Do neck pain patients and healthy individuals differ in smooth pursuit neck torsion test?

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Abstract
Neck pain patients experience inability to smoothly follow a target with their eyes during neck torsioned position (SPNT). Although SPNT test has been commonly reported in clinical practice and research settings, no studies reported differences in eye movement control when applying different target movement amplitudes. The aim of the study was to examine differences in SPNT test between neck pain patients and healthy controls when applying different target movement amplitudes. Thirteen patients and fifteen healthy controls performed SPNT test using three different target movement amplitudes (30°, 40° and 50°). Eye movement data was collected using infrared video-oculography. SPNT difference was calculated for each of the three amplitudes. Two-way repeated measures analysis of variance showed statistically significant differences between the two groups and between the three amplitudes observed with statistically significant interaction effect. Post-hoc tests revealed differences between the groups for each target movement amplitude and between the amplitudes (50° amplitude for healthy and 40° for neck pain patients). Differences between neck pain patients and healthy controls were observed during SPNT test for all target movement amplitudes. Keywords: neck pain patients, oculomotor disfunction, eye movements

Ali se pacienti z bolečinami v vratu razlikujejo od zdravih posameznikov v natančnosti sledilnega pogleda med torzijo vratu?

Povzetek
Bolečina v vratu povzroča slabšo zmožnost sledilnega pogleda, predvsem v položaju torzije vratu (SPTV). Test SPTV se pogosto uporablja v klinične diagnostične in raziskovalne namene, vendar v literature ni mogoče zaslediti podatkov kako je natančnost sledilnega pogleda odvisna od spreminjanja amplitude gibanja tarče. Namen naše študije je bil preveriti razlike v SPTV testu izvedenem z različnimi amplitudami gibanja tarče med pacienti z bolečino v vratu ter zdravimi preiskovanci. V študijo je bilo vključeno 13 pacientov z bolečino v vratu in 15 zdravih preiskovance, ki so izvedli SPTV test z tremi različnimi amplitudami gibanja tarče (30°, 40° in 50°). Gibanje oči smo zajemali s pomočjo infrardeče video-okulografije. Za vsako izmed navedenih amplitud gibanja tarče smo izračunali razliko SPTV. Dvosmerne analiza variance za ponovljene vzorce je pokazala statistično značilne razlike med skupinama in med merjenimi amplitudami s statistično značilnim interakcijskim učinkom. Post-hoc obdelave so pokazale statistično značilne razlike med skupinama pri vseh opazovanih amplitudah gibanja tarče ter med amplitudami (50° amplitude pri zdravih in 40° amplitude pri pacientih). Raziskava je potrdila razlike med pacienti z bolečino v vratu in zdravimi preiskovanci v SPVT testu pri vseh opazovanih amplitudah gibanja tarče. Ključne besede: pacienti z bolečino v vratu, okulomotorične disfunkcije, gibanje oči

1. INTRODUCTION

Visual disturbances are commonly reported in patients with neck pain disorders (Tjell & Rosenhall, 1998; Treleaven et al., 2005) of which the most prevalent symptoms of visual complains are difficulty concentrating to read, blurred vision, words jumping on the page, visual fatigue and eye strain (Treleaven & Takasaki, 2014). These can have a negative effect on patients' quality of life such as reading and driving a car (Gimse et al., 1997; Takasaki et al., 2013).

Visual disturbances are caused by malfunctions of the oculomotor system. According to Peterson (2004) oculomotor dysfunctions in neck pain patients are believed to be caused by a mismatch of sensory information derived from cervical proprioceptors, vestibular and visual system. As a result, deficiencies in eye movement control are frequently investigated in clinical practice and research settings. In 1998 Tjell and Rosenhall (1998) proposed a clinical test to measure deficiencies of smooth pursuit eye movements in patients with neck pain disorders, central vertigo and Meniere disease which presented with high sensitivity and specificity to differentiate those with cervical spine derived oculomotor dysfunctions. The test is usually performed in a neutral position and when the trunk is rotated underneath a stationary head for 45° (to the left and to the right), called smooth pursuit neck torsion test (SPNT). A positive test is when the results are worse in the torsional positions compared to the neutral position. Abnormal values of the test typically indicate error in proprioceptive information derived from the neck, transmitted by cervico-collic and cervico-ocular reflexes (Tjell & Rosenhall, 1998). The SPNT test has moderate to good reliability (Majcen Rosker, et al., 2021) and has been proposed as a specific test for detecting cervical spine related oculomotor dysfunction (Janssen et al., 2015; Treleaven et al., 2008). Most studies investigated precision of smooth pursuit eye movements by exploring differences between eye movement velocity as opposed to target movement velocity (gain). As the main measured outcome of the test during the neutral position and neck torsioned positions is gain, difference in gain between the neutral and neck torsioned positions ($SPNT_{diff}$) should be investigated. Based on the results from the study by Majcen Rosker et al. (2021) intra-visit reliability of smooth pursuit neck torsion test varies between different target movement amplitudes for neck pain patients and healthy controls, possibly indicating differences in oculomotor performance between amplitudes and groups.

The main aim of the study was to determine whether a parameter of $SPNT_{diff}$ differ between healthy subjects and idiopathic neck pain patients. The second aim was to determine whether $SPNT_{diff}$ varies across different amplitudes of target movement in neck pain patients and healthy individuals.

2. MATERIALS AND METHODS

Participants

Thirteen patients with chronic neck pain (9 women and 4 men; average age 43.2 ± 4.8 years, range 29 – 51 years, average pain duration 13.6 ± 8.3 months) and fifteen healthy individuals (10 women and 5 men; average age 37.8 ± 6.1 years, age range 25-49 years) were enrolled in the study. Healthy individuals were recruited among university staff, doctoral students and their friends. Patients with chronic neck pain were referred by an orthopaedic surgeon and were previously assessed for suitability via the telephone interview. Each patient enrolled in the study underwent magnetic resonance imaging assessment, confirming some type of lower cervical spine structural impairment (disc protrusions or herniations at the levels from C4 to Th1, facet joints osteoarthritis at the levels from C5 to Th1, low grade spondylolisthesis and cervical spinal stenosis). Chronic neck pain patients had to experience pain in the neck for at least 6 months to 5 years to be considered for the study and were required to present with a minimum of 50° of cervical rotation to each side. Inclusion criteria for each group was age range between 18 and 55 years. In addition, patients were required to fill out Dizziness handicap inventory questionnaire (DHI) where a minimum score of 20/100 was required for enrolment in the study. Furthermore, patients were required to mark pain intensity on a 10 cm horizontal line with ends marked "no pain" (left) and the "worst pain imaginable" (right) on the visual analogue scale (VAS) (Boonstra et al., 2014; Kamper et al., 2015). To be considered in the study chronic neck pain patients had to present with a minimum score of 4 on VAS. All subjects had to be free from previous injury to the neck or head, shoulder or upper extremities pain, any neurological or vestibular disorders, and were required to take no medication or alcohol for the last 24 hours prior to participating in the study. All participants were required to read and sign a consent form. The study was approved by the national medical ethics committee (number: 0120-47/2020/6) and was performed in accordance with the declaration of Helsinki.

Equipment

A 100-Hz infrared eye tracking device (Pro Glasses 2, Tobii, Danderyd, Sweden) was used to measure and record eye movements during smooth pursuit tasks. Prior to the experiment, a single target calibration routine was performed in the Tobii Pro Glasses Controller (Tobii Pro Glasses Controller, Tobii, Danderyd, Sweden). Individuals were required to track a horizontally moving target of a red dot (size 0.5° of visual angle) which was projected on a white screen 150 cm away at an eye level. Subjects were sitting on a custom-made rotatable chair with upper body fixed to the back support. Hip angle was 80° of flexion, while their feet were placed flat on the floor. All measurements were conducted by the same examiner.

Experiment

Patients with neck pain and healthy individuals were required to answer the questionnaire of DHI and mark pain intensity on VAS. The testing protocol consisted of three different chair positions: (i) neutral position (ii), rotation of the trunk for 45° to the left and (iii) rotation of the trunk for 45° to the right under the stationary head. The order of chair rotations was pseudo-randomized across subjects. In the neutral position the anterior-posterior longitudinal axis of the chair was aligned in parallel to the line running from the middle of the screen and the middle of the chair. During trunk rotation their head was in a neutral position while their trunk was rotated. All tests were performed in an isolated room with dim light.

Before the test, all subjects performed 5 familiarizations warm up cycles. For each condition subjects were required to track 10 cycles of cyclic sinusoidal target movements with 60 seconds rest intervals. Subjects were tested at 3 different amplitudes of 30°, 40° and 50° for each of the above-mentioned chair position. All tasks were performed in a random order. Each chair rotation was followed by a 5 min rest and a recalibration of the eye-tracking device.

Data analysis

The eye movement data were filtered for blinks, saccades and fixations using the Tobi Pro Lab software (Tobii Pro lab 1,145, Tobii, Danderyd, Sweden). The square waves were removed from the eye movement data using a custom-written software in Matlab (R2017b, MathWorks, Natick, Massachusetts, United States). The eye movement data was fitted with a corresponding sinusoid of a 0.2 Hz representing movement of the reference signal. The horizontal eye movements were analysed using *gain,* calculated as the ratio between fitted eye velocity amplitude and visual target velocity amplitude as described by Tjell et al. (2002). Average *gain* from the 6^{th} to 9^{th} cycle from each task was used for reliability calculations. In addition, smooth pursuit neck torsion difference ($SPNT_{diff}$) was calculated as presented in Equation 1. The calculation was adapted and is similar to that described by Tjell et al. (2002):

$$SPNT_{diff} = Gain\ neutral - \frac{Gain\ torsion\ L + Gain\ torsion\ R}{2}$$

Equation 1: gain neutral represents the average gain in the neutral position from the 6^{th} to 9^{th} cycle, Gain torsion L represents the average gain during the left neck torsion position from the 6^{th} to 9^{th} cycle and Gain torsion R represents the average gain during the right neck torsion position from the 6^{th} to 9^{th} cycle.

Statistical analysis
Statistical analysis was performed in SPSS (SPSS 23.0 software, SPSS Inc., Chicago, USA). Descriptive statistics were calculated and represented as mean and standard deviation. Normality of distribution in all tests was analysed using Shapiro-Wilk test. Two-way repeated measures analysis of variances was applied to test for differences: group (healthy controls and neck pain patients) × amplitude (30°, 40° and 50°). Effect size was calculated using the partial eta square η^2, and was treated as $\eta^2 > .01$- small, $.06 < \eta^2 < .14$ - medium and high when η^2 was higher than .14 19. Two-tailed t-test for independent samples was used for pairwise comparisons between the two groups. A two-tailed t-test for dependent samples was used for post-hoc comparisons between amplitudes. The effect size in t-tests for dependent and independent samples was calculated using Cohens d (d). For all statistical tests, the level of statistical significance (p) was set at $p < .05$. All p values in post-hoc t-tests and correlation tests were adjusted for multiple comparisons according to the Benjamin and Hochberg procedure.

3. RESULTS

Results for the two-way repeated analysis of variance are presented in Table 1. Statistically significant differences in $SPNT_{diff}$ were observed between the two groups. Moreover, statistically significant differences were observed for the three different amplitudes. In addition, the interaction effects proved to present with statistically significant differences.

Table 1

	Group			Amplitude			Group*Amplitude		
	F	P	η^2	F	P	η^2	F	p	η^2
$SPNT_{diff}$	21.241	0.000	0.721	5.486	0,042	0,207	4.976	0.044	0.017

$SPNT_{diff}$ – smooth pursuit neck torsion difference, F – F statistic, p – statistical significance, η^2 – partial eta square.

Results of the post-hoc t-tests for the differences between the groups presented with statistically significant differences at each individual amplitude (for amplitudes of 50° t = 9.618, p = 0.000, d = 0.421, for amplitudes of 40° t = 8.155, p = 0.000, d = 0.497 and for amplitudes of 30° t = 4.317, p = 0.000, d = 0.264). Post-hoc tests for differences in $SPNT_{diff}$ between amplitudes for each individual group are presented in Figure 1. In the group of healthy individuals, $SPNT_{diff}$ differed statistically significant between 50° and 40° of 30° target movement amplitudes. In patient group, the 40° target movement amplitude differed statistically significant from the 50° and 30° amplitudes.
Based on averages and standard deviations (Figure 1) $SPNT_{diff}$ in neck pain patients was higher as in healthy controls. In Healthy control, $SPNT_{diff}$ at 50° target movement amplitude was lower as compared to other two target movement amplitudes. In neck pain patients, the 40° target movement amplitude tended to be higher as compared to 30° and 50° target movement amplitudes. These trends have also been confirmed by a statistically significant interaction effect in the two-way analysis of variance.

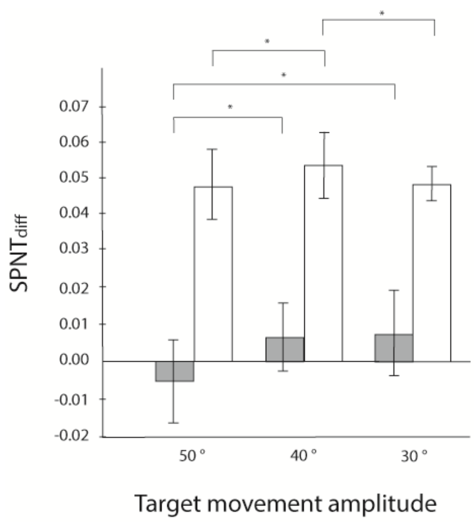

Figure 1: grey columns represent healthy controls and white columns represent patients with neck pain

4. DISCUSSION

The main aim of the study was to determine whether a parameter of $SPNT_{diff}$ differs between healthy subjects and idiopathic neck pain patients and to determine whether $SPNT_{diff}$ varies across different amplitudes of target movement in both groups. According to the results from our study a parameter of $SPNT_{diff}$ showed statistically significant differences between healthy individuals and neck pain disorders patients which was not amplitude dependent.

Differences between the two groups could be related to the presence and level of pain patients were experiencing. Patients from our study presented with pain in lower cervical spine. The latter could lead to less variability in active head and neck movements (Alsultan et al., 2019) and increased stiffness especially in the lower part of the cervical spine. As a result, upper cervical spine would have to increase compensatory movements during daily tasks possibly leading to increased laxity in upper cervical spine and disuse of suboccipital muscles. In addition, prolonged disuse could lead to atrophy and fatty infiltration of suboccipital muscles (Hallgren et al., 1994) commonly seen in neck pain disorders patients. These may result in a decrease of muscle spindle and Golgi tendon organ density, which could influence kinaesthetic awareness. As suboccipital muscles have high amount of muscle spindles (Kulkarni et al., 2001) a decrease would result in altered proprioceptive feedback and consequently sensory mismatch between vestibular, visual and proprioceptive input leading to less accurate eye movement reference frame (Majcen Rosker et al., 2021).

More specifically, abundance of muscle spindles found in the upper cervical spine act as important contributors towards kinaesthetic senses, responding to ramp-and-hold stretch with a rate of discharge that is proportional to the magnitude of the stretch (Proske & Gandevia, 2012). Consequently, 45° of neck torsion during SPNT test would stretch muscle spindles which could contribute towards sensory mismatch commonly seen in neck pain disorders patients and consequently alter oculomotor performance.

Heterogeneity of neck pain disorders pathologies could lead to proprioceptive stimulation of different structures during the same condition. According to Yang et al. (2017) degenerative changes in intervertebral discs found in patients with neck pain and cervicogenic dizziness possess an increased amount of free nerve endings and Ruffini corpuscles. As neck pain disorders patients complaining of dizziness have greater deficits in eye movement control (Treleaven et al., 2005) discogenic pathologies commonly seen in neck pain disorders patients could influence SPNT test result. An important limitation of our study was that a variety of neck pain disorders patients were included in the analysis altogether. Therefore, future studies should subgroup them in order to gain a more in-depth insight into the underlying mechanisms influencing oculomotor disfunction.

Clinical reasoning for deciding which amplitude to use during SPNT test has failed to provide consensus amongst different researchers. Tjell and Rosenhall (1998) were the first to introduce the SPNT test and suggested to apply 40° of neck torsion amplitude. Since then, inconsistencies were found across the literature regarding which amplitude of target movement should be used (Janssen et al., 2015; Treleaven et al., 2005).
According to the results of this study, target movement amplitude during SPNT test does not play a crucial role in oculomotor functions. According to Bexander and Hodges (2019) individuals without upper cervical spine trauma present with bilateral activation of obliquus capitis inferior (OI) when their eyes are moving in each direction while their head is stationary. The OI is an important stabilizer of the atlanto-axial joint that importantly contributes towards the first 45° of head rotation (Steilen et al., 2014). In addition, Bexander and Hodges (2019) report of greater OI activity with increase in eye movement amplitude, suggesting higher co-contraction, possibly increasing stiffness and sensory feedback. These results could possibly be observed if parameter of gain would be solely investigated. $SPNT_{diff}$ did not show differences between amplitudes which could be partially due to the inferior reliability of this parameter (Majcen Rosker et al., 2021).

5. CONCLUSION

Based on the results from our study a parameter of $SPNT_{diff}$ is able to show differences between neck pain patients and healthy controls. However, results were not amplitude dependent. Future studies should investigate the most sensitive amplitudes of the SPNT test between healthy subjects and neck pain disorders patients in order to provide information on classification ability.

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