated in this experiment (eight men/four women, 26±3 years, 172±7 cm tall, 68±14 kg). All subjects were naïve to our whiplash perturbation and protocols, provided written informed consent, and were paid a nominal fee for participating. The research protocol was approved by a clinical ethics review board and conformed to the Declaration of Helsinki.

Instrumentation

Electromyographic activity was measured using a combination of indwelling and surface electrodes. Indwelling electrodes consisted of twisted pairs of insulated 0.05 mm wire (Stablohm 800A; California Fine Wire, Grover Beach, CA, USA), with 2 mm of exposed wire at each recording end. The ends of the indwelling wires were shaped into hooks to anchor the wires in the muscle tissue and prevent the recording site from shifting during trials. Wires were inserted bilaterally into the multifidus muscle at the C4 and C6 spinal levels using 25 gauge needles under ultrasound guidance (SonoSite MicroMaxx; SonoSite, Inc., Bothell, WA, USA) [18]. Surface EMG electrodes (Ambu Blue Sensors: N type; Ballerup, Denmark) were placed bilaterally over the sternocleidomastoid (SCM) muscle and cervical