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Research Report

The Cervico-Ocular Reflex Is Increased In People With Non-Specific Neck Pain

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Abstract

Background. Neck pain is a widespread complaint. People experiencing neck pain often present an altered timing in contraction of cervical muscles. This (altered) afferent information elicits the cervico-ocular reflex (COR), which stabilizes the eye in response to trunk-to-head movements. The vestibulo-ocular reflex (VOR) elicited by the vestibulum is thought to be unaffected by afferent information from the cervical spine.

Objective. Measurement of COR and VOR in people with non-specific neck pain.

Design. Cross-sectional design according to the STROBE statement.

Methods. An infrared eye-tracking device was used to record the COR and the VOR while the participant was sitting on a rotating chair in darkness. Eye velocity was calculated by taking the derivative of the horizontal eye position. Parametric statistics were performed.

Results. The mean COR gain in the control group (N= 30) was 0.26 (SD= 0.15), against 0.38 (SD= 0.16) in the non-specific neck pain group (N= 37). Analyses of covariance were performed to analyze differences in COR and VOR gains with age and gender as covariates. Analyses of covariance showed a significantly increased COR in people with neck pain ($p= 0.046$). The VOR between the control group with a mean VOR of 0.67 (SD= 0.17) and the non-specific neck pain group with a mean VOR of 0.66 (SD=0.22) was not significantly different ($p= 0.203$).

Limitations. Measuring eye movements while the participant is sitting on a rotating chair in complete darkness is technically complicated.

Conclusions. This study suggests that people with non-specific neck pain have an increased COR. The COR is an objective non-voluntary eye reflex and an unaltered VOR. This study shows that an increased COR is not restricted to traumatic neck pain patients.

Introduction

Neck pain is a major problem worldwide, and is a common reason for individuals to seek care from physiotherapists and manual therapists.^{1,2} In addition to pain, concomitant symptoms are often present, including headache (65% of cases), dizziness (31%)³, and visual disturbances.⁴ Visual disturbances in people with neck pain might be related to deficits in oculomotor control.⁵⁻⁸ In the majority of people with neck pain, a specific cause cannot be identified, and the term "non-specific neck pain" is used.^{9, 10}

People experiencing neck pain often present functional disorders (such as an altered timing in contraction) of the cervical muscles, such as the m. longus colli and the m. longus capitis.¹¹⁻¹³ These cervical muscles provide information to, and receive information from, the central nervous system.¹⁴⁻¹⁶ Animal studies have showed that pain has profound effects on muscle spindle afferents.^{17, 18} In humans, cervical pain leads to, for instance, a worse joint position sense indicating a disturbed proprioception.¹⁹⁻²¹ Afferent information from the cervical muscles is sent to the vestibular nuclei where it converges with other information regarding head movements relayed by the visual and vestibular systems.²² It can be argued that incongruences between the cervical, vestibular, and visual systems are likely to be associated with dizziness and decreased postural stability.²³

The cervical afferents are not only important for controlling head movements. They are also involved in the cervico-ocular reflex (COR). The COR stabilizes the eye in response to trunk-to-head movements.²⁴⁻²⁶ The COR operates in conjunction with the vestibulo-ocular reflex (VOR). The VOR stabilizes the eye in response to vestibular input, i.e., movements of the head in space. The COR is elicited by proprioception of the facet joints of the cervical spine and deep muscles of the neck. The strength of the COR can be modified as a result of altered visual input²⁷ and by immobilization of the cervical spine by means of a stiff neck collar.²⁸

The COR increases in people aged over 60 years as a compensatory mechanism for the sensory loss of the vestibulum.²⁹ In people with a Whiplash Associated Disorder (WAD), this compensatory mechanism is not seen^{28, 30}. The strength of the COR is increased in people with WAD although there is no compensatory decline in VOR.^{30, 31} To date, no research on COR in people with non-specific neck pain has been conducted.

Here we describe the two eye movement reflexes (COR and VOR) in people with non-specific neck pain who are likely to have deficits in neck proprioception.³² Therefore, we expect that the COR but not the VOR will be altered, compared to healthy controls.

Methods

The guidelines of the STROBE statement (Strengthening the Reporting of Observational Studies in Epidemiology)³³ were used for the outline of this paper.

Design Overview

We conducted a cross-sectional study involving participants with neck pain and healthy controls.

Setting and Participants

Participants with neck pain were recruited via physiotherapy practices in Rotterdam, The Netherlands. People with non-specific neck pain were asked personally by their physiotherapist to participate in the study. These physiotherapists had been briefed about the study and had information letters for the patients. If patients formally consented to being contacted by the investigator, the physiotherapist contacted the investigator. Healthy controls were recruited by means of an information letter spread among co-workers, students, and other people in the Erasmus University Medical Center and the Rotterdam University of Applied Sciences having no personal or legal relationship with the investigator. All

participants were recruited and tested between October 2012 and September 2014. The study was approved by the local ethical board of the Erasmus MC. All participants gave prior written informed consent.

Participants with neck pain were eligible if they 1) were between the ages of 18 and 65 years; 2) spoke Dutch; 3) experienced non-specific neck pain (defined as the sensation of mild to moderate pain and discomfort in the neck area with possible radiation to the thoracic spine and one or both shoulders) continuously for less than one year; and 4) were physically able to undergo COR and VOR measurements (which involved sitting immobilized in a chair for 30 minutes). Participants were excluded if they: 1) used medication that influenced alertness or balance (*e.g.*, benzodiazepines, barbiturates); 2) suffered from any neurological disorder, or had vestibular or visual problems; or 3) had a history of neck trauma (a history would make the diagnosis specific instead of non-specific). Healthy controls were eligible if they; 1) were between the ages of 18 and 65; 2) spoke Dutch; 3) had not experienced any complaints of the cervical spine (including cervicogenic headache and dizziness) in the last 5 years; and 4) were without a history of neck trauma.

Demographic and Clinical Characteristics

Participants filled in a standard demographic questionnaire (gender and age were measured and labeled as possible confounders). In participants with neck pain, the intensity of perceived pain was evaluated using a numeric pain rating scale (NRPS), the functional disability due to neck pain was evaluated using the Neck Disability Index (NDI), and the Dizziness Handicap Inventory (DHI) was used to assess the perceived handicap due to dizziness. The NRPS, NDI, and DHI have shown good psychometric properties in people with neck pain.³⁴⁻³⁶

In all participants, the cervical range of motion (CROM) was measured with a CROM device (Performance Attainment Associates, USA). The CROM device consists of a magnet and

three compass-like instruments positioned in the three directions of neck mobility (rotation, flexion/extension, and lateroflexion). The CROM measures the maximum range of motion (in degrees) in each of these directions.³⁷

Recording of Reflexive Eye Movements

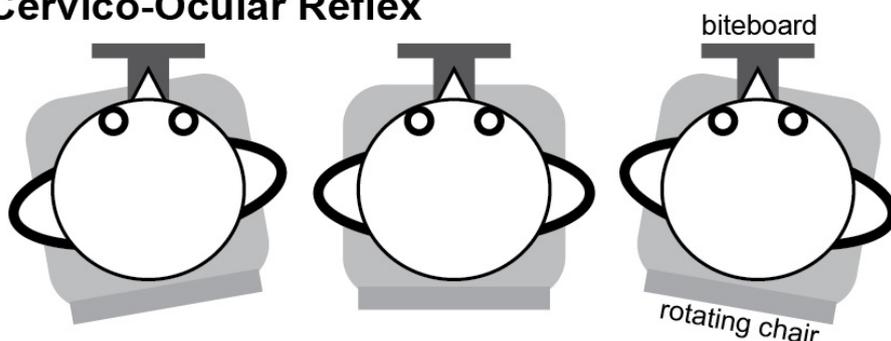
Monocular (left) eye positions were recorded by infrared video-oculography (Eyelink 1, SMI, Germany: see van der Geest & Frens³⁸) at a sample rate of 250 Hz. Eye position was calibrated using the built-in nine-point calibration routine. Eye movements were recorded during either cervical or vestibular stimulation in complete darkness by rotating the chair in which the participant was seated. The chair was attached to a motor (Harmonic Drive, Germany) that ensured sinusoidal chair rotation without any backlash. The trunk was fixed to the chair at shoulder level by a double-belt system. A sensor connected to the chair recorded chair position, and stored the data on a computer along with eye positions.

In both stimulation paradigms (COR and VOR), participants were instructed to keep their eyes open during the stimulation and to look at a position directly in front of the set-up. This position was briefly indicated by means of a laser dot before the rotation started. Head position was fixed in both conditions by means of a custom-made biteboard. In both stimulation paradigms, the position of the biteboard was set so that the axis of rotation was under the midpoint of the inter-aural line.

During the COR stimulation, the biteboard was mounted to the floor to fix the position of the head in space (see Figure 1). Rotation of the chair induced pure cervical stimulation, which elicits the COR in isolation. The chair was rotated for 134 seconds around the vertical axis with an amplitude of 5.0 degrees and a frequency of 0.04 Hz. This yielded 5 full sinusoidal rotations of the chair with a peak velocity of 1.26 degrees/s. During the VOR stimulation, the biteboard was mounted to the chair so that rotation of the chair induced pure vestibular

stimulation (see Figure 1). The chair was rotated for 33 seconds around the vertical axis with an amplitude of 5.0 degrees and a frequency of 0.16 Hz. This yielded 5 full sinusoidal rotations of the chair with a peak velocity of 5.03 degrees/s.

Cervico-Ocular Reflex



Vestibulo-Ocular Reflex

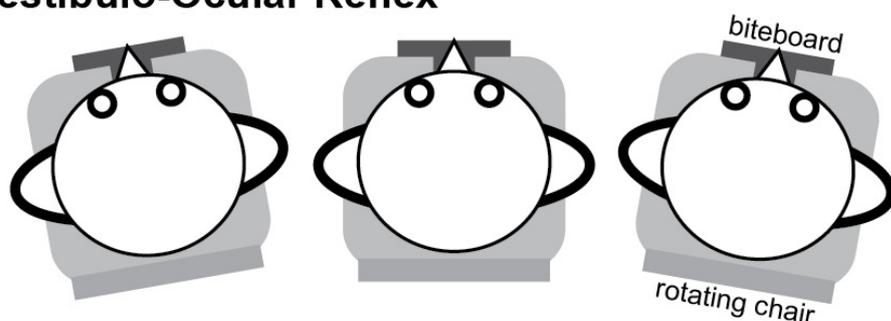


Figure 1. A schematic representation of the experimental set-up. In both paradigms the participants had to look at a position directly in front of the set-up. For the COR, the body of the subjects was rotated while the head of the participants was held fixed relative to the floor to fixate the position of the head in space. For the VOR, the body of the subjects was rotated while the head of the participants was held fixed relative to the chair.

Data Processing and Analyses

Eye velocity was calculated by taking the derivative of the horizontal eye position signal.

After removal of blinks, saccades, and fast phases (using a 20 degrees-per-second threshold),

a sine wave was fitted through the eye velocity signal data. Stimulus velocity was derived

from chair position (COR and VOR measurement) data. The gain of the response was defined

as the amplitude of the eye velocity fit divided by the peak velocity of the chair rotation

(COR: 1.26 degrees/s, VOR: 5.03 degrees/s). Therefore, a gain of one reflects that the peak

velocity of the eye was the same as the peak velocity of the chair rotation. All data processing was done with Matlab R2013a (The MathWorks Inc., Natick, MA).

Statistical Analysis

Descriptive statistics were computed for the entire sample for the gains of the COR and VOR (outcome parameters), NDI, DHI, perceived pain, CROM (outcome variables), and age and gender (possible confounders). Since the data was distributed normally (Kolmogorov-Smirnov test), parametric statistics were applied. Two analyses of covariance (ANCOVA) were performed to analyze differences in COR and VOR gains, respectively, between healthy controls and participants with neck pain with age and gender as covariates. Correlations between the gains (outcome parameters) and outcome variables were assessed using Pearson correlation coefficients. An alpha level of $P < 0.05$ was considered significant for all statistical tests. The data was analyzed with IBM SPSS Statistics for Windows, version 22 (IBM Corp., Armonk, NY).

Results

Forty one participants with neck pain and 30 healthy controls participated in the study. Eye movement recordings were successful in 37 participants with neck pain. In two participants, it was not possible to track the eye of the participant; in one participant, calibration of the eye tracking failed, and in one participant we failed to store the data properly on the hard disk.

Table 1 shows the group characteristics. Healthy controls were on average 13.8 years younger than participants with neck pain. There was a correlation between the VOR gain and age in the control group ($r=0.370$, $p=0.048$). In the neck pain group, there was no correlation between the VOR gain and age ($r=0.163$, $p=0.364$). No other correlations between age, COR gain, VOR gain, and the CROM were found within each group (all $r < 0.291$).

TABLE 1

Comparison of demographic and questionnaire data between asymptomatic controls and participants with neck pain.

| | Control (N=30) | | Neck pain (N=37) | |
|------------------------------|----------------|------------|------------------|------------|
| | Mean (SD) | 95% CI | Mean (SD) | 95% CI |
| Age in years | 28.3 (9.1) | 25.7, 32.3 | 42.1 (12.3)* | 36.5, 44.9 |
| Male/female | 15/15 | - | 12/25 | - |
| COR | 0.26 (0.15) | 0.21, 0.32 | 0.38 (0.16)* | 0.31, 0.42 |
| VOR | 0.67 (0.17) | 0.61, 0.74 | 0.66 (0.22) | 0.56, 0.72 |
| CROM Rotation | 139 (18) | 133, 146 | 134 (27) | 126, 145 |
| CROM flexion/extension | 133 (23) | 123, 139 | 111 (25)* | 103, 122 |
| Pain | - | - | 4.1 (2.0) | 3.5, 4.8 |
| Neck Disability Index | - | - | 23.4 (12.8) | 20.5, 28.4 |
| Dizziness Handicap Inventory | - | - | 18.2 (17.3) | 12.3, 24.7 |

NDI scores range from 0 (no disability) to 100 (maximal disability), DHI scores range from 0 (no disability) to 100 (maximal disability), CROM= cervical range of motion. Age and gender were identified as possible confounders.

* Significant difference between control and neck pain group at $p < 0.05$.

Participants with neck pain showed an increased COR after controlling for age and gender,

$F(1,62) = 4.15$, $p = 0.046$, $\eta^2 = 0.063$), but no significant difference in VOR $F(1,58) = 1.66$ $p =$

0.203 , $\eta^2 = 0.028$), compared to healthy controls. The CROM was reduced in participants with

non-specific neck pain in the vertical plane (flexion/extension, $F(1,60) = 4.21$, $p = 0.045$,

$\eta^2 = 0.066$), but not in the horizontal plane (Rotation, $F(1,60) = 0.33$, $p = 0.568$, $\eta^2 = 0.005$).

The correlation between the gains of the two eye movement reflexes was not significant when

the data were pooled ($r = 0.211$, $p = 0.102$; Figure 2), or analyzed per group, neck pain group

($r = 0.304$, $p = 0.091$) and in the control group ($r = 0.152$, $p = 0.431$).

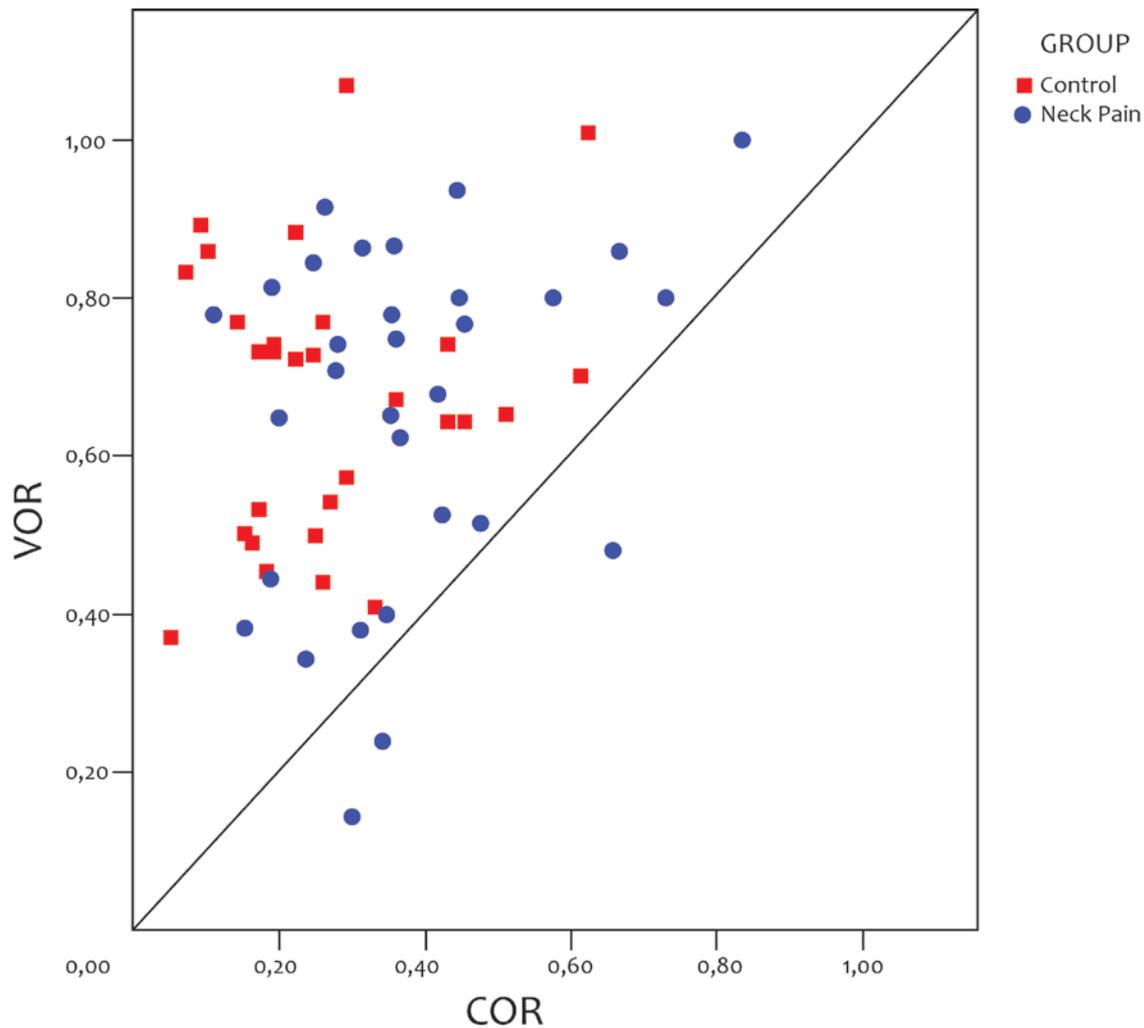


Figure 2. Scatterplot of the COR and VOR for all participants.

In addition, correlations between the COR or VOR on the one hand, and pain levels, location of the neck pain, range of motion of the cervical spine, NDI, or DHI scores on the other hand were not significant (r between 0.037 and -0.233, all $p > 0.172$). The correlation between COR gain and pain level at the moment of measurement was close to significance ($r = -0.304$, $p = 0.07$).

Discussion

We observed a higher COR but an unaltered VOR in a group of participants with non-specific neck pain group compared to a group of healthy controls. This is the first study investigating the COR in non-traumatic neck pain. Similar results were obtained in a previous study in

people with WAD.⁵ This suggests that an increased COR is not restricted to specific patient groups with neck pain.

An explanation for an increased COR in people with neck pain could be altered afferent information from the cervical spine. In the cervical spine, the information from muscles is a dominant source of information.^{39, 40} Deficits in afferent information are suggested by MRI studies showing a widespread presence of fatty infiltrates in the neck muscles of patients with chronic whiplash⁴¹ and to a lesser extent in idiopathic neck pain.⁴² Furthermore, muscles of the cervical spine (especially in the suboccipital region) have an exceptionally high density of muscle spindles.^{43, 44} An alteration of afferent information of the cervical spine is therefore likely to affect the COR.

Another explanation is that people with neck pain avoid movements in the end-range of motion. This could also alter afferent information of the cervical spine and, in turn, affect the COR. Our data suggest that this might be the case for the vertical plane where we observed a reduction in the range of motion in participants with neck pain. However, the higher age in the non-specific neck pain group could also explain the reduced range of motion.⁴⁵ In the rotational plane, there was no difference between the two groups in contrast to other studies.⁴⁶ This difference could be explained by the low to moderate neck pain and disability levels in our neck pain group.

Normally, the afferent information from the vestibular and cervical system cooperate in order to maintain a clear visual image during head and eye movements⁴⁷. Our findings suggest that the VOR does not compensate for the increased COR in the neck pain group. This mismatch between COR and VOR could lead to visual disturbances,⁴ dizziness,⁴⁸ and postural control disturbances.⁴⁹⁻⁵¹ In our study, we found no correlation between pain levels, dizziness and the

COR. This lack of correlation could be explained by the fact that the study population scored rather low on both the DHI and NPRS.

Measuring eye movements in patients might be useful for diagnostic and therapeutic purposes. For instance, it is not possible to influence COR deliberately. This makes the COR an objective outcome measure of oculomotor function that could be used as an additional test in clinical settings. This objectivity contrasts with other rather subjective outcome measures used to diagnose neck pain, such as questionnaires on disabilities and pain intensity.

However, objectively quantifying the ocular reflexes also has some limitations. For instance, eye movements need to be measured with adequate precision and accuracy. In the present study, we measured reflexive eye movements by means of video-oculography.^{38, 52, 53}

Measuring eye movements while the participant is sitting on a rotating chair in complete darkness is technically complicated. Furthermore, video-oculography is rather expensive. A cheaper and easier way to measure eye movements is by means of electro-oculography (EOG). Although this method is widely used in clinical settings, it is less suitable for recording VOR and COR eye movements due to its limited accuracy and reliability.^{52, 53}

Another limitation is related to the fact that that we only observed group effects. It would be interesting to investigate the possibility of assessing oculomotor control on an individual level, or as part of a function profile of people with neck pain. Another interesting question yet to be answered is whether it is possible to use the COR as an outcome measure to evaluate the effectiveness of interventions in people with neck pain. In a future study, we will make a direct comparison of the COR between people with non-specific neck pain, people with WAD, and people without neck pain. It might well be that there is a difference between in the COR between these groups. Another interesting direction for future research could be to

investigate the relationship between COR and visual complaints, which occur frequently in people with neck pain⁴.

We conclude that a deficit in eye stabilization function, namely an increased COR, can also be observed patients suffering from neck pain without any direct causes, i.e., non-specific neck pain. We suggest that the evaluation of oculomotor control in patients with neck pain and concomitant symptoms such as decreased postural stability might be worthwhile in clinical settings.⁵⁴

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