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# Neck muscle fatigue alters the cervical flexion relaxation ratio in sub-clinical neck pain patients

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ABSTRACT

*Background:* The cervical flexion relaxation ratio is lower in neck pain patients compared to healthy controls. Fatigue modulates the onset and offset angles of the silent period in both the lumbar and cervical spine in healthy individuals; however, this response has not been studied with neck pain patients. The purpose of this study was to determine if cervical extensor fatigue would alter the parameters of the cervical flexion relaxation more in a neck pain group than a healthy control group.

*Methods:* Thirteen healthy and twelve neck pain patients participated. Cervical extensor activity was examined bilaterally and kinematics of the neck and head were collected. An isometric, repetitive neck extension task at 70% of maximum elicited fatigue. Participants performed 3 trials of maximal cervical flexion both pre and post fatigue.

*Findings:* The healthy controls and neck pain groups fatigued after 56 (41) and 39 (31) repetitions, respectively. There was a significant interaction effect for the flexion relaxation ratio between the control and neck pain groups from pre to post fatigue trials ($F_{1,96} = 22.67$, $P = 0.0001$), but not for onset and offset angles ($F_{1,96} =$ 0.017, $P = 0.897$), although the onset and offset angles did decrease significantly for both groups following fatigue ($F_{1,96} = 9.26$, $P = 0.002$).

*Interpretation:* Individuals with mild to moderate neck pain have significant differences in their neuromuscular control relative to controls, experienced myoelectric fatigue with fewer repetitions in a shorter time, had a lower cervical flexion relaxation ratio at baseline and had an inability to decrease this ratio further in response to fatigue.



## 1. Introduction

Advances in technology within many industries have led to an increased risk of musculoskeletal disorders in the general population (Falla, 2004). Neck pain (NP) affects 30–50% of Canadians every year, placing a large financial burden on healthcare organizations (Hogg-Johnson et al., 2008). In many cases, NP is initiated in the workplace due to prolonged, non-neutral postures (Ming et al., 2004; Yoo et al., 2011) often occurring with overhead work that results in increased muscle loading and fatigue (Shin et al., 2012). A sedentary lifestyle, with our dependence on technology such as computers, laptops, tablets and cell phones also contributes to this issue (Ming et al., 2004). In addition to posture and loading, abnormal neck muscle recruitment patterns is a proposed mechanism of injury for individuals with persistent NP (Murphy et al., 2010a) and this needs to be further explored.

Spinal disorders play a significant role in poor stabilization of the spine (Murphy et al., 2010b). The strength and endurance of the cervical flexor muscles are reduced in NP patients (Falla, 2004) and this has been associated with pain during the performance of dynamic movements (Brandt et al., 2004). NP patients are unable to fully relax their cervical extensor muscles (CEM) and have increased muscle activity during full forward cervical flexion (Maroufi et al., 2013). One of the most common objective assessment methods that can discriminate between NP patients and asymptomatic healthy controls is the cervical flexion relaxation ratio (FRR) (Maroufi et al., 2013). Erector spinae activity, which controls the lumbar spine during flexion and extension, is reduced or absent once full trunk flexion is reached during slow and controlled flexion (Gupta, 2001), and is known as the flexion relaxation phenomenon (FRP). During the FRP, there is a transfer of the extensor moment from the active (muscles) elements to the passive (intervertebral disks, ligaments and fascia) structures of the spine. To ensure spinal stability, these two subsystems (active and passive) must be coordinated, along with the neural subsystem, or dysfunction may result (Descarreaux et al., 2008; Hashemirad et al., 2009). Passive structures may become

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damaged and the altered load sharing between active and passive tissues in NP patients might put the previously injured structures at a greater risk of injury when performing prolonged or repetitive activities to fatigue (Gupta, 2001; Nimbarte et al., 2014). Full relaxation during flexion does not happen in NP patients, possibly due to increased stretch sensitivity (Marshall and Murphy, 2006) and in full cervical flexion, chronic NP participants have shown a lack of myoelectric silence compared to healthy individuals (Marshall and Murphy, 2006). Therefore, the FRP can be used as a reliable marker to discriminate individuals with NP from asymptomatic individuals (Maroufi et al., 2013; Murphy et al., 2010a). Maroufi et al. found CEM relaxation in 85.7% of controls and in only 36.3% of chronic NP patients (Maroufi et al., 2013). The authors also reported that the CEM activity in chronic NP patients was higher during movement than the control group. The higher extensor activity may represent an altered pattern of motor control that enhances the activity of the CEM to protect the spine from further injury in full neck flexion (Maroufi et al., 2013). Additionally, the FRR, which is a ratio of the maximum muscle activity in re-extension to the average muscle activity in the relaxation phase (Murphy et al., 2010a; Nimbarte et al., 2014), is lower in low back pain (Marshall and Murphy, 2006) and NP (Murphy et al., 2010a) patients in comparison to healthy controls. Evidence suggests that this impairment can be rehabilitated following spinal manipulation and exercise interventions (Marshall and Murphy, 2006, 2008; Murphy et al., 2010b). To date, the cervical FRP has not yet been extensively explored in NP patients, especially when considering the influences of muscle fatigue.

Few studies have investigated the effects of CEM fatigue on parameters of the cervical FRR, as well as, the onset and offset of myoelectric silence. A previous study involving the lumbar FRR found that the initiation of the onset angle of the silent period (corresponding to a decrease in EMG activity in the flexion phase) appeared earlier after fatigue of the lumbar extensor muscle and the EMG offset angle (corresponding to an increase in EMG activity in the extension phase) occurred later during extension (Descarreaux et al., 2008). The authors suggest that this prolonged silent period could be due to a decreased ability of the fatigued extensor muscles to stabilize the vertebral segments and they transfer the load to passive tissues earlier during trunk flexion. An alternate explanation is that the deeper trunk extensors took over from the fatigued superficial extensor muscles to stabilize the cervical spine. It is possible that in the case of pain, previously injured structures may be at risk of further injury during fatiguing activities. In one recent study, the FRR was explored in healthy individuals during two shoulder postures (neutral and shrugged) (Nimbarte et al., 2014). The FRP was used to explore post CEM fatigue changes. The CEM fatigue was generated using the Sorensen protocol by participants lying prone on a table and holding their head parallel to the floor, against gravity. The authors found that neutral shoulder FRR significantly declined after fatigue, with an earlier onset and later offset of the myoelectric silent period, resulting in an increased duration of the silent period. In this context, the silent period was identified as the time difference between the onset angle and offset angle. This work indicates that neck extensor fatigue and shoulder position modulates the FRP and increases activity of the CEM in full cervical flexion (Nimbarte et al., 2014). Therefore, to continue the progression of understanding NP, there is a need to explore the effects of CEM fatigue on parameters of the cervical FRP in NP patients.

Participants with mild to moderate back and NP represent a population that might be predisposed to fatigue related injuries, and thus, can provide insightful interpretations into pain and neck motor control. A recent study comparing healthy individuals and those with mild neck or back pain found that the cervical FRR significantly decreased following ten minutes of a below knee lifting task. However, the link between neck muscle fatigue and the effects on neck motor control are underexplored in those with NP. This study attempts to address this by investigating the effect of CEM fatigue with a repetitive, isometric sub-maximal fatigue protocol in subclinical NP patients. The purpose of this study was to determine if CEM fatigue would alter the parameters of the cervical flexion relaxation more in a neck pain group than a healthy control group. It was hypothesized that fatigue would increase the CEM activity during full cervical flexion and/or during the extension phases, which could alter the neuromuscular responses to the FRR. We would expect to see smaller changes in the NP group because their FRR was already altered. We also hypothesized that we would not see the same changes in onset and offset angles in the neck pain group because they would already have a comprised ability to generate alternate load sharing strategies in response to fatigue due to the fact that they already had altered motor control.

## 2. Methods

### 2.1. Participants

Thirteen healthy controls and twelve subclinical NP patients participated. Handedness was confirmed by the Edinburgh Handedness Inventory (EHI) self-report questionnaire (Cohen, 1961) and neck pain was confirmed with the Neck Disability Index (NDI) self-report questionnaire (Vernon, 2008). Healthy participants were free from chronic or recurrent neck, shoulder, or elbow pain for at least 3 months prior to this study (NDI scores of 0–4), and the sub-clinical NP participants had mild (NDI scores of 5–14) to moderate (NDI scores of 15–24) NP for at least three months prior to this study. Participant age, height, weight, NDI and EHI data are found in Table 1. This study was approved by the University of Ontario Institute of Technology Research Ethics Board.

### 2.2. Flexion relaxation protocol

A cervical flexion–relaxation task measured CEM activity during full cervical flexion. Participants began with an upright, neutral neck position, flexed to end range, and then extended to the neutral head

**Table 1**
Participant demographics and self-report measures.

| | Healthy control group (7 males–6 females) | Neck pain group (5 males–7 females) |
|---|---|---|
| | Mean (SD) | Mean (SD) |
| Age (years) | 25.76 (4.51) | 23.5 (3.81) |
| Height (cm) | 168.69 (8.91) | 168.75 (15.38) |
| Weight (kg) | 66.15 (13.41) | 73.16 (21.57) |
| NDI score | 1.15 (1.51) | 9.75 (3.88) |
| Duration of NP (years) | 0 | 3 (2) |
| Repetition of NP (times per week) | 0 | 4 (2) |
| EHI score | 72.72 (25.72) | 71 (17.91) |
| | One participant was strongly left hand dominant (−100) and one was ambidextrous (+20). The rest were strongly right hand dominant. | One participant was strongly left hand dominant (−100) and one was ambidextrous (+30). The rest were strongly right hand dominant. |