Is perception of visual verticality intact in patients with idiopathic cervical dystonia?

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Abstract

Objective: Idiopathic Cervical Dystonia (CD) is a focal dystonia characterized by an abnormal tilted or twisted head position. This abnormal head position could lead to a distorted perception of the visual vertical and spatial orientation. The aim of this cross-sectional study was to investigate whether the perception of the visual vertical is impaired in patients with CD.

Methods: The Subjective Visual Vertical test (SVV) was measured in 24 patients with CD and 30 controls. The SVV test is conducted in a completely darkened room. A laser bar is projected on an opposing white wall which is deviated from the earth's gravitational vertical. Participants were seated with their head unrestrained and were instructed to position this bar vertically. The deviations in degrees (°) are corrected for the side of laterocollis in order to measure the E-effect.

Results: We found that patients were able to position the laser bar as equally close to the earth's gravitational vertical as controls (+0.67° SD±2.12 vs +0.29° SD±1.08, *p*=0.43). No E-effect was measured.

Conclusions: Notwithstanding the abnormal position of the head, perception of the visual vertical in patients with idiopathic CD is intact, possibly because of central neural compensatory mechanisms.

Keywords: orientation, subjective visual vertical, spasmodic torticollis, cervical dystonia

Introduction

Cervical Dystonia (CD) is one of the most common forms of focal dystonia. It is a movement disorder characterized by sustained or intermittent contractions of neck muscles causing abnormal, often repetitive movements, head postures or both. Dystonic movements are typically patterned, twisting and may be tremulous [1]. It is associated with not only motor but also sensory deficits and pain [2, 3]. The causality can be genetic but in this study we focus on idiopathic late-onset CD. Dysfunction of the basal ganglia is present in the pathophysiology of CD[4–7], accompanied by abnormal integration of sensorimotor information [8–10]. Imaging studies are inconsistent in which brain region is affected in CD, showing multiple brain regions are involved [7, 11, 12], leading to the network model [13] with recent evidence for cerebellar involvement [12–16].

Orientation of the individual in space requires central integration different sensory input such as somatosensory, visual and vestibular information. This orientation contributes to the detection of head and body position, motion, postural orientation and stabilization [17–20]. The afferent sensory input projects to parietal, subcortical, (pre)motor structures and somatosensory areas of the perisylvian cortex [4, 21, 22], areas which may be affected by CD. Spatial orientation can be measured in multiple ways, here, we address the perception of visual verticality. In studies concerning the perception of verticality, the Subjective Visual Vertical test (SVV) is frequently used [23–26]. This test is performed in complete darkness in which subjects set a laser bar straight, adjusted to align with the perceived direction of gravity [27]. The SVV measures otolithic function [28–30] and shows distortions of the SVV score when somatosensory or vestibular input are altered [4, 19, 30]. Distortion of the SVV has been documented in peripheral [28, 31, 32] and central vestibular disorders [33] and in stroke [17, 34].

In idiopathic CD, the abnormal position of the head could alter vestibular input and somatosensory cervical information and could therefore distort perception of verticality. Moreover, because of the head tilt, an E-effect could be present. When in normal subjects the head tilts on the body (<60°), subjects overestimate the tilt and compensate by setting the laser bar to a contralateral tilt of the visual vertical. This is referred to as the "E-effect" [35]. It is unclear whether patients with idiopathic CD exhibit a similar reaction, since previous research shows conflicting results. The conflicting results may arise from multiple methodological differences where the SVV test is performed in different head positions. With uncorrected head position, i.e. dystonic head posture [24], or passive correction of the head position to a neutral position in line with the trunk, the perception of the visual vertical is intact [23, 25]. Whereas actively correcting the patients head to an upright posture results in a deviation of the visual vertical [26]. The conflicting results of older and more recent studies call for additional research. Especially because previous studies failed to correct the SVV score for the direction of the head on body tilt. Secondly, it is clinically more relevant to assess visual verticality with the head unrestrained in the dystonic posture since impaired perception of verticality could lead to difficulties in reading or mobility [17] as moving in space is influenced by spatial orientation.

The aim of this cross-sectional study is therefore to evaluate whether the perception of visual verticality is impaired in patients with idiopathic CD without correcting the head position and with additional analysis of the data, controlling for the presence of a right or left head tilt (i.e. laterocollis).

Methods

Setting and Participants

Adult subjects with a diagnosis of idiopathic CD were recruited in a tertiary care center at the department of Neurology in the Antwerp University Hospital. All eligible patients were contacted and a total of 24 patients with idiopathic CD agreed to participate. All participants were diagnosed by an experienced neurologist in accordance with the European Federation of Neurological Societies / Movement Disorders Society European Section (EFNS/MDS-ES) guidelines [36] and received regular treatments of botulinum toxin injections. The assessment took place at least 3 months after the last injection, immediately prior to a new injection of botulinum toxin. People were excluded with impaired vision (which could not be corrected by glasses or contact lenses), or when they showed clinical features suggestive for vestibular dysfunctions, other neurological disorders or a segmental distribution of dystonia. Additional exclusion criteria were set for the control group: bothersome neck pain in the last 6 months, neck or head trauma in the last 5 years, vestibular or neurological disorders.

Head tremor was assessed by the Tsui scale [37]. Disease severity was measured by the Toronto Western Spasmodic Rating Scale (TWSTRS) and Cervical Dystonia Impact Profile (CDIP-58) [38, 39], which have been proven valid and reliable [40].

The protocol was approved by the Ethics Committee of the University Hospital of Antwerp (reference number 14/8/74) and all participants provided informed consent before participating. The assessment took place in the Multidisciplinary Motor Centre Antwerp (M^2OCEAN).

The subjective visual vertical test

The Subjective visual vertical (SVV) test was performed to measure the visual perception of verticality in relation to the earth's gravitational vertical [41, 42] by the Difra Vertitest type DI072010 (Difra, Belgium). The vertitest is positioned behind the participants and projects a laser bar of approximately 1 m on an opposing white wall. Prior to testing, the vertical projection of the line was calibrated by a plumb line. Participants sat on a chair without backrest with the arms resting on their lap and both feet resting flat on the floor in a completely darkened room. Head position was not corrected in the patients with CD and control subjects kept the head in a neutral position. Both researcher and participant obtained a remote to rotate the laser bar either clockwise (CW) or counterclockwise (CCW). The laser bar was made invisible to the participant when the researcher set the bar in the starting roll position. The participant then rotated the laser bar to a vertical position using the remote control. The deviation in degrees (°) was noted where a CW deviation of the bar results in a positive SVV score and a CCW in a negative score. The fixed order of the 7 starting roll positions of the laser bar in relation to the earth's vertical was 20° CCW, 10° CW, 5° CCW, 0° (earth's vertical), 5° CW, 10° CCW and finally 20° CW. The average of the 7 trials was calculated. The vertitest has an accuracy of 0.1°.

Participants performed 1 practice trial and did not receive any feedback about their performance during the assessment. No time limits were set for the adjustments.

Sample Size

Sample size was based on the deviation in SVV scores in healthy subjects performing a head tilt [43] and patients with CD [26]. Seventeen subjects were required in each group in order detect a difference in perception of verticality of 2° with a standard deviation of 2° at 80% power and 95% confidence.

Data processing

The SVV test results in positive and negative values. If patients with CD show an E-effect, we expect a CW deviation and positive values in patients with left laterocollis (see Fig.1). Patients with right laterocollis would have a negative SVV score because of the CCW deviation. When calculating a mean SVV score of patients with right or left laterocollis, this would lead to a value close to 0. Therefore, the raw SVV score of patients with left laterocollis were multiplied with -1. This is from here on reported as corrected SVV score and allows comparison between subjects.

PLEASE INSERT FIG 1 ABOUT HERE

Fig. 1 Example of a positive Subjective Visual Vertical (SVV) score in a participant with left laterocollis

Statistical analysis

Statistical package for social sciences, SPSS 22 (SPSS Inc, Chicago, USA) for Windows was used for statistical analysis. Descriptive statistics were used for mean age, number of men and women and patient descriptives. Normality was tested by a Shapiro-Wilk test. To detect inter group differences in perception of the SVV, an unpaired T-test was performed. To verify if disease severity or disease duration affects the SVV score, a Pearson correlation coefficient was calculated. To detect differences in the SVV score between controls, patients with and patients without head tremor a One Way ANOVA test was used.

Results

Participants

In the patient group, 4 men and 20 women with idiopathic CD participated with a mean age of 59.2 year (range 30-86 year, SD ±8.7 year). Of the participants with CD, 91.6% had a combined form of CD in which the head both tilts and rotates on the trunk and 11 patients showed a visible tremor, for more details see Table 1. The control group consisted of 12 males and 18 females with a mean age of 59.4 year (range 32-85 year, SD ±17.4). No difference in age was found between groups (p=0.930). The mean disease duration was 13.0 year (±8.7y), mean disease severity measured by the TWSTRS was 36.0 (±9.7) and 47.7 (±13.8) measured by the CDIP-58 (see Table 2).

PLEASE INSERT TABLE 1 ABOUT HERE

PLEASE INSERT TABLE 2 ABOUT HERE

SVV score

The mean deviation of the visual vertical in subjects with CD, as measured by the raw SVV score, was not different from the control group (p=0.760). Subjects with CD placed the visual vertical equally close to the earth's gravitational vertical as the control group (raw SVV score of +0.14° versus +0.29°). When the results are controlled for the left or right head tilt, the mean corrected SVV score of the patient group is slightly larger but not different from the patient group (+0.67° ±2.12° versus +0.29° ±1.08°) (p=0.43), see Table 1 and Fig.1. No E-effect is measured.

Head tremor has no impact on SVV scores as subjects with or without tremor did not score differently (p=0.634), neither compared to controls (p=0.906). Males or females did not score differently (p=0.087). No correlation was found between disease duration or severity of laterocollis as measured by the severity scale of the TWSTRS, and the corrected SVV score (p=0.834 and 0.142 resp.).

The variability in the perception of the visual vertical was twice as large in the patients with idiopathic CD than in the control group (SD of 2.12 versus 1.08).

PLEASE INSERT FIG 2 ABOUT HERE

Fig 2 Difference in mean corrected Subjective Visual Vertical (SVV) scores of controls and patients with idiopathic Cervical Dystonia

Discussion

The aim of the present study was to investigate the perception of visual verticality in patients with idiopathic CD by means of the subjective visual vertical test. The SVV adjustments in patients with CD, with their head unrestrained in the dystonic posture, were not significantly different from those of healthy controls.

Previous reports are unclear whether the perception of visual verticality is intact in patients with CD. Mostly because of differences in methodology. Anastasopoulos and co-workers assessed patients with CD in both a passively corrected and uncorrected head position [23, 24] and found no deviation of visual verticality nor E-effect. Müller and co-workers studied patients with an active correction of the head position and found a deviation of the visual verticality [26]. The active correction of the head position induces a head-on-body tilt in patients as the resting head position is altered. This active correction of the head position might alter the somatosensory input more than a passive correction of the head position, therefore leading to the measured E-effect. The major limitation of previous research however was that the side of head tilt was not always taken into consideration. This was addressed in our sample by correcting the raw SVV score for the side of laterocollis. Yet, our data showed that patients place the subjective visual vertical within normal limits so the dystonic head posture does not lead to an E-effect. The larger standard deviation observed in our sample in patients is similar to the increase in variability of the SVV-score in healthy subjects performing a head-on-body tilt [30]. Contrary to previous research, we did not a priori exclude patients with head tremor. The presence of tremor however, did not affect the results of the SVV score (p=0.906). We therefore believe that head tremor does not affect perception of visual verticality.

Deviations of the SVV can occur if one of the sensory afferent signals is impaired. Idiopathic CD is characterized by an abnormal head position, which may alter vestibular and somatosensory afferent input. Our patient group however, might have adapted to this new situation by seemingly ignoring this altered sensory input since no perturbation in the perception of verticality is present. The absence of an E-effect could imply that patients with idiopathic CD have altered the egocentric reference frame to the deviated head posture in realigning the head posture with the reference frame. Therefore, the new deviated head posture can be perceived as normal and does not lead to an E-effect. Two hypothesis can be formulated. One hypothesis is the long term asymmetrical sensory input could be reset to a new normal condition with an intact spatial orientation by central compensation. The SVV is an indicator for vestibular disorders and primarily for the graviceptive otholith organs. As participants with vestibular symptoms were excluded in this study and the peripheral vestibular function has been proven intact in CD [44], this seems however an unlikely explanation. The second hypothesis is sensory reweighting. When addressing multisensory tasks such as spatial orientation or maintaining an upright posture, sensory weighting occurs in order to give meaning to different sensory input [45–47]. Spatial orientation is based upon visual, vestibular and somatosensory input. In a sensory weighting model where multiple sensory systems provide information for one physical variable (in this case, visual verticality), the physical variable is computed as a weighted sum of all sensory input [47, 48]. When one or more sources of sensory input is impaired, signals from intact sensory systems weigh more in the integration and compensate for the default sensory information. This has previously been demonstrated in patients with stroke [49] and has been suggested for patients with CD [50]. In idiopathic CD, there is no indication that visual input is impaired, peripheral vestibular functions are intact [44] and it appears that somatosensory input from the neck is impaired [51]. Additionally, graviceptional input also arises extravestibularly from muscle spindles, mechanoreceptors of the joints and through the abdominal viscera graviceptors [20, 30, 52, 53]. Consequently, in idiopathic CD, the somatosensory input from other graviceptors could be reweighted without considering somatosensory input from the neck.

Gender could be a potential source of bias. Since the prevalence of CD is higher in females, a higher percentage of females was included in the patient group compared to the control group. However, to the best of our abilities, we could not find previous reports in which perception of verticality is subject to gender differences.

The sample of 24 patients might seem small. Particularly since CD is a rare condition, we find this sample reasonable. Previous research reported on data of 10, 15, 28 and 29 patients [23–26]. Pooling of the data would enhance the power of the findings. However, due to heterogeneity of methodology, this is not possible.

In conclusion. The abnormal head posture in idiopathic CD does not result in a perturbations of the perception of visual verticality. The scope of future research could focus on the role of other afferent sensory input systems such as the somatosensory input or afferent input from the neck in order to maintain spatial orientation, especially in dynamic conditions.

Compliance with Ethical Standards:

Funding: This study was funded by Academic project Antwerp University G815

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Conflict of interest

The authors declare that they have no conflict of interest.

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Figure 2

Click here to download Figure Fig.2.boxplot SVV score patients and controls.jpg

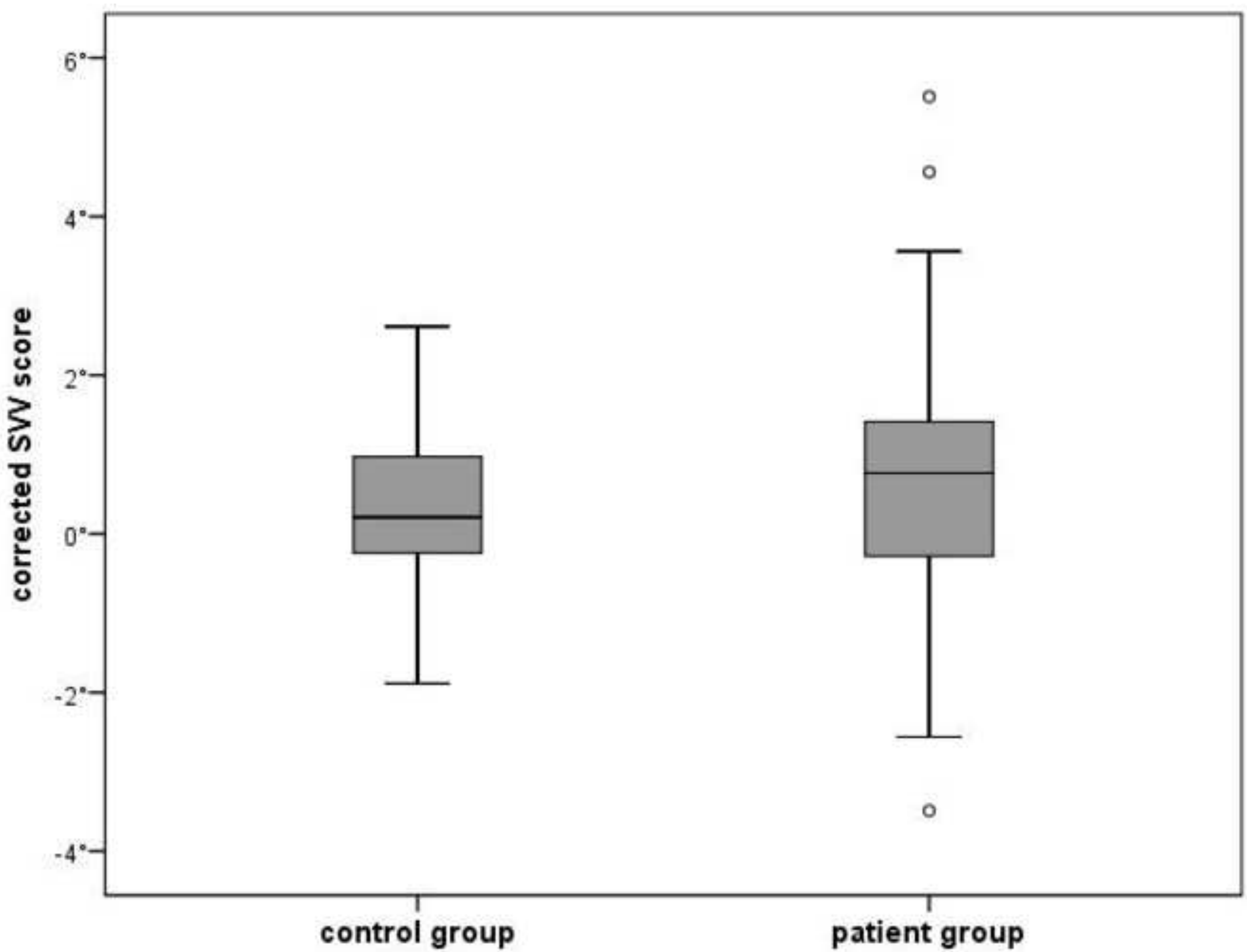

Figure 1

Click here to download Figure SVV_left laterocollis.tif

Table 1

Table 1: Patient characteristics

Subject	Gender	Age (years)	Duration CD (years)	Type of CD	Degree of head tilt	Raw SVV (°)	Corrected SVV (°)	tremor	TWSTRS /85	CDIP-58 /100
1	F	44	2	Right T + Left La	1	-0.84	0.84	0	34,87	68,62
2	M	41	7	Right La	1	-0.29	-0.29	0	29,5	41,03
3	F	76	14	Right T + Left La + Left Lateral shift	1	-1.06	1.06	0	44,75	49,66
4	F	68	15	Left T	0	0.69	0.69	0	28,25	36,21
5	F	35	9	Left T + Re	0	-1.77	-1.77	0	26,75	48,62
6	F	71	7	Right T + Right La + sagittal shift forward	1	1.27	1.27	0	36	41,72
7	F	58	11	Right T + Left La	1	-0.66	0.66	4	40,25	42,41
8	F	62	7	Right T + Left La	1	-1.13	1.13	0	44,75	67,93
9	F	61	9,5	Right T + Right La + An	1	0.57	0.57	0	56	53,79
10	F	59	14	Right T + Left La	2	1.64	-1.64	1	27	41,72
11	M	71	8	Right T + Right La + sagittal shift backward	3	4.56	4.56	0	41,75	34,83
12	M	56	18	Right T + Right La	1	1.56	1.56	2	30,25	43,79
13	F	30	11	Right T + Right La	1	-0.27	-0.27	4	21,75	25,86
14	M	43	8	Right T + Right La	1	0.67	0.67	0	36,75	44,48
15	F	70	7	Right T + Left La	2	2.56	-2.56	0	26,75	30,34
16	F	55	10	Right T + Right La	2	2.07	2.07	1	34,75	50,00
17	F	70	35	Right T + Right La	1	-0.07	-0.07	4	40,25	75,86
18	F	86	34	Left T + Right La + An	2	5.51	5.51	1	27,25	28,62
19	F	74	8	Left T + Right La	2	1.07	1.07	4	27	42,07
20	F	48	9	Right T + Right lateral shift	0	-3.49	-3.49	2	46,25	73,45
21	F	59	17	Left T + Left La	3	-2.34	2.34	0	61,75	63,10
22	F	71	31	Left T + Left La + An	2	-1.00	1.00	1	30,5	38,97
23	F	50	6	Right T + Right La	2	-2.29	-2.29	0	38,5	55,86
24	F	64	15	Right T + left La	2	-3.56	3.56	4	34,125	45,52
mean		59.25	13.02			0.14	0.67		36,07	47,69
SD		±13.96	±8.72			±2.22	±2.12		±9.74	±13.79
range		30 - 86	2 - 35			-3.56 – 5.51	-3.49 – 5.51		27.0 – 61.7	28.6 – 73.4

Legend: M=male, F=female, T=torticollis, La=laterocollis, An=anterocollis, Re=retrocollis,
Degree of tilt = degree of laterocollis (head on body tilt): 0: no tilt, 1: mild laterocollis 1°-15°, 2: moderate laterocollis: 16°-35°, 3: severe laterocollis >35°
TWSTRS=Toronto Western Spasmodic Rating Scale, CDIP-58=Cervical Dystonia Impact Profile, sd= standard deviation
Tremor according to Tsui scale: product of severity x duration (severity: 1=light 2=severe and duration 1=intermittent 2= constant)(Tsui et al. 1986)

Table 2

Table 2 Demographic features

	Patients (n=24)	Controls (n=30)	*p*
Male/female ratio	4/20	12/18	
Age (years)	59.2 ±13.9	59.4 ±17.4	0.930
Mean disease duration (years)	13.0 ±8.7		
Mean score on TWSTRS	36.07 ±9.74		
Mean score on CDIP-58	47.69 ±13.79		
Mean raw SVV score (°)	+0.14 ±2.22	+0.29 ±1.08	0.760
Mean corrected SVV score (°)	+0.67 ±2.12	+0.29 ±1.08	0.432

SVV score: mean deviation expressed in degrees ±SD, TWSTRS: Toronto Western Spasmodic Torticollis Rating Scale, CDIP-58: Cervical Dystonia Impact Profile, p: p-value, mean corrected SVV score where the raw SVV score is corrected for starting position of the head: raw SVV scores of patients with left laterocollis are multiplied by -1