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FIT2012-0177

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URL Conference Papers Series: www.atiner.gr/papers.htm

Printed in Athens, Greece by the Athens Institute for Education and Research.


ISSN **2241-2891**
13/09/2012

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This paper should be cited as follows:

**Dehner, C. and Kramer, R.** (2012) "**Postural Control Deficit in Acute QTF Grade II Whiplash Injuries**" Athens: ATINER'S Conference Paper Series, No: FIT2012-0177.

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**Abstract**

Tetra-ataxiametric posturography in chronic pain patients after whiplash injuries of the cervical spine has revealed an impaired regulation of balance. However, so far it is unclear if this is caused by the accident or other factors that are associated with the pain chronification process. The objective was to investigate the balance control in patients with acute QTF grade II whiplash injuries of the cervical spine.

40 patients with acute QTF grade II whiplash injuries and 40 healthy matched controls were examined on a posturography platform. The stability index $ST_\Sigma$ and the Fourier analysis $FA_\Sigma$ (0.10-1.00Hz) were established for eight standing positions and sum scores were calculated. The pain index was established using a visual analog scale ranging from 0-100. A follow-up examination was conducted for the patients after two months.

The patients with acute whiplash injuries of the cervical spine achieved significantly poorer results for both $ST_\Sigma$ and $FA_\Sigma$ than the healthy controls. There were no differences between the eight standing positions for both $ST_\Sigma$ and $FA_\Sigma$. After two months, 17 patients had no change in the pain development, 21 patients showed an improvement in pain intensity and 2 patients had deteriorated. The subgroup of patients with improvement in pain intensity showed a significant improvement in balance control concerning the $FA_\Sigma$ compared to patients with unchanged pain intensity.

Patients with acute whiplash injuries have a reduced balance control as compared to matched controls. This study gives an indication that post-traumatic neck pain is associated with impairments of postural control.

**Acknowledgements:** The experiments comply with the current laws of Germany and were performed inclusive of ethics approval.

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## Introduction

Besides neck pain and restricted movement, patients who have suffered whiplash injuries of the cervical spine frequently complain of an impaired regulation of balance (Hinoki, 1984; Evans, 1992; Kortschot & Oosterveld, 1994; Spitzer et al., 1995; Radanov, 1998). While the diagnostic and therapeutic endeavours have so far focused on the neck pain and the restricted movement of the cervical spine, balance disturbances have been given less attention.

Regulation of balance is a complex function of the sensorimotor system. Information that is received by the sensory systems from the environment has to be centrally translated into motor responses. Several sensory systems such as the visual, vestibular and peripheral somatosensory systems exert an effect on the regulation of balance (Chester, 1991; Rubin et al., 1995; Loudon et al., 1997). It is assumed that in patients with whiplash injuries, the function of the peripheral somatosensory system is impaired because of damage to the proprioceptors of the neck, and that this results in an impaired regulation of balance (Hinoki, 1984; Gimse et al., 1997; Loudon et al., 1997; Kelders et al., 2005).

Posturography was developed in order to determine the functional capability of the regulation of balance. Using a measuring platform, weight shifts are determined with force sensors while the weight is borne on the lower extremities. Information can thus be gained on the balance and stability of the subject.

Posturographic investigations in patients with chronic symptoms after whiplash injuries of the cervical spine unanimously demonstrate a poorer regulation of balance in the whiplash group as compared to healthy subjects (Roth & Kohen-Raz, 1998; El-Kahky et al., 2000; Kogler et al., 2000; Madeleine et al., 2004; Treleaven et al., 2005a; Treleaven et al., 2005b). However, it has not yet been fully established what causes the persistent whiplash associated disorders (WAD) and the resulting impaired regulation of balance (Kogler et al., 2000). In patients with chronic cervical spine pain, structural injuries such as facet joint pathologies and intervertebral disc lesions have been reported with an incidence of up to 84% (Bogduk & Aprill, 1993; Bogduk, 1995) and are discussed as being the cause of postural control system distortion (Gimse et al., 1997; Loudon et al., 1997). However, it is not precisely known whether these are direct consequences of the accident or result of secondary degenerative changes. There is only one study which describes that chronic pain patients with and without whiplash injury differ in their regulation of balance (Roth & Kohen-Raz, 1998). Furthermore, chronic pain and psychological effects are discussed to affect the central nervous system's modulation of proprioceptive afferent information (Gamsa & Vikis-Freibergs, 1991). Not only accident-related causes but also degenerative and psychological causes are thus conceivable.

Against this background, it would be interesting to know whether postural disturbances also occur shortly after a whiplash injury. At that time, degenerative and psychological factors are unimportant in comparison to the accident-related factors in the determination of the causes. There are no posturographic investigations in patients with acute whiplash injuries in the literature to date. The present study will thus investigate the regulation of balance in a patient group with acute whiplash injuries of the cervical spine compared to a matched pair non whiplash control group in order to answer the following questions:

1. Are there differences in the regulation of balance between patients with acute QTF grade II whiplash injuries of the cervical spine and healthy subjects?
2. Does the elimination of the visual, somatosensory or vestibular system lead to a decrease in balance control?
3. Does the patients' regulation of balance change over a period of two months after the accident?

## Materials and Methods

*Subjects*

QTF grade II whiplash injuries of the cervical spine (patients with neck pain and musculoskeletal signs) were the only inclusion criterion that was defined for the study. Patients with QTF grade I whiplash injuries of the cervical spine (patients with neck pain, stiffness or tenderness only), patients with QTF grade III whiplash injuries of the cervical spine (neck pain and neurological signs) and QTF grade IV whiplash injuries of the cervical spine (patients with neck pain and fracture or dislocation) were excluded from this analysis. Furthermore patients who had suffered previous injuries of the cervical spine or who had muscular, neurological or mental disorders were excluded from participation in the study. Patients who had degenerative diseases or pain of the cervical spine or the lower extremities were also excluded. The control group, which consisted of healthy subjects and was made up of medical students and hospital staff, was established by forming matched pairs with regard to year of birth and gender. They were not matched with regard to body weight, which is inversely proportional to stability (Kohen-Raz, 1991; Rogind et al., 2003), as this was automatically taken into account by the software of the posturographic system that was used. The work has been approved by the appropriate ethical committees and the subjects gave informed consent to the study.

*Study Procedure*

Using a standardised procedure, the patient group was examined on a posturography platform (Tetrax IBS®, Neurodata GmbH, Vienna, Austria) within the first week (Pat 1) after the trauma (median (3days); range (1day - 6days)) and eight weeks after the date of the first examination (Pat 2) (Kohen-Raz, 1991). On both measurement dates the patients were questioned about subjective balance disturbances. At the first examination all patients were given a prescription for a physiotherapy program 2 times a week for a period of 5 weeks. The physiotherapy program consisted of soft-tissue treatment, joint mobilization and measures for strengthening and stabilization of the cervical spine. The control group was only examined on one occasion (Norm). The examination was conducted by an investigator who was blinded with regard to history, clinical finings and status (patient/subject).

The TETRAX IBS® system measures the subject's dynamic weight distribution via four independent pressure sensors (left heel = A; ball of the left foot = B; right heel = C; ball of the right foot = D) which are incorporated in two foot platforms (see Fig. 1). A detailed description of the system is available elsewhere (Kohen-Raz, 1991). For the measurement, the subject stands barefoot on the measuring plates, which are positioned in parallel at hip width, assuming an upright, relaxed position with arms hanging loosely. For the controlled modification of sensory input from the visual, vestibular and somatosensory systems and for the assessment of the compensatory ability within the postural system eight different position tests were performed (Tab. 1). Each of the posturographic tests took 30sec.

*Parameters for Analysis*

1. *Stability Index (ST)*, calculated as the square root of the sum of the squared differences between adjacent pressure fluctuation signals, sampled at a rate of 32 Hz. ST describes the state of general stability and is an indicator of a person's stability (Roth & Kohen-Raz, 1998). The higher the score, the greater the sway and instability (Kohen-Raz, 1991). A sum score $ST_{\Sigma}$ of the eight different position tests was calculated and used for group comparison.
2. *"Fourier" Analysis (FA):* Fourier analyses of the postural recordings were performed. Abnormal postural performance due to peripheral causes is characterized by a high intensity of sway in the frequency range of 0.10-1.00Hz (Kohen-Raz, 1991; Oppenheim et al., 1999). Again we used the sum score $FA_{\Sigma}$ for group comparison.
3. *Pain (P):* The patients' pain score was determined according to a visual analog scale (0-100) on both measurement dates. The difference between the first and second measurements was calculated to define the development of the pain. "Pain unchanged" (PU) was defined as a minor difference of +/-10, "pain deteriorated" as a difference of >10 and "pain improved" (PI) as a difference of <-10.

*Statistical Analysis*

The differences between the controls and patients' acute examinations were tested for statistical significance with the non-parametric Wilcoxon signed-rank test for linked samples. To compare the eight standing positions for both parameters, the differences were analysed with the Friedman test for linked samples. The difference between the patients' acute and follow-up examinations was tested for statistical significance with the non-parametric Wilcoxon rank-sum test comparing the subgroups (PU, PD and PI). The significance level $\alpha$ was set at $p = 0.05$.

## Results

*Subject Participation*

Of the 76 patients with distortion injuries of the cervical spine who were treated in the emergency department, 59 patients fulfilled the inclusion criteria, of whom 6 patients declined to participate so that 53 patients were investigated in the first examination. 13 patients had to be excluded from the study because they were not prepared to report for the follow-up (investigation after eight weeks). Of the 40 patients in the patient group, 14 were female and 26 were male (median age: 29; range 15-42).

The median pain score was 40 (10-90) in the first examination and 15 (0-70) in the second examination. In the first examination, 4 patients reported a short sensation of dizziness and balance disturbances. At the time of the second examination, none of the patients complained of dizziness or balance disturbances.

*Comparison of Patients and Controls*

The patients differed significantly from the controls with regard to the stability index ($ST_{\Sigma}$) (p=0.0001). The median difference of the stability index ($ST_{\Sigma}$) between patients and controls was 37.1 (range: -30.2 - 147.4). Also the Fourier analysis ($FA_{\Sigma}$) shows a significant difference (median: 60.2; range: -57.1 - 406.0) (p= 0.0001) (Figure 2).

*Comparison of the Eight Standing Positions*

When comparing the eight standing positions, there is no significant difference between patients and controls either for the stability index (p=0.533) or for the Fourier analysis (p=0.287) (Figures 3 and 4).

*Comparison of First and Second Examinations of the Patients*

17 patients had no change in the pain development, 21 patients showed an improvement in the pain intensity and 2 patients had deteriorated. The subgroup PD was not analysed statistically due to the small sample size (n=2). The median difference of the $FA_{\Sigma}$ between the patients' acute and follow-up examinations was 10.0 (range: -33.0 - 121.0) in the subgroup PU and -4.0 (range: -133.0 - 65.0) in the subgroup PI. There was a significant improvement in the subgroup PI (p=0.028). In the $ST_{\Sigma}$, the median difference between patients' acute and follow-up examinations was 0.5 (range: -42.8 - 281.0) in the subgroup PU and -13.2 (range: -346.2- 83.8) in the subgroup PI There was no significant improvement in the subgroup PI (p=0.106) (Figure 5).

## Discussion

This study shows that patients who have suffered a QTF grade II whiplash injury have a posturographically measurable impairment of their balance control, which deviates significantly from the performance of a matched-pair control group. However, only four patients complained of balance disturbances or sensations of dizziness shortly after the trauma and none of the patients complained of these symptoms after 8 weeks. Moreover, the four individuals with subjective balance disturbances did not have the poorest posturographic results. Our results thus fail to show a correlation between clinical symptoms and posturographic measurements.

By contrast, Treleaven et al. (2005a) found that the balance control in patients with persistent WAD and dizzy spells is significantly reduced as compared to those without dizziness. The authors assume that this is because the patients with dizzy spells are affected not only by abnormal cervical information but also by an additional disturbance of the vestibular system.

This would mean that postural disturbances become clinically symptomatic only when several subsystems involved in balance control fail at the same time. It is conceivable that the failure of a subsystem can be compensated by other systems, at least when the requirement profile involves everyday tasks (Rubin et al., 1995; Loudon et al., 1997). So far it has not been investigated whether the measurable postural deficits could still manifest themselves during the performance of more complex balance tasks such as walking on ladders and scaffolding or specific sports activities. As balance control is a basic human ability, the theory of compensability of postural subsystems is quite logical.

The results of our study show that no change can be provoked in the parameters $ST_{\Sigma}$ and $FA_{\Sigma}$ by an increase in the stress on the visual, vestibular and somatosensory subsystems in acute whiplash patients. Consequently, these subsystems do not seem to be disturbed in our population. This is also plausible because there was no clinical evidence of a persistent disturbance in the above-mentioned subsystems in any of the subjects. The disturbances in the peripheral somatosensory subsystem, which have been observed in chronic pain patients, can thus hardly be considered a direct consequence of the accident (Hinoki, 1984; Gimse et al., 1997; Loudon et al., 1997; Kelders et al., 2005) .

We additionally tried to use different head positions to apply stress on the cervical spine that was injured in the accident. As this also failed to produce any measurable change in the $ST_{\Sigma}$ and $FA_{\Sigma,}$ one can conclude that either the effect of the cervical efferences on postural control was not disturbed or that the stress applied in the chosen provocation tests was not sufficient to influence balance control. It is possible that a stronger (measurable) effect may be observed under more complex dynamic task conditions or if the head is specifically held in painful positions. The results of this study thus show an impairment of balance control in close temporal association with the accident, so that a causal relationship is likely. However, the results do not allow any conclusions with respect to the localisation of the observed disturbance.

The use of posturography for the documentation of therapeutic successes has been described on several occasions (Furman, 1994; Karlberg et al., 1996; Gustafson et al., 2000; Kammerlind et al., 2001). Therapeutic success is normally measured by the improvement of symptoms that most affect the patient. In whiplash patients, these are pain and restricted movement which quickly recede in a high percentage of patients (Grifka et al., 1998; Obelieniene et al., 1999; Partheni et al., 2000). After an eight-week follow up, 21 of 40 patients showed an improvement in pain intensity and balance control while in

17 patients, who showed no change in the pain intensity, the balance control was unaffected and remained disturbed. A correlation between pain intensity and disturbed balance control has so far only been observed in patients with a persistent WAD (Roth & Kohen-Raz, 1998; Treleaven et al., 2005b). When these results are combined, one can assume that disturbed balance control is correlated with neck pain after an acute WAD.

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**Figure 1.** *Left: foot platforms with load cells labelled A, B, C, D; above them are the attachable foam cushions. Right: test person standing on the foot platforms*

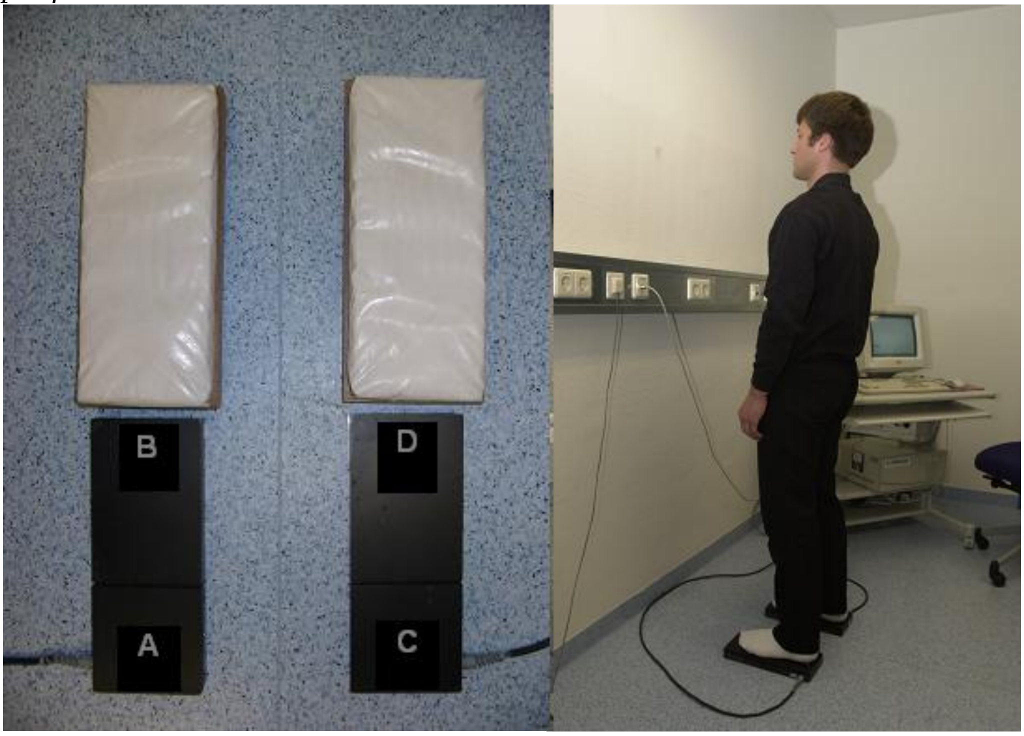



**Figure 2.** *Comparison of the stability index ($ST_\Sigma$) and the frequency analysis ($FA_\Sigma$) between the acute examination of the patients (Pat 1) and the control group (Norm). The graphs show the median, 1st quartile (lower edge of box), 3rd quartile (upper edge of box), maximum and minimum (upper and lower end of range line) of the differences.*

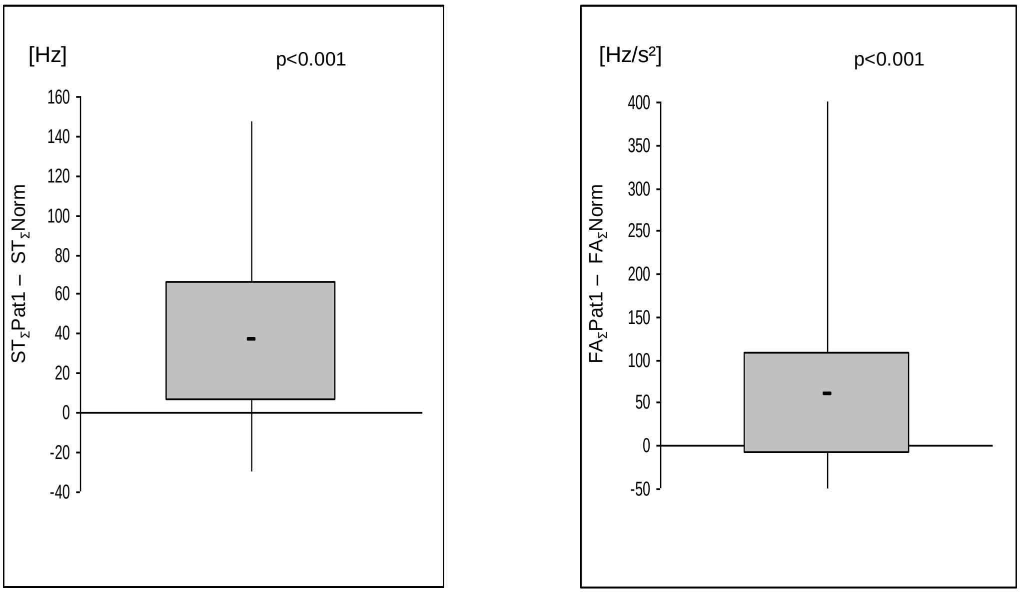


**Figure 3.** *Comparison of the stability index ($ST_{\Sigma}$) in the eight standing positions between the acute examination of the patients (Pat 1) and the control group (Norm). The graphs show the median, 1st quartile (lower edge of box), 3rd quartile (upper edge of box), maximum and minimum (upper and lower end of range line) of the differences.*

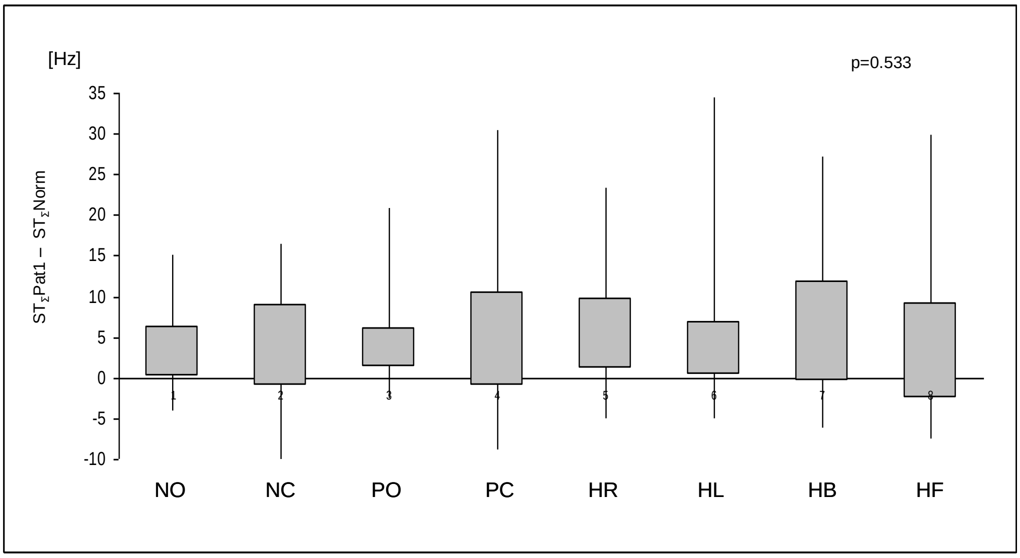



**Figure 4.** *Comparison of the frequency analysis ($FA_{\Sigma}$) in the eight standing positions between the acute examination of the patients (Pat 1) and the control group (Norm). The graphs show the median, 1st quartile (lower edge of box), 3rd quartile (upper edge of box), maximum and minimum (upper and lower end of range line) of the differences.*

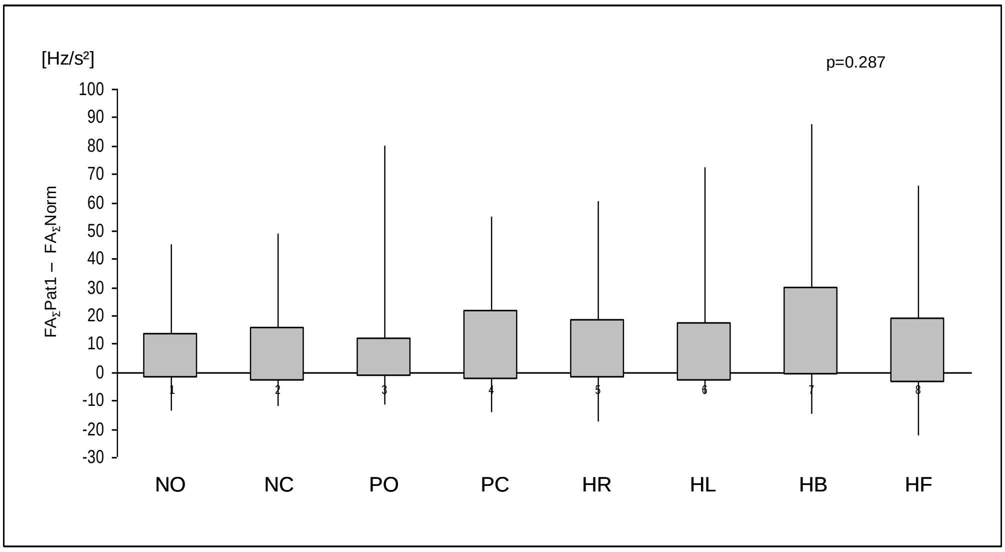
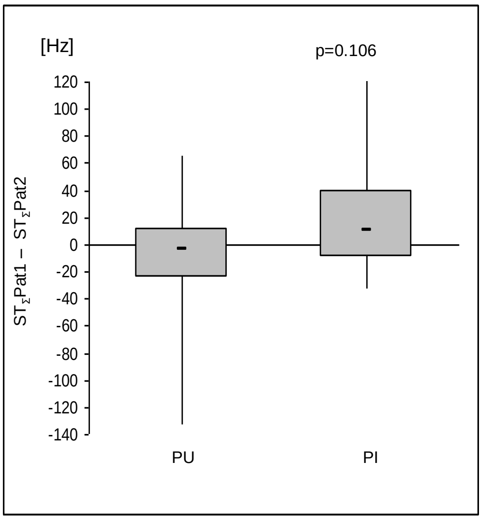


**Figure 5.** *Comparison of the subgroups PU (pain unchanged) and PI (pain improved) concerning the stability index ($ST_{\Sigma}$) and the frequency analysis ($FA_{\Sigma}$) between the first (Pat 1) and second examinations (Pat 2) of the patients. The graphs show the median, 1st quartile (lower edge of box), 3rd quartile (upper edge of box), maximum and minimum (upper and lower end of the range line) of the differences.*



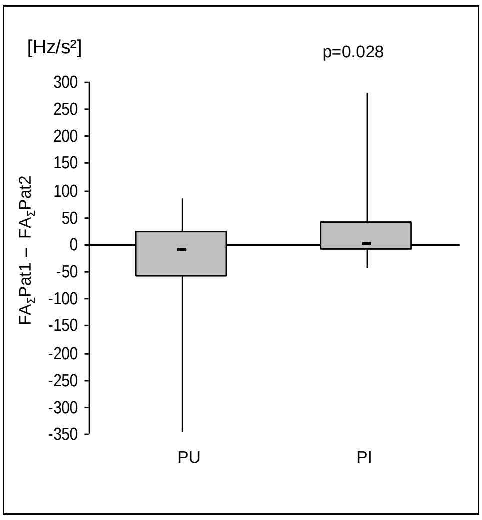




**Table 1.** *Testing conditions for the eight posturographic tests*

| Positions | Head position | Eyes | Ground | Purpose |
|---|---|---|---|---|
| **NO** | neutral | open | solid | neutral position |
| **NC** | neutral | closed | solid | elimination of visual system |
| **PO** | neutral | open | elastic | elimination of somatosensory system |
| **PC** | neutral | closed | elastic | elimination of somatosensory and visual system |
| **HR** | rotated to the right | closed | solid | elimination of visual system and vestibular stress |
| **HL** | rotated to the left | closed | solid | elimination of visual system and vestibular stress |
| **HB** | reclined | closed | solid | elimination of visual system, vestibular and cervical stress |
| **HF** | inclined | closed | solid | elimination of visual system, vestibular and cervical stress |