In idiopathic cervical dystonia movement direction is inaccurate when reaching in unusual workspaces

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Keywords: cervical dystonia, movement direction, directional error, unusual position, reaching movements

Short title: Inaccurate movement direction in cervical dystonia

Article published as: Marinelli L, Pelosin E, Trompetto C, Avanzino L, Ghilardi MF, Abbruzzese G, Bove M. In idiopathic cervical dystonia movement direction is inaccurate when reaching in unusual workspaces. Parkinsonism Relat Disord. 2011 Jul;17(6):470-2. doi: 10.1016/j.parkreldis.2011.01.017. Epub 2011 Feb 22. PubMed PMID: 21334958.

Abstract

When reaching movements are performed in an unusual area of work, normal subjects produce a rightward directional error. This has been considered to be caused by an impaired representation of limb configuration, which hampers the actual movement vector. Motor programming has been found to be impaired in dystonia. To understand how patients affected by idiopathic cervical dystonia (CD) perform reaching movements in an unusual area of work, we investigated 10 CD patients and 10 age-matched controls. Reaching movements on a digitized tablet were recorded both with the right arm aligned to the midline (central position) and shifted to the right (lateral position), but hidden from view. While differences in the main kinematic parameters were not affected by the position both in patients and controls, the directional error was significantly increased in dystonic patients for the lateral position. We hypothesise that an impaired integration of proprioceptive information with the motor output and egocentric spatial perception could be responsible for a greater error in spatial representation of hand location and consequently to an increased directional error in dystonic patients.

Introduction

The knowledge about mechanism underlying abnormal motor control in idiopathic dystonia is still limited. Kinematic studies have disclosed abnormalities in patients with dystonia [1-3] that suggest an impairment of both proprioception and motor programming, not only in the affected body parts, but also in unaffected segments [2-4].

In reaching movements, the spatial location of the target is remapped from retinotopic into egocentric coordinates, then target information is combined with hand position information in order to form a simplified hand-centered plan of the intended movement trajectory as an extent and direction in extrinsic space [5]. One of the most important kinematic measures reflecting trajectory planning is movement direction [5], which is indeed encoded by specific cortical neurons, whose discharge pattern is closely related to movement direction [6]. When performing reaching movements in everyday activities, the initial hand position is usually close to the midline in front of the subject's body. Performing reaching movements with the right arm displaced to the right and out of sight can be considered to happen very rarely, since usually the trunk is rotated toward the target. We define “unusual area of work” as the condition when the right outstretched arm performs a reaching movement without the subject's trunk facing it. In this setting, normal subjects aim their movements with a rightward directional error [5]. The authors hypothesise that this directional bias is caused by an impaired representation of limb configuration, which hampers the actual movement vector [5]. Our objective is to understand how patients affected by idiopathic cervical dystonia perform reaching movements in an unusual area of work to test the possible occurrence of defective spatial representation of the moving arm.

Materials and methods

Subjects

The same subjects involved in our previous study [2] have been included, consisting in 10 patients, 5 men and 5 women, with idiopathic cervical dystonia (CD) (age, mean ± SD: 50.5 ± 10.13 years) and 10 aged-matched normal controls (NC), 4 men and 6 women (age 46.4 ± 12.6 years). All subjects were right-handed, without cognitive impairment (MMSE>26) or psychiatric diseases. Mobility at the elbow and shoulder joints was normal and painless in all participants. No segmental spread of dystonia was present in the patients. The amplitude of head deviation from primary position at rest was evaluated with a goniometer in sitting position [7]. The experiments were conducted in accordance with the

Declaration of Helsinki and written informed consent was obtained from all participants under a protocol approved by the institutional review board.

Experimental design

The subjects were seated in front of a computer screen and moved their right (dominant) limb on a digitizing tablet. The height of the seat was adjusted so that the arm was moving in a horizontal plane at the shoulder level. Two different sessions were then performed consecutively. In one session the subjects' elbow and shoulder joint angles were set at about 90° and 135°, respectively (central position), so that the hand was aligned to the sagittal midline. In the other session the subjects' elbow was set instead at 90° and the shoulder joint at about 180° (lateral position), so that the hand was displaced to the right. During the experiment an opaque shield was used to prevent vision of the hand and the tablet and a seat belt restrained trunk's movements.

The targets comprised eight circles placed at 10 cm from a central starting point with an interval of 45°. They were presented in a random order on the computer screen at 3 second intervals in blocks of 32 movement trials (4 complete cycles of 8 movements each). Subjects were instructed to make out and back movements with overlapping strokes and to reverse rapidly, without stopping at the target. Instructions were also to move as fast as possible without correction during the movement. At the beginning of each trial, the position of the hand was displayed on the screen together with the starting point. Then, the cursor feedback was removed and subjects performed the movements without visual feedback. After a few blocks for familiarization with the testing apparatus, all subjects performed 3 blocks of movements in a central position and another 3 blocks on movements in a lateral position. The normal subjects and the dystonic patients were randomized in performing either the central or lateral position as the first task. All patients and controls performed the task with their head against the head-rest. Patients were able to maintain the head spontaneously in the straight position without any special effort and without instructions from our part. This is akin to the well-known "sensory trick" phenomenon that greatly reduces EMG activity in dystonic muscles. No patients reported pain or fatigue in the neck muscles during the motor task and no abnormal muscle activation was observed.

Data collection and analysis

Head rotation was measured in dystonic patients as the absolute deviation from midline before performing the movements in the central and lateral position.

Hand trajectories were sampled at 200 Hz and analyzed as in previous works [8]. For each movement we computed: the normalized hand path area, measured as the area enclosed by the hand path divided by the square of movement length [8]; the reversal lag, that is the time interval between the end of the outgoing motion and the onset of the back motion [2]. For outgoing motion, we also computed the following parameters: reaction time, movement extent (that is the linear distance between the starting and ending point of the movement), peak of velocity, peak of acceleration and movement time. We also computed the symmetry of the velocity temporal profile, that is the ratio between the time at peak velocity and total movement duration.

Statistical analysis

The kinematic parameters in the central and lateral positions were compared using a mixed-model ANOVA with the variable "group" (CD patients and controls) as between-subject factor and the variable "limb position" (central and lateral) as within-subject factor. When ANOVA gave a significant result ($p<0.05$), the post-hoc Bonferroni test was used to assess significant differences among groups and testing times.

Pearson's linear regression analyses were also performed to determine correlations between head rotation and directional error.

Results

Head Rotation

Head rotation, considered as absolute deviation from the midline, was 38°±9 (SE). The direction of the rotation was leftward in 6 patients and rightward in 4. No significant difference was found between head rotation measured in the central and lateral position just before starting the tasks.

Kinematic parameters

We evaluated the normalized hand path, reversal lag, reaction time, movement extent, amplitudes of peak of velocity and peak of acceleration, movement time and symmetry index in dystonic patients and controls both in central and lateral positions. All the above parameters were significantly different (p always < 0.05), thus confirming our previous results [2]. However, all the parameters did not change between the central and lateral position in control subjects and also no significant difference between the two conditions could also be observed in dystonic patients.

Directional Error

While performing the movements in the central position, both dystonic patients and controls showed a slight counterclockwise (positive) deviation (dystonic patients: 3.6°±1, controls: 3.9°±1). Conversely in the lateral position, both dystonic patients and controls showed a slight clockwise (negative) deviation (dystonic patients: -8.5°±0.9, controls: -5.8°±0.5). Directional error was significantly different between dystonic patients and controls ($F[1,72]=5.7$, $p=0.02$) and between central and lateral positions ($F[1,72]=284.2$, $p<0.0001$) (Figures 1 and 2).

Considering the movements in the central position only, no significant difference could be found between dystonic patients and controls ($F[1,36]=0.1$, $p=0.7$); in the lateral position instead, the dystonic patients produce a greater clockwise directional error compared to controls ($F[1,36]=9.8$, $p=0.0035$).

In dystonic patients no significant correlation was found between head rotation and directional error in central position ($r=0.54$, $p=0.10$) and lateral position ($r=0.40$, $p=0.26$). Also no significant correlation was found between directional error in lateral position and disease duration ($r=-0.3$, $p=0.4$).

Discussion

In this study we analyze the motor performance of dystonic subjects while performing reaching movements in an unusual area of work. Patients and controls have been evaluated not only with their right arm aligned to the sagittal midline (central position), but also displaced to the right (lateral position). We can consider the central position, with the arm just in front of patient's body, as the position usually adopted during everyday tasks; all subjects are used to performing most reaching movements in such usual condition with optimal precision and speed. Conversely, lateral position requires movements to be performed with the arm outstretched; this is more unusual and could determine an impaired motor performance. Hiding the cursor on the screen after the training blocks and preventing the vision of the moving arm resulted in reaching movements guided only by proprioceptive information. In a previous study [2] we showed that motor performance of patients with cervical dystonia is also impaired in non-affected segments such as the upper limb. While performing reaching movements, dystonic patients appeared slower, trajectories were more round-shaped and the out and back movements were not consecutive as in control subjects. Our present data confirm such observations and show that all kinematic parameters (with the exception of the directional error) were no different between central and lateral positions in both normal controls and dystonic subjects. When normal subjects perform movements in the unusual lateral position without being able to see their arm moving, the direction of the movement is deviated clockwise compared to the usual central position. Since such directional error is not present when the subjects are able to see their moving hand in relation to their bodies, it has been hypothesised that in normal subjects this directional bias is due to an error in the spatial representation of hand location as provided by the proprioceptive system alone [5]. When dystonic patients perform reaching movements in the central position, the directional error is similar to that of the control subjects. While performing movements in the lateral position, dystonic patients also produce a clockwise directional error that is significantly increased compared to control subjects. It can be suggested that the directional bias observed in normal subjects is somewhat magnified in dystonic patients, possibly because of a greater error in the spatial representation of hand location or in relation to an impaired integration of proprioceptive information with the motor output [9]. Previous studies have shown that the processing of spatial information and visuomotor integration also relies on posterior parietal cortex [10] and that patients with cervical dystonia performing movements with the non-dystonic hand indeed activate posterior parietal cortex less than normal controls [4]. The reduced parietal activations in patients with cervical dystonia may thus indicate an impaired integration of the somatosensory consequences of movement in space, leading to a mismatch between representation of body scheme and external space [4].

Interestingly, patients with cervical dystonia are impaired in tasks involving mental rotation of body parts. Such tasks are considered to rely on body-centered egocentric spatial perception and involve parietal cortex [11]. Mental rotation can be considered mainly an explicit test since attention and awareness are involved, while the reaching tasks performed in this study involve a great deal of motor automaticity and the resultant directional bias is not perceived by the subjects. Despite these differences, both tasks require egocentric spatial perception, which is impaired in cervical dystonia [12] and may involve the parietal cortex as a common point between two different neural networks.

Increased directional error while performing upper limb movements in an unusual workspace can be considered a peculiar characteristic of cervical dystonia, which could be related to an impaired activation of the posterior parietal cortex and could be useful in better understanding the pathogenesis of dystonia.

References

[1] Inzelberg R, Flash T, Schechtman E, Korczyn AD. Kinematic properties of upper limb trajectories in idiopathic torsion dystonia. J Neurol Neurosurg Psychiatry 1995;58:312-9.

[2] Pelosin E, Bove M, Marinelli L, Abbruzzese G, Ghilardi MF. Cervical dystonia affects aimed movements of nondystonic segments. Mov Disord 2009;24:1955-61.

[3] Putzki N, Stude P, Konczak J, Graf K, Diener H, Maschke M. Kinesthesia is impaired in focal dystonia. Mov Disord 2006;21:754-60.

[4] de Vries PM, Johnson KA, de Jong BM, Gieteling EW, Bohning DE, George MS et al. Changed patterns of cerebral activation related to clinically normal hand movement in cervical dystonia. Clin Neurol Neurosurg 2008;110:120-8.

[5] Ghilardi MF, Gordon J, Ghez C. Learning a visuomotor transformation in a local area of work space produces directional biases in other areas. J Neurophysiol 1995;73:2535-9.

[6] Schwartz AB, Kettner RE, Georgopoulos AP. Primate motor cortex and free arm movements to visual targets in three-dimensional space. I. Relations between single cell discharge and direction of movement. J Neurosci 1988;8:2913-27.

[7] Bove M, Brichetto G, Abbruzzese G, Marchese R, Schieppati M. Neck proprioception and spatial orientation in cervical dystonia. Brain 2004;127:2764-78.

[8] Moisello C, Bove M, Huber R, Abbruzzese G, Battaglia F, Tononi G et al. Short-term limb immobilization affects motor performance. J Mot Behav 2008;40:165-76.

[9] Abbruzzese G, Marchese R, Buccolieri A, Gasparetto B, Trompetto C. Abnormalities of sensorimotor integration in focal dystonia: a transcranial magnetic stimulation study. Brain 2001;124:537-45.

[10] Andersen RA, Zipser D. The role of the posterior parietal cortex in coordinate transformations for visual-motor integration. Can J Physiol Pharmacol 1988;66:488-501.

[11] Fiorio M, Tinazzi M, Ionta S, Fiaschi A, Moretto G, Edwards MJ et al. Mental rotation of body parts and non-corporeal objects in patients with idiopathic cervical dystonia. Neuropsychologia 2007;45:2346-54.

[12] Anastasopoulos D, Nasios G, Psilas K, Mergner T, Maurer C, Lücking CH. What is straight ahead to a patient with torticollis?. Brain 1998;121 (Pt 1):91-101.

Figure 1

Sample trajectories from patients and controls in the "central" and "lateral" positions. An increased clockwise directional error can be visually recognized in both groups.

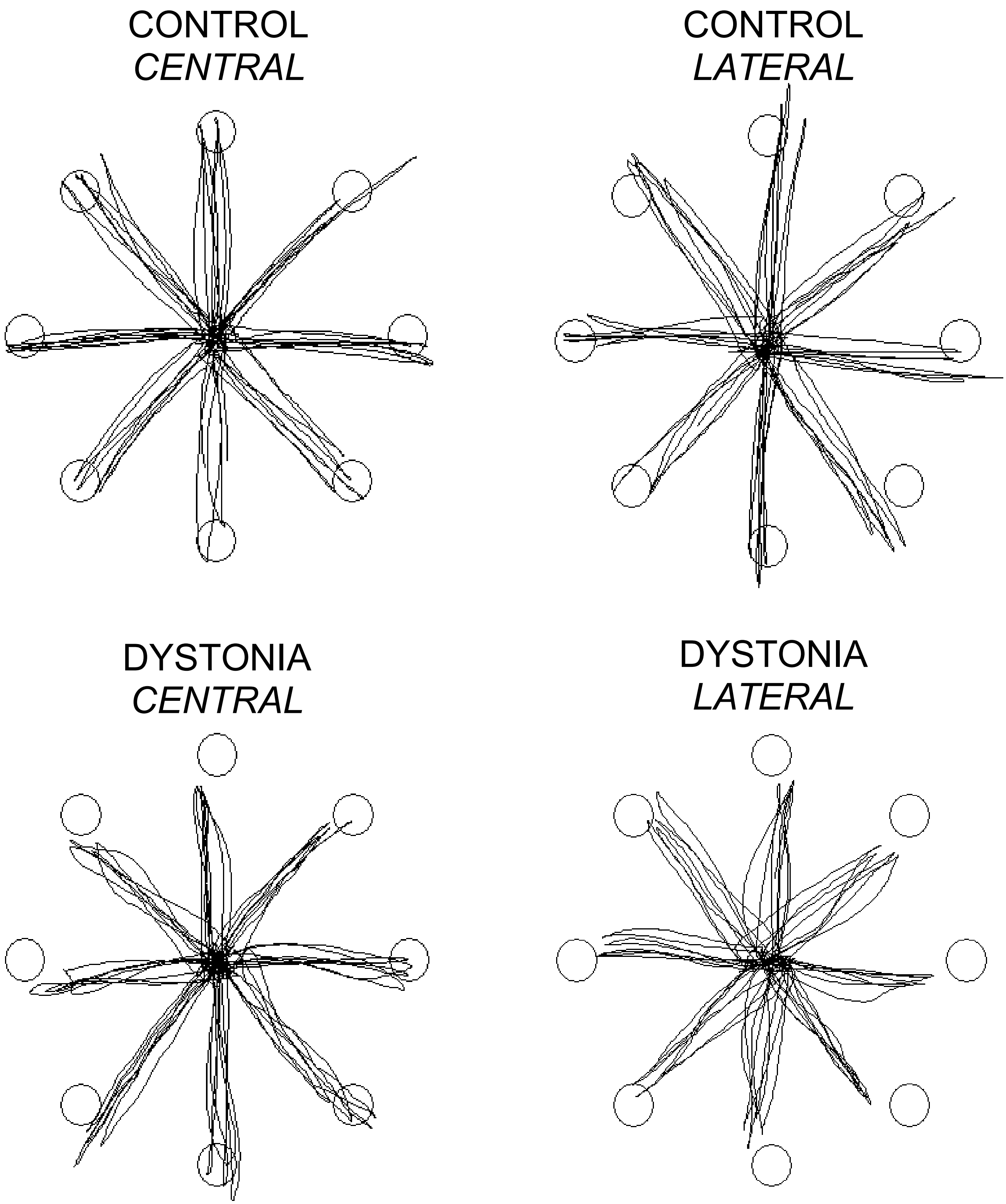

Figure 2

Average movement direction vectors (degrees) of patients (thick line) and controls (thin line) in "central" and "lateral" positions. Dashed lines indicate the standard error for each vector. Dystonic patients show an increased clockwise (negative values) directional error in the lateral position.