

Impaired neuro-motor control in chronic whiplash and tension-type headache

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Abstract

Background

The purpose of this study is to support the hypothesis that the neuro-motor control of the neck muscles is impaired in the diseases of chronic whiplash and tension-type headache. This hypothesis is based on a previous study, and if confirmed, it indicates that the central nervous system may be part of the pathophysiology of these diseases. For further verification, we designed a laser tracking method for standardized and quantitative measurements of movements of head and hand. The hand was included as a presumed normal reference to the head movements.

Methods

A new laser tracking instrument was designed to monitor the ability of a test-person to track a reference point on the wall by a laser fixed to the forehead or held in the hand. The reference point moves in runs of a circle or a square at three different speeds 10, 20 or 30 cm/sec thus providing 6 runs for both head and hand per test-person. We used a 1x1x1 m set-up geometry. The data of each run was processed on-line. Groups of 22 patients diagnosed with chronic whiplash associated disorder, 19 patients diagnosed with chronic tension-type headache and 37 control persons were compared.

Findings

A small but highly significant dyscoordination of head movements was observed in both patients groups, and in whiplash also of the hand.

Interpretation

Our study confirms the hypothesis that the neuro-motor control of the neck muscles is impaired in both chronic whiplash and tension-type headache. In our view this observation implicates that the central nervous system may be involved in the primary pathology of both these diseases. Accordingly, we suggest a provisional term 'cervical dyssynergia' for these diseases, and suggest further studies along this paradigm.

Introduction

The purpose of this study is to support the hypothesis that the neuro-motor control of the neck muscles is impaired in the conditions of chronic whiplash and tension-type headache. This is of interest since the underlying cause of the chronic muscular pain and tenderness in the neck in these conditions has not yet been clarified. It seems reasonable to assume that if the coordination of head movements is impaired, then the neuro-motor control system within the central nervous system would be involved as part of the pathophysiology. Coordination of head movements seems to be impaired in these conditions as indicated by a previous study of head movements (1) using a 'Fly method' (2). This method was originally designed for diagnostic purposes in whiplash and is based on a randomly moving cursor on a

computer screen. It cannot easily be standardized for further studies. Therefore, we have developed a method based on head laser tracking to provide repeatable measurements of coordinated head movements during standardized conditions and of low amplitude to safely eliminate a possible confounding effect of movement released neck pain.

Methods

The laser tracking instrument generates a green reference light point moving in preset geometric figures such as a circle or a square at preset speeds on the wall or a screen in front of the test person, who is equipped with a common laser pointer fixed to the forehead like a common headlamp, or held in the hand. The test person tracks the reference point with his laser point. The position of the two points is continuously recorded by a camera placed on a tripod behind the test person and fed into the computer for on-line data processing. The test person is sitting in a chair facing the wall or screen at a distance of 1 m measured from the tip of the laser pointer. The size of the projected geometric figures facing the test person is 1 m in diameter or side length in order to maintain a 1x1x1 m geometry in the set-up so that the angle which the neck must be turned left and right and up and down during the test is within 30 degrees from the midline. It was ensured that these borders were safely within the non-pain causing amplitude of head movements in each single patient. After one trial run, each person completed the same routine comprising six runs with the dominant hand holding the laser pointer, and followed by the same six runs with the laser pointer fixed to the forehead. The person was asked to keep the elbow and upper arm along the body in order to immobilize the shoulder region and only move the forearm and hand during the hand test.

The six runs comprised three circles followed by three squares each at the preset speed of either 10, 20 or 30 cm/sec in this sequence. The circle runs lasted 31, 15 and 10 seconds and the square runs 40, 20 and 13 seconds, respectively. There was a brief intermission between each run of about half a minute allowing for computer processing of the run and setting of the next run. Each run was automatically initiated by showing the whole geometric figure on the wall and a green 10 cm in diameter start point located to the right on the circle or in the upper right corner of the square. The start point would then automatically diminish in size and within five seconds reach the size of the reference point and start to move clockwise along the indicated geometric figure at the preset speed.

The instrument consisted of a light projector BenQ 3D DLP MW621ST and a NET GimeGO GO433B GigE camera with a SV-0614H lens from VS Technology with a 635 nm band pass filter. The projector and the camera was mounted on an aluminum rack and fixed to a tripod. The projector and the camera was controlled by a MatLab R2013B programmed Lenovo IdealPad laptop Y510p - 16 GB 2xGF-GT750M 2GB. The instrument samples the distance and position of the laser point in relation to the reference point 30 times per sec and provides an online calculation of mean and standard deviations immediately after each run on the basis of 300 to 1200 sampled paired point positions depending on the duration of the run. Furthermore, each run is stored and can be reviewed in real time.

For further technical details about the instrument and its performance please contact co-author Anders Lei.

Patients and control persons

In general, all participants were selected within the age group 18 - 60 years. The limit 60 years was chosen to avoid a possible effect of age on the laser tracking performance. Furthermore, all participants must be without other chronic pain conditions or other chronic diseases of any kind, and without previous whiplash injuries.

Symptoms and signs of muscular tenderness were recorded on a scheme on site prior to the laser tracking test.

Chronic whiplash patients

The whiplash group comprised 22 patients and are presented in Table 1 and 2. They were selected over a one year period (2013) among a group of whiplash patients with persisting symptoms for more than one year and therefore according to the Danish legal practice referred to medical examination as part of the insurance claim procedure. Among those examined by our senior author JA, 25 presented with a whiplash associated disorder grade 2 and complied with the above mentioned general conditions. They all responded positively to the option of enrolling in the planned present laser tracking study. Three were later excluded due to lack of cooperation with the laser pointer.

The whiplash grade 2 diagnosis was based upon the criteria given by the Quebec Task Force on Whiplash-Associated Disorders (3). These were complaints of neck pain and muscular tenderness in the neck but having a normal or only slightly reduced neck mobility and no neurological signs. Time interval between their injury and the present study was one-two years in ten, two-three years in eight and more than three years in eight patients. Their legal claims were settled by a compensation in 17 and not yet settled in five patients.

Chronic tension-type headache patients

The tension-type headache group comprised 27 patients and are presented in Table 1 and 2. They were primarily referred to the Danish Headache Centre and enrolled in a physiotherapy treatment scheme at the Centre. 26 complied with the above mentioned general conditions and were presented with the option to participate in this study. 19 accepted while seven declined. The diagnosis chronic tension-type headache was based upon the criteria given by the ICDH-3 for this specific diagnosis associated with pericranial tenderness (4).

Control persons

58 persons were recruited among the staff of the Danish Headache Centre Glostrup (N=11) and the staff of the Danish National Research Centre for the Working Environment (N=47). They all completed a brief

'on the spot' review and physical examination prior to their participation. 37 persons were eligible for inclusion in the study while 21 were not. Of these, four had chronic conditions, eight were on medications for other illnesses, one had a previous whiplash injury, and eight appeared to have muscular tenderness in the neck by the 'on the spot' physical examination.

Statistics

The instrument samples the position of the test persons laser point in relation to the reference point at a rate of 30 samples per sec, and calculates the deviation between the points. The result is presented as a mean and standard deviation immediately after each run. The run is stored and can be presented graphically.

To compare mean and median distances from the reference point, Student's t-test (t-test P-values) and Kruskal-Wallis one-way analysis of variance (K-W P-values) was performed, respectively. Combined P-values were calculated from the sets of P-values by applying a modified generalized Fisher method for dependent tests (5). We used bootstrap re-sampling with 5000 samples to estimate correlations among P-values.

Results

Patients and control persons

Sex, age and working status are indicated in Table 1, and symptoms and clinical signs in Table 2. Table 2 indicates that the symptoms and clinical signs of the two patient groups were quite similar. In addition to neck pain, all but one of the whiplash patients also had headache. In addition to headache all but two of the tension-type headache patients also had neck pain and muscular tenderness in the neck. Most of the patients in both groups also had pain and muscular tenderness in the anterior neck muscles.

Head and hand movements

The statistics of the distances between the test persons laser point and the reference point during the runs are presented in Table 3 by mean \pm SEM values and indicated in cm. Clearly, the head laser tracking is less accurate in both patient groups in comparison to control, while the hand laser tracking is less accurate in the whiplash group but not in the headache group. In the different runs (circle, square, different speeds) the mean distances between the reference point and the laser tracking point were all larger in the patient groups in comparison to control. This tendency was highly significant as indicated by the combined P-values for the head movements in both groups and hand movements in the whiplash group.

Discussion

This study supports previous studies by indicating a slight but certain dyscoordination of head movements during these specific task performances, whether it is tracking a randomly moving screen cursor as in previous studies by the 'Fly method' (1,2) or tracking a reference spot moving in circles or squares on the wall as in this study. This points in our view towards an impaired neuro-motor control of the clinically involved muscle groups in the neck in both conditions. Movement associated neck pain was ruled out as confounder to these measurements since it was ensured that the amplitude of the movements were safely within the non-pain causing amplitude of head movements in each single patient.

There are other indicators of a disturbed neuro-motor control in these patients. If we consider the great number of EMG studies of the affected neck muscles in chronic whiplash and tension-type headache it is clear that neuro-motor control is not normal. It is not classical dystonic either, but the EMG activity is generally increased in correlation with muscle tenderness, see e.g. Jensen and Rasmussen (6), and presents with greater co-activation of accessory muscles (7), but also co-activation of antagonist muscles as in dystonias may be observed (8). As some of these authors indicate, these observations are signs of a 'spinal hyperexcitability' and neural 'reorganization of motor control strategy'. On the sensory side, the well established lower pain and reflex thresholds in these patients are also indicative of a state of 'spinal hypersensitivity' see e.g. Bendtsen (9) and Banic et al (10). Furthermore, eye movements appear to be dyscoordinated. This has been shown in whiplash patients by several studies (11,12), and in tension headache by one single smaller study (13).

Taken together, these observations in our view all indicate impaired neuro-motor control in these diseases, not only of the neck muscles, but also of the eye muscles and in chronic whiplash even of the arm muscles, as observed in this study.

Considering the pathophysiology of whiplash and tension-type headache it is our view, that these findings point in the direction of a dysfunction of the central nervous system i.e. a lesion within the central nervous system which could be of primary nature. A review of clinical characteristics of chronic whiplash seems to support a central rather than a peripheral lesion as a primary cause. These characteristics are mainly the lack of evidence of any structural lesion in the neck, lack of correlation between trauma energy and symptoms, initial symptoms delay, high prevalence of chronicity, and physical therapy refractoriness.

Lack of primary structural lesion in the neck. A main problem considering a primary peripheral neck pathology in whiplash is the lack of a primary structural lesion like a facet joint distortion or ligament or muscle fiber strain. Such signs may occur but most commonly they do not and no specific lesions have been observed by several thorough MRI studies neither in the acute nor chronic state (14,15,16).

Lack of correlation between impact energy and clinical symptoms. Castro et al (17) indicate that 60% of whiplash cases occur at speeds less than 15 km/hr and appear more frequent when only relatively slight vehicle deformation occurs. In fact, most whiplash cases occur at low speed and low impact energy collisions with either weak or no 'dose-response' between impact severity and outcome. This observation

seems better explained by a central rather than a peripheral mechanism of disease such as distortion or fiber strain.

Initial symptoms delay. The initial findings including delay in onset of head ache and neck pain in whiplash was studied by Sturzenegger et al (18,19) in 117 consecutive cases followed for 12 months. They reported delays in onset of head ache of 10 hours and in neck pain of 11 hours after trauma in the patients who recovered within 1 year, and delays of 5 and 8 hours, respectively, in the non-recovery patients. These delays seems in better accordance with a developing pathology rather than an acute primary structural lesion.

High percentage of chronicity. Chronicity is relatively high in whiplash when compared to acute structural pain causing posttraumatic conditions such as distortions or muscle fiber strain in the extremities. Radanov et al (20) followed 117 consecutive cases of acute whiplash and observed that 24% were still symptomatic after 1 year and 18 % after 2 years. However, chronicity may be even higher as indicated in later studies. Kasch et al (21) indicate symptoms at one year to be about 40% in 'high risk' and about 15% in 'low risk' groups. The Bone and Joint Decade 2000-2010 Task Force on Neck Pain (22) indicates similar high percentages of chronicity in whiplash after one year or longer on basis of a review of 226 articles related to prognostic factors. A study of 446 patients from Ontario Canada and free of litigation and the seeking of compensation and followed for 2 years showed the chronicity to be about 40% in the common whiplash grade 2 group (23).

Lack of effective therapy. It has been rather disappointing that various rehabilitation programs in the initial phase of whiplash appear ineffective and in fact tend to slow recovery . This applies to fitness therapy and multidisciplinary in- or outpatient rehabilitation programs (24) and other patterns of care provided by GP's, chiropractors and other specialists (25). There is even a trend that the more intense the therapy by frequency the more it slowed recovery. Again, this therapy refractoriness seems in better accordance with a central rather than a peripheral disease mechanism.

Conclusion. Our overall impression from the present data taken together with previous data as discussed above, is that chronic whiplash and tension-type headache share a pathology situated in the parts of the central nervous system responsible for the neuro-motor control of the neck muscles, and in whiplash also of the hand muscles. Other studies indicate that the eye muscles are also affected. We suggest the term 'cervical dyssynergia' for this pathology since it is diffuse and discrete. We consider that this pathology may be the primary cause of the chronic muscular pain and tenderness in these diseases. It may arise spontaneously as in tension-type headache or follow a minor trauma as in whiplash. Further studies with focus on this shift in paradigm concerning these diseases seem warranted.

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Tables

Table 1

	Chronic whiplash N=22	Tension-type headache N=19	Control persons N=37
Female/male	18/4	17/2	27/10
Age median range	38 18-54	38 24-50	36 24-58
Work* Sick leave/ reduced time pension	17 1/4 0	16 3/0 0	37 0/0 0

* work included being on education (in the present series none) or unemployed (one in the chronic whiplash group)

Table 2

	Chronic whiplash N=22	Tension-type headache N=19	Control persons N=37
Neck Pain, all	22	17	0
Daily	15	10	
Some days/week	7	7	
Some days/month	0	0	
Neck pain on the day of the study*			
0 (none)			0
1 (slight)	3	6	
2 (medium)	9	6	
3 (severe)	10	7	
	0	0	
Headache, all	21	19	4
Daily	6	5	
Some days/week	15	13	
Some days/month	0	1	4
Headache on the day of the study*			
0			
1	12	11	0
2	5	6	
3	5	2	
	0	0	
Muscular Tenderness	22	17	0
Dorsal neck	12	16	0
Anterior neck			
Medication			
Paracetamol	6	3	0
NSAID	5	5	0

*Pain severity scale according to The International Classification of Head Ache Disorders (4) (0 absent, 1 light, not disturbing normal daily activities, 2 medium, disturbing but not preventing normal daily activities, 3 severe, preventing normal daily

activities).

Table 3

			Control		Chronic Whiplash				Tension-type Headache			
Type	Geometry	Speed cm/sec	Mean cm	SEM	Mean cm	SEM	P-value K-W	P-value t-test	Mean cm	SEM	P-value K-W	P-value t-test
Head	Circle	10	1.13	0,03	1.38	0,15	0.49	0.12	1.38	0,074	0.003	0.006
		20	1.62	0,06	1.89	0,17	0.32	0.16	2.01	0,12	0.006	0.009
		30	2.09	0,08	2.93	0,51	0.09	0.11	2.52	0,22	0.12	0.07
	Square	10	1.07	0,04	1.24	0,083	0.06	0.07	1.20	0,050	0.03	0.04
		20	1.58	0,05	2.24	0,34	0.28	0.07	1.76	0,088	0.08	0.10
		30	2.14	0,09	2.84	0,36	0.14	0.07	2.53	0,21	0.11	0.10
Combined P-values							0.16	0.03			0.03	0.03
Hand	Circle	10	0.66	0,02	0.75	0,023	0.002	0.003	0.69	0,027	0.33	0.37
		20	0.88	0,02	1.06	0,062	0.003	0.015	0.92	0,040	0.73	0.50
		30	1.13	0,03	1.34	0,12	0.12	0.10	1.17	0,044	0.58	0.56
	Square	10	0.71	0,02	0.78	0,044	0.17	0.18	0.67	0,025	0.87	0.66
		20	0.94	0,03	1.05	0,059	0.04	0.08	0.95	0,028	0.53	0.81
		30	1.22	0,03	1.46	0,11	0.007	0.049	1.30	0,062	0.30	0.30
Combined P-values							0.02	0.002			0.79	0.79

Mean distance between the laser-point and the reference point in circle and square runs at three different speeds for the two patient groups and the controls. Differences between patient groups and controls were tested with Student's t-test and Kruskal-Wallis one-way analysis of variance, and combined P-values were estimated.