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VERTICAL POSTURE AND HEAD STABILITY IN PATIENTS WITH CHRONIC NECK PAIN

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Objective: **To evaluate postural performance and head stabilization of patients with chronic neck pain.**
Design: **A single-blind comparative group study.**
Subjects: **Patients with work-related chronic neck pain ($n = 9$), with chronic whiplash associated disorders ($n = 9$) and healthy subjects ($n = 16$).**
Methods: **During quiet standing in different conditions (e.g. 1 and 2 feet standing, tandem standing, and open and closed eyes) the sway areas and the ability to maintain the postures were measured. The maximal peak-to-peak displacement of the centre of pressure and the head translation were analysed during predictable and unpredictable postural perturbations.**
Results: **Patients with chronic neck pain, in particular those with whiplash-associated disorders, showed larger sway areas and reduced ability to successfully execute more challenging balance tasks. They also displayed larger sway areas and reduced head stability during perturbations.**
Conclusion: **The results show that disturbances of postural control in chronic neck pain are dependent on the aetiology, and that it is possible to quantify characteristic postural disturbances in different neck pain conditions. It is suggested that the dissimilarities in postural performance are a reflection of different degrees of disturbances of the proprioceptive input to the central nervous system and/or of the central processing of such input.**

Key words: neck pain, whiplash injury, work-related myalgia, single-blind method, posture, balance, head stabilization, proprioception.

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INTRODUCTION

Several studies have reported significant disturbances of vertical posture during various standing and walking conditions in patients with chronic neck pain (1–4). There are however conflicting reports on the characteristics of postural sway during quiet standing in patients with chronic neck pain. McPartland et al. (5) reported similar body sway in patients suffering from chronic neck pain to that seen in healthy subjects. In contrast, poor balance and increased sway have been reported in several studies of patients with chronic musculoskeletal pain of various aetiologies including patients with whiplash injuries (1–4, 6). In studies of the migration of the centre of pressure (CoP), increased sway has been indicated for patients with cervical dizziness and vertigo (7, 8). Patients with chronic neck pain have been reported to develop significantly larger mean torque during simple balance test, compared with healthy control subjects, but not during more challenging tests such as one-foot and tandem standing (5). However, it has also been shown that the ability to execute different postural tasks is reduced with increasing task complexity in patients with whiplash associated disorders (WAD) (4).

One purpose of the current study was to resolve the controversy about the effects of chronic neck pain on postural sway during quiet standing in various conditions. Two hypotheses were suggested.

Hypothesis-1: patients with chronic neck pain, compared with healthy controls, are expected to show increased postural sway and reduced ability to successfully complete various balance tests.

Hypothesis-2: the differences in the sway and in the inability to complete tests are expected to become more pronounced in more challenging postural tasks.

The maintenance of balance during quiet standing is only one component of everyday tasks faced by the system for postural stabilization. Equally, or even more, important is the system's ability to generate appropriate corrective signals in the presence of expected and unexpected postural perturbations (for reviews, see 9, 10). A disturbed control of back muscles that stabilize the trunk has been demonstrated in patients with low back pain during rapid arm movements (11). In patients with chronic neck pain, postural perturbations that cause perturbation of the head posture with respect to the trunk appear to be particularly important since they directly influence the painful region. Thus, an additional hypothesis was suggested. Patients with chronic neck pain are expected to show increased sway and poor head stabilization in the presence of postural perturbations (*Hypothesis-3*).

Cervical muscles in patients with chronic neck pain have been shown to be morphologically different from non-painful neck

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Table I. *Anthropometric and pain characteristics of the 2 groups of patients with chronic neck pain (work-related pain (WRP), whiplash associated disorder (WAD)), and of a corresponding group of healthy subjects. Mean values with standard deviation in brackets, except for the distribution of men and women in each group and for the prevalence of vertigo and unsteadiness, which are given in number of patients/subjects*

Characteristics	Control ($n = 16$)	WRP ($n = 9$)	WAD ($n = 9$)
Men	3	0	3
Women	13	9	6
Age (years)	41 (9)	40 (9)	44 (10)
Height (cm)	168 (8)	165 (7)	171 (10)
Weight (kg)	70 (14)	73 (18)	79 (14)
Pain duration (months)		97 (68)	87 (77)
Pain intensity (mm)*		52 (16)	49 (23)
Vertigo**		2	6
Unsteadiness**		1	5

* Average pain intensity over the last week was assessed on a blank 100-mm visual analogue scale, where 0 mm corresponded to “no pain at all” and 100 mm to “the worst imaginable pain”.
** The numbers of patients who through a questionnaire reported “vertigo” and “unsteadiness” as occurring “rather often” or “very often”.

muscles (for references, see 12). It has also been reported that vibration of neck muscles in patients with chronic neck pain induces exaggerated perturbing effects of the vertical posture (1), indicating that their balance disorders might be related to altered sensitivity of proprioceptors within the neck muscles (2, 13). This is supported by animal studies showing that the output from muscle spindles in neck muscles is significantly changed during activation of nociceptors in neck muscles and cervical facet joints (14, 15). Studies of patients with WAD indicate that they have more severe balance disturbances compared with patients with work-related chronic neck pain (4, 6), suggesting that a whiplash trauma imposes disturbances of the proprioceptive output from the neck region, and/or causes motor control dysfunction that is not present in chronic neck pain without a traumatic origin. To test possible effects of aetiology on sway characteristics and on the ability successfully execute various balance tests, we investigated 2 groups of patients, those who suffered from work-related chronic neck pain and those who had developed chronic neck pain following a whiplash injury.

METHODS

The study was designed as a single-blind, controlled comparative group study. The study was approved by the ethics committee of the Faculty of Medicine at Umeå University (dnr 00–160).

Subjects

Eighteen patients participated in the study (15 women and 3 men). They were all referred to a 4-week treatment period at the Saxnäsgårdens Rehabilitation Centre. After being fully informed about the aims and methods of the study, all patients gave their written consent to participate.

The primary criteria for inclusion were chronic neck pain with the duration of at least 6 months. Exclusion criteria were neurological disease, signs of brain damage, rheumatic disease and severe pain in other body parts than the neck. Patients with hip, knee or ankle injuries, with documented impairment of the vestibular system and those who used medication with side-effects on the postural control system, were excluded.

For 9 patients, the primary aetiology of the neck pain was a whiplash trauma, mostly as a result of car accidents (in short, patients with WAD). For the other 9 patients, the chronic neck pain had developed progressively and was, for all but 1, related to working conditions as reported by the patients (patients with work-related pain; in short, WRP patients). Most of them had worked for several years in occupations known to be associated with a high risk for developing chronic musculoskeletal pain conditions (e.g. secretary, cleaner and manufacturing labour). For 1 of the patients included in the WRP group, a clear relationship to work could not be found. All patients in both groups tested negative for vestibular system impairments according to a clinical, manual test for vertigo originating from dysfunction of the vestibular system and the neck, respectively (16). No screening for post-traumatic stress syndrome was applied.

The control group comprised 16 healthy volunteers (13 women and 3 men) and was compiled to match the patient group by age and gender (Table I). Inclusion criteria were absence of neck pain, dizziness or vertigo over the last year, and lack of episodes of severe neck problems prior to that. The same exclusion criteria were used for both the control and the patient group. Information on aetiology, exclusion and inclusion criteria was obtained from a combination of sources, i.e. from medical records, manual examinations and by asking the patients specific questions. The same physician and 2 physical therapists executed the entire selection procedure.

Anthropometric and pain characteristics, compiled from questionnaires, of the 3 study groups are shown in Table I. It should be noted that the patients in both groups suffered from long-lasting and severe neck pain. There were no significant differences between the 2 patient groups regarding the anthropometric parameters, pain duration, pain intensity and prevalence of self-reported vertigo. The patients with WAD reported a significantly higher prevalence of self-reported unsteadiness ($p < 0.05$, chi-square).

Apparatus

A static force platform (Kistler Force Measurements, type 9807, Kistler Instrumente AG, Switzerland) was used for evaluation of the postural sway. The sampling frequency was set to 30 Hz. Movement of the neck was measured by an electromagnetic positioning system (FASTRAK™, Polhemus Inc., USA) which has been demonstrated to have good reliability in studies of cervical motion (17). For calculation of the neck movement, 2 receivers were used. One was located on the forehead by a specially constructed helmet (R_{HD}), and the other was taped on the skin above the dorsal spinal process of Th_1 (R_{TR}). The sampling frequency of each receiver was 60 Hz.

The device for the load drop tests (see below) consisted of a 70-cm long wooden rod with a diameter of 3 cm, with a hook at the middle. A bag of adjustable weight was attached to the hook. The hook could be disengaged using either a switch placed on the rod, which was operated by the subject, or a handheld switch operated by the experimenter. Shoulder movements during the arm lift test (see below) were recorded through a FASTRAK-receiver attached to one end of the wooden rod (sampling frequency 40 Hz).

Signals from the force platform, the switch controlling the hook on the load-drop device, along with a synchronization signal from the FASTRAK-system, were collected on a PC through a 12-bit analogue-digital data acquisition processor (DAP; Microstar Laboratories, USA). These data, together with signals from the FASTRAK-receivers, were displayed on-line and stored on files. Pre-recorded instructions were given to the subjects during the test sessions.

Procedure

The balance tests involved quiet standing in the following conditions:

- Romberg position, defined as standing with feet together, heel-to-heel and toe-to-toe, with open and closed eyes (18).
- Tandem standing with one foot in front of the other, heel-to-toe, with the dominant foot behind, with open and closed eyes. The dominant

foot was defined as the supporting leg in ball kicking. The test-retest correlation for the Tandem standing test has been reported to be between 0.66 and 0.96 (19–20).

- Standing on one foot, right and left (One Foot Right, One Foot Left), with the medial side of the lifted foot against the medial side of the calf of the contralateral leg (toes touching the medial malleolus), with open eyes. The test-retest correlation for one foot standing with open eyes has been reported to be 0.68 (21).

Two different perturbation tests were performed with the subjects standing in the Romberg position with closed eyes:

- With the instruction to perform a bilateral movement with their straight arms as fast as possible, from a vertical to a horizontal position, maintain the horizontal arm position for a few seconds, and then return their arms to the vertical position, the subjects made 6 trials with 15-second rest periods in-between (Arm-Lift). During the arm movements the subjects were holding a wooden rod pre-loaded with a weight corresponding to 3% of the bodyweight.
- The subjects were instructed to hold the load-drop device with both hands and with the arms extended in the horizontal plane. The load-drop device was pre-loaded with a weight corresponding to 3% of the of the bodyweight. The load was either unexpectedly released by the experimenter (Drop-Exp), or released intentionally by the subject (Drop-Self). Both tests were repeated 6 times with a 15-second resting period between each trial.

The tests were performed in a quiet, undisturbed room. The subjects were standing barefooted on the force platform with the feet parallel to the y-axis of the platform and with the arms crossed over the chest (except in the arm lift and load drop tests). In the tests with open eyes, the subject focused on a black dot, with the diameter of 0.2 metres, which was located on the wall approximately 3 metres away and adjusted to match the height of the subjects' eyes.

The same experimenter, who was blinded to the subjects' neck pain status (i.e. unaware of whether the subjects suffered from chronic neck pain or not), executed all tests. The instructions given to the subjects during the individual tests were recorded on tape and presented through loudspeakers in order to provide identical instructions and time intervals for all subjects. Approximately 1 hour was needed to complete the entire series of tests. The test procedure followed a standardized protocol in which the order of the individual tests was randomized across subjects. However, in order to familiarize the subjects with the test procedure, the simple 2 feet standing test was always performed first (Romberg position). Furthermore, to avoid muscle fatigue and pain, the arm lift and the drop load tests were never executed in a succession. The subjects were encouraged to take a break whenever they felt increased pain or fatigue, or when their focus on the instructions or task declined.

The duration of the quiet standing tests (without perturbation) was 30 seconds. The instruction, "stand as still as possible" was repeated before each test (including the perturbations tests). A trial was considered as a failure if the subjects moved a foot, moved their arms from the chest (except in the arm lift and load drop tests) or opened their eyes during the closed eyes tests. If a subject failed to maintain the posture for 30 seconds, the test was repeated once. When a patient failed in both attempts, the patient was considered as unable to accurately execute the test. However, for 1 WAD patient during standing on the right foot, CoP-data was included in the sway analysis in spite of failure after 25 seconds in his best attempt (i.e. for this patient, right foot standing was counted as a failure).

Data processing and analysis

In-house software was used to organize the data, and MatLab codes were written for calculations (ver 5.3, 1999, MathWorks Inc., USA). For the quiet standing tests, sway area was used as the outcome variable. The sway area was calculated with principal component analysis along 2 orthogonal axes, computing the area of an ellipse covering 95% of the data points. The analysis of the CoP (i.e. the point of application of the resultant reactive force acting on the body from the support surface) was made on the 20 second-time window located in the centre of the 30 second-recording period.

In the perturbation tests Drop-Self, Drop-Exp and Arm-Lift, the maximal CoP peak-to-peak displacement in the anterioposterior direction (CoP_{pp}), was analysed. The maximal anterioposterior displacement of the head translation ($Head_{pp}$) was measured by the relative positions of the R_{HD} and R_{TR}. Time zero (t_0) was defined as the time when the load was dropped (in both drop load tests) or when the shoulder flexion began (in the Arm-Lift test). For both CoP_{pp} and $Head_{pp}$ the maximal amplitude within 1 second after t_0 was used to quantify the perturbation effects. In the Arm-Lift test, the range of movement of the shoulder (ROM_{SH}) and peak velocity of arm movement (VEL_{SH}) were calculated based on the data from the receiver attached to the wooden rod.

Statistics

All statistics were done using the SPSS (ver 11.0, 2001, SPSS Inc, USA). Chi-square test was used to explore differences between the groups for dichotomous variables (i.e. success or failure). For numerical variables, both multivariate analysis of variance (MANOVA) and one-way analysis of variance (ANOVA) were used to compare the 3 groups (control, WRP, WAD). To ensure that the basic assumptions for MANOVA were fulfilled, all models were tested with Box's test of equality of covariance matrices, and Levene's test of equality of error variances and normal distribution of the unstandardized residuals (22). If any of these tests showed significant results, the variables were transformed using natural logarithms. Cook's distance test was used to detect outliers (23). These were excluded from the analyses if they continued to stand out as outliers after logarithmic transformation. For clarity and comparisons only non-transformed data is presented in the result section.

The condition tested in the MANOVA-models was subjects, i.e. control, WRP and WAD groups. The power was high in all significant MANOVA-models (mean, 0.84; range, 0.74–0.94), indicating sufficient size of the study groups. For evaluation of statistic significance of the MANOVA-models, the Wilks' Lambda was used. For *post-hoc* tests in ANOVA, Tukey's Honest Significant Difference test was used.

RESULTS

Ability to complete the balance tasks

All subjects completed the following tests successfully: Romberg position with open eyes, Romberg position with closed eyes, and Tandem standing with open eyes. Significant differences between the groups were found in the ability to perform Tandem standing with closed eyes, which none of the patients with WAD were able to maintain for the required 30 seconds. In the same test, 4 patients with WRP failed (WAD vs WRP, $p < 0.01$) and 3 control subjects (WAD vs control, $p < 0.001$). During standing on the right foot, significant differences were observed between the WAD (4 failed) and WRP groups (none failed; WAD vs WRP, $p < 0.05$) and the control group (none failed; WAD vs control, $p < 0.005$). Standing on the left foot, however, did not show any significant differences (1 patient failed in each of the WRP- and WAD-groups).

Sway area – effects of vision

Examples of spontaneous displacements of the CoP in the plane of the force platform during quiet standing in the Romberg position, are presented in Fig. 1. It can be seen that the area covered by the trajectory of the control subject is smaller than that of the patient with WAD. For the 3 groups, the average sway areas recorded in the Romberg position with open and closed eyes are shown in Table II. The MANOVA-model for these conditions revealed significant effects of subjects (F[4,54] =

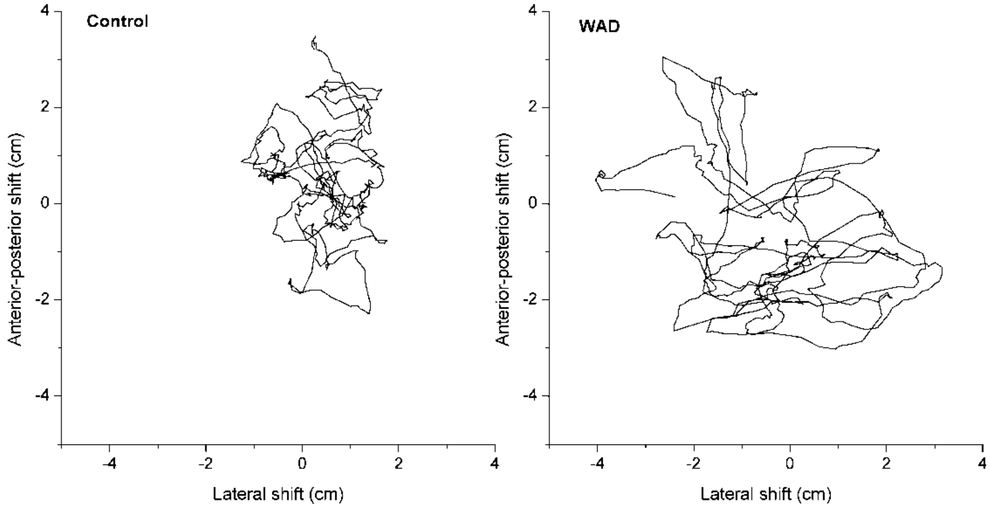

Fig. 1. Typical centre of pressure migration patterns for a representative control subject and a patient with whiplash associated disorder (WAD) during standing in the Romberg position with closed eyes for 20 seconds.

2.87; $p < 0.05$). The one-way ANOVA was significant for Romberg with closed eyes and the *post-hoc* tests showed significant differences between the control and WAD groups (Table II).

Sway area – effects of posture

The average sway areas for the 3 groups during standing in different postures with open eyes are shown in Table II. The data suggests that the sway area increased with increasing difficulty of the postural condition, in particular for the patients with WAD. The MANOVA-model for effects of posture was significant for subjects ($F[8,42] = 3.79$; $p < 0.01$). The one-way ANOVA was significant for One Foot Left. The WAD group demonstrated significantly larger sway area than both the WRP and control groups (Table II).

Sway and head stability – effects of arm movement and load drop

Effects of self-initiated and unexpected perturbations on the CoP and the head translation were studied using the Drop-Self, Drop-Exp and Arm-Lift tests. Figure 2 illustrates a representative example of the CoP_{pp} and the $Head_{pp}$ induced by the Drop-Exp test. Both the CoP_{pp} and the $Head_{pp}$ showed characteristic large amplitude shifts in the anterioposterior direction after the load release (t_0).

In order to evaluate possible differences in the kinematics of the arm lift movement, VEL_{SH} and ROM_{SH} were compared between the groups. The one-way ANOVAs revealed no differences in ROM_{SH}, while the control subjects moved their arms (VEL_{SH}) significantly faster than the patients with WRP (Table III). The average CoP_{pp} obtained for the 3 groups in the Drop-Self, Drop-Exp and Arm-Lift tests are shown in Table III. The MANOVA-model of CoP_{pp} demonstrated significant differences for subjects ($F[6,50] = 3.03$; $p < 0.05$). The one-way ANOVAs showed significant effects of the Drop-Self and Drop-Exp tests, and close to significant differences of the Arm-Lift test ($p = 0.054$). The *post-hoc* tests revealed significant differences between the WRP and the WAD group on all 3 tests, while the patients with WAD and control subjects differed on the Drop-Self and Drop-Exp tests only (Table III).

Table II. *Average sway area (in cm^2) with standard deviation (SD) in different conditions of quite standing, separately shown for the control subjects, patients with work-related pain (WRP) and patients with whiplash associated disorders (WAD). F- and* p-*values of one-way ANOVAs*

	Control		WRP		WAD			
Condition	Mean	SD	Mean	SD	Mean	SD	F	*Post-hoc*
Effect of vision in Romberg								
n	16		9		7			
Open eyes	6.6	±4.7	10.5	±7.3	9.6	±5.7	1.6	
Closed eyes	10.9	±6.5	16.6	±11.7	26.9	±14.7	5.4*	Control vs WAD**
Effect of posture – open eyes								
n	16		8		4			
Romberg	6.6	±4.7	9.0	±6.4	10.8	±6.5	1.2	
Tandem	11.6	±8.5	13.1	±7.2	15.8	±2.1	0.5	
One foot – right	13.6	±7.9	14.8	±11.9	21.8	±16.8	1.0	
One foot – left	10.2	±3.9	10.6	±5.9	23.1	±3.3	14.1***	Control vs WAD*** WRP vs WAD***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

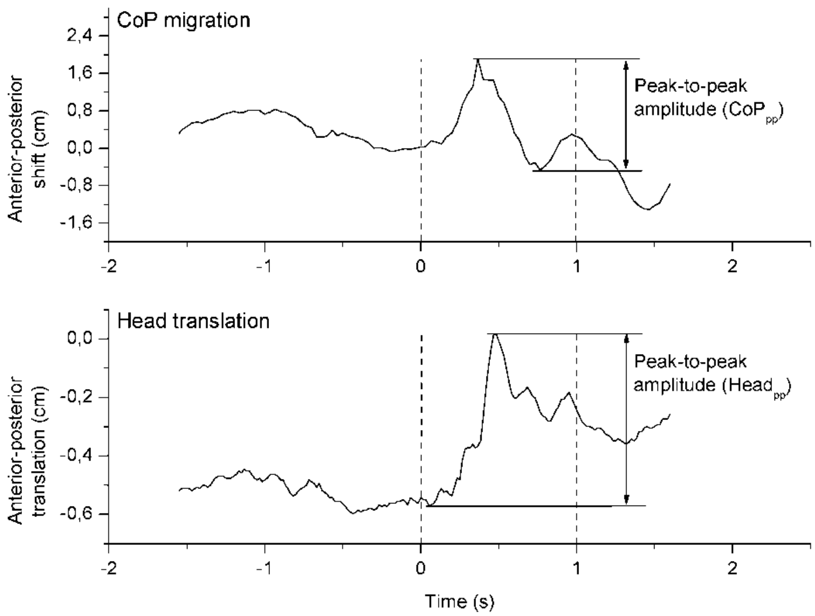

Fig. 2. Example of centre of pressure trajectory (CoP_{pp}) and head translation ($Head_{pp}$) recorded from a patient with whiplash associated disorders during the Drop-Exp test (i.e. the load was unexpectedly dropped by the experimenter while the patient was standing in the Romberg position with closed eyes holding the load-drop-device with straight arms in the horizontal plane). The perturbation effects were quantified as the maximal peak-to-peak amplitudes in the anterioposterior direction within 1 second immediately after the load was dropped (t_0).

The average head translations ($Head_{pp}$) for the 3 groups are shown in Fig. 3. The MANOVA-model of $Head_{pp}$ revealed significant effects for subjects (F[6,50] = 2.83; $p < 0.05$). The one-way ANOVAs were significant for both Drop-Self (F[2,28] = 4.03; $p < 0.05$) and Drop-Exp (F[2,28] = 7.87; $p < 0.01$). The *post-hoc* tests for Drop-Self and Drop-Exp showed significant differences between the control and WAD groups ($p < 0.05$ and $p < 0.005$, respectively).

DISCUSSION

Despite the fact that a rather small number of patients and subjects were included in the present study, a number of significant differences in balance and head stabilization were observed between patients with chronic neck pain and healthy subjects. These differences indicated a strong dependence on the aetiology of the neck pain, i.e. larger differences between the patients with WAD and the control subjects than between the patients with WRP and the control group. The design of the study allow us to address the hypotheses on postural sway and head stabilization in chronic neck pain (see Introduction), and the results indicate that it is possible to quantify characteristic postural disturbances in neck pain of various origin.

Changes in postural stability with task complexity

Making the task of vertical standing more challenging, by closing the eyes and by moving from standing in Romberg position to Tandem standing and one foot standing, resulted in increased sway and decreased ability to complete the task across all subjects. The differences between the WAD group and the other 2 groups increased with increasing difficulty of the postural task (Table II). The WAD patients were particularly likely to fail in the more challenging tasks. It seems conceivable that the rate of success in a particular postural task is related to the ability to keep the postural sway below a given threshold. These observations support both *Hypothesis-1* and *2*, and are in line with earlier reports (4, 6). Similar effects have also been described on patients with chronic low back pain (24).

Postural adjustments to perturbations

The most pronounced differences between the WAD and the WRP group were observed when external perturbations were added to a quite standing task. We used 2 tests to assess how well the subjects maintained vertical posture and head stability during self-imposed mechanical perturbations. Voluntary bilateral arm movements have been used in many studies of postural adjustments to perturbations (25, 26). Arm movement imposes torque on the trunk and other body segments, and is accompanied by postural corrections leading to shifts of the centre of mass (10). The impact of such perturbations seems to be related to the speed of arm movement. In our study, the control subjects moved their arms faster than both the WAD and WRP patients, although the differences were significant only in comparison to the WRP group (Table III). Hence, one would expect transient mechanical perturbations associated with the movement to be larger in the control subjects. However, the amplitude of the anterioposterior CoP-displacement immediately following the perturbation was larger in patients with WAD, in spite of the smaller perturbations (Table III).

The load-release tests, which were independent of the subjects' ability to perform fast movements (27), also showed a significant difference between the groups. In both the self-triggered and experimenter-triggered load release tests, the patients with WAD demonstrated increased displacement of the CoP immediately following the perturbation, as compared to the control subjects and the patients with WRP. Taken together, these findings suggest a major impairment of the ability to

Table III. *Range of movement (ROM_{SH}) and average peak velocity (VEL_{SH}) in the Arm-Lift test, and average anterioposterior peak-to-peak shift of CoP (CoP_{pp}) during perturbation tests (Arm-Lift, Drop-Self and Drop-Exp tests). Mean values with standard deviation (SD) are separately shown for the control subjects, patients with work-related pain (WRP) and patients with whiplash associated disorders (WAD). F- and p-values of one-way ANOVAs*

	Control ($n = 16$)		WRP ($n = 9$)		WAD ($n = 6$)			
Condition	Mean	SD	Mean	SD	Mean	SD	F	*Post-hoc*
ArmLift kinematics								
ROM_{SH} (°)	73.9	±9.6	73.6	±13.7	77.2	±12.6	0.2	
VEL_{SH} (°/s)	260	±62	184	±75	200	±82	3.8*	Control vs WRP*
Effect of perturbation on CoP_{pp}								
Arm-Lift (cm)	2.6	±0.7	2.2	±0.5	3.2	±0.9	3.2	WRP vs WAD*
Drop-Self (cm)	2.4	±0.5	2.2	±0.3	3.0	±0.5	5.3*	Control vs WAD* WRP vs WAD*
One-Exp (cm)	2.5	±0.5	2.6	±0.5	3.7	±1.1	5.4*	Control vs WAD** WRP vs WAD*

$*p < 0.05$; $**p < 0.01$.

maintain body posture during perturbations in patients with WAD, which is in support of *Hypothesis-3*.

Chronic neck pain and head stabilization

Fast arm movements and load releases unavoidably induce perturbations on both the vertical posture and the head stability, because of the mechanical coupling of different body segments. Our observations of head translation occurring immediately after a perturbation revealed that the patients with WAD demonstrated larger neck motion as a result of both self-triggered and experimenter-triggered perturbations (Fig. 3), which is in agreement with *Hypothesis-3*. The larger neck motion could be a result of an inadequate ability to co-ordinate the neck muscles, potentially leading to larger perturbing torques acting on the head. The latter is supported by Jull (28), who showed increased activity in superficial neck muscles in patients with in combination with a decreased ability to perform controlled neck flexion, implying a disturbed control of the neck muscles involved in neck stabilization.

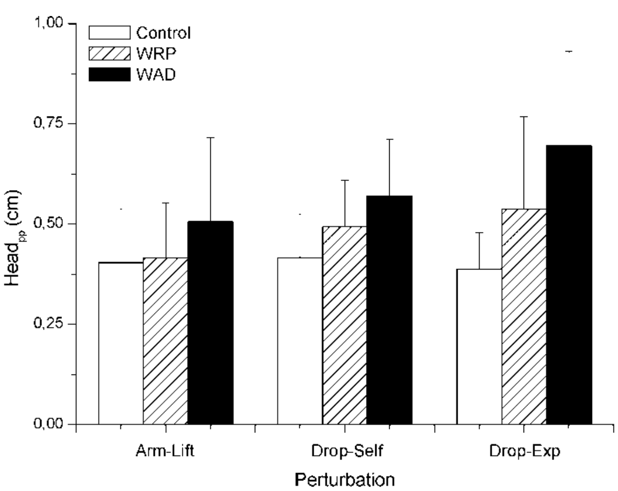

Fig. 3. Average anterioposterior peak-to-peak head translation ($Head_{pp}$) and standard deviation, separately shown for the control, whiplash associated disorders group (WAD) and work-related pain group (WRP), in a rapid arm lift test (Arm-Lift), in load-drop tests initiated by the subjects (Drop-Self) and by the experimenter (Drop-Exp). In all tests the subjects were standing in the Romberg position with closed eyes (control, $n = 16$; WRP, $n = 9$; WAD, $n = 6$).

Possible explanations for the observed differences between WAD and WRP

There is a risk that the differences found between WAD and WRP to some extent could have been due to a selection bias inferred by the small number of patients included in the study. Although a multifactorial inclusion/exclusion procedure was applied, it can not be ruled out that partly different results would have occurred if other criteria had been used. Yet, since all patients showed typical characteristics of chronic neck pain syndromes, and outliers were identified through stringent criteria, it seems more likely that the observed differences had other causes.

Motor control disturbances found in patients with chronic neck pain are thought to be due largely to changed proprioceptive signals from neck muscles (e.g. 2, 13). It has been shown that activation of nociceptors in muscles and joints excite fusimotor neurones, which alter the sensitivity of the muscle spindle afferents (14, 15, 29–30). A disturbed sensitivity of the fusimotor system could be triggered by long-lasting exposure to awkward postures or static/repetitive work, such as in WRP, or by a massive, transient afferent input onto the fusimotor neurones from nociceptors and mechanoreceptors in muscles, tendons, ligaments and joint capsules (15, 29), which is likely to occur during a whiplash trauma. Thus, the differences in postural performance found between the 2 patient groups might reflect different degrees of disturbance of the fusimotor system, causing differences in the proprioceptive precision (29, 30), perhaps in combination with permanent damage to cervical soft tissue, the spinal cord and/or the brain stem in some patients with WAD (31–33).

Another possibility, which does not exclude effects of changed proprioception, is that the observed differences to some extent may be related to adaptive adjustments of postural control strategies developed by patients with chronic neck pain. Adaptive changes of posture and movement have been reported in subjects with atypical movement patterns (for review, see 34). The slower arm movements of the patients with neck pain, together with their increased head motion and sway area during perturbations, could be a reflection of control strategies adopted to minimize the risk of repeated neck injuries. However, it remains to be elucidated whether or not motor control strategies with a protective purpose are developed in chronic neck pain.

Concluding remarks

Our experiments have confirmed earlier reports on increased postural sway and decreased ability to maintain more demanding standing posture in patients with chronic neck pain, and, in addition, showed major differences in vertical postural and head stability to perturbations. The differences between the patients with WAD and those suffering from WRP suggest that deficits in proprioception and motor control, rather than the chronic pain itself, may be the main factors defining the clinical picture in different chronic neck pain conditions. Consequently, qualitative and quantitative measures of postural performance and head stabilization could be used to increase the precision and efficiency of diagnosis and rehabilitation of chronic neck pain of different aetiology.

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