

Postural stability in patients with back pain

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30 patients with back pain were subjected to stabilographic investigations in order to disclose possible loss in their postural stability system (PSS). Basing on traditional parameters we can discriminate only the most acute group with "unbearable" pain from other patients. On the other hand, the autoregressive (AR) approach allowed us to find meaningful differences also between patients with moderate level of pain and the control group. The results indicate that AR modelling produces the opportunity to evaluate physiological and biomechanical parameters characterising the operation of the neuro-muscular system (NMS) responsible for human balance. Those parameters are much more sensitive to the level of malfunction of the stability system, presenting more accurate and differentiated picture of individual cases. It confirms the power of AR-based reasoning and gives new insight into the operation of the PSS.

Keywords: postural stability, centre of pressure, back pain, ischialgia

1. Introduction

The lack of objective measures of postural stability is a typical problem encountered by clinicians and therapists. What remains, is subjective assessment of the patients' motor constraints, which in moderate cases may be insufficient. This information may be supplemented by even more imperfect interview as patients accustom themselves to their motor disorders.

Evaluation of the performance of motor functions responsible for maintaining a proper body balance is not easy. The only practical method, which can be regarded as commonly accessible, is stabilography. This technique is based on the recordings of the centre-of-pressure (COP) signals during stance performed on a force platform. Typical changes in the COP amplitude assume values of 10–25 mm [1], which result from instantaneous displacements of the centre-of-gravity (COG) and corrective movements accomplished by ankle and hip joints [2, 3]. The COG displacements rarely exceed 15 mm and corrective activities are quite concealed from sight, as their basic purpose is to produce corrective forces, which are damped by the body mass. The increase of these results of 10 mm may be regarded as a sign of the stability sys-

tem impairment. These figures explain how easy it is to make mistakes while attempting to evaluate the standing performance without proper equipment.

Examination of patients with stability disorders has two important aspects. First, it is aimed at objective assessment of the symptoms and, if possible, the detection of the underlying reasons in order to improve our knowledge of the mechanisms of motor disorders. As a result, the most efficient treatment may be indicated. Second, by means of studying pathology, it allows us to improve our knowledge about the intact motor control systems [4].

The purpose of the present paper is to evaluate postural stability in patients with back pain. In an attempt to improve the efficacy of the diagnosis, the traditional stabilography [5, 6] was augmented by the autoregressive (AR) model representing the above-mentioned corrective movements [7, 8]. Mathematical modelling with the application of the second order AR processes leads to the estimation of two AR parameters characteristic of the postural performance of a given subject. The consecutive comparison of that parametric model with the mass, spring, and damper system allows us to evaluate stiffness and damping of ankle and hip joints. We hypothesise that pathological changes measured by the AR technique in the latter biomechanical and physiological properties of ankle and hip joints can be linked with what we know about the reasons of this disease. We expect that those postural measures will discriminate between patients claiming different levels of pain and allow us to perform a quantitative diagnosis of the subjects' postural stability system.

2. Material and method

Nine female and twenty-one male patients participated in the study. They suffered from pain located at the lumbar part of the spine, radiating inwards the lower extremities with positive Lesegue' sign. The patients' age was 41.6 ± 9.3 years, body mass 78.7 ± 14.1 kg and height 173 ± 11.3 cm. The average period of the pain existence was three months and the declared pain level on the ten point's scale was between 5 and 10. In order to investigate the possible relation between the pain level and postural performance, the group was divided into 16 patients in moderate state (pain level 5–8, meaning average to sharp pain) and 14 patients in acute state (pain level 9–10, unbearable pain). The control group constituted 19 subjects (9 female and 10 male). Their age was 35.2 ± 4.8 years, body mass 69.5 ± 8.7 kg and height 173 ± 9.1 cm. All subjects signed an informed consent and agreed to take part in the examinations.

The subjects were asked to perform three trials lasting 20 s each, standing in quiet upright stance on a force platform. In order to exclude signals with extreme values, which might be expected among suffering people, the time series displaying the maximal and minimal ranges were eliminated from the further analysis. Consequently, a single recording describing his/her performance during the experiment represented each subject. Each member of the control group performed one single trial. The sampling frequency was 20 Hz.

For all accepted COP signals the following standard parameters were computed: range, standard deviation, mean velocity and mean radius. Then their mathematical models in the form of the AR processes were found according to the procedure described below:

1. Low-pass filtering (the cut-off frequency – 2 Hz).
2. Exponential smoothing with parameter $\alpha = 0.1$.
3. Maximum likelihood estimation of two parameters of AR model for the residual signal from step (2).
4. Computing of the peak frequency (PF) of the last signal.
5. Computing of postural stiffness, viscosity and relative damping on the basis of comparison of the AR model with the discrete form of the second order differential equation, which describes angular displacement in joint as a function of torque.

More detailed description of that procedure is available in [2, 7]. All computations were performed using STATISTICA™.

3. Results

The traditional parameters exhibit insufficient diagnostic capabilities. Only patients with the highest pain level display significant increase of amplitude indices in frontal plane ($P < 0.001$). The results in some patients resemble the results obtained in healthy subjects in one leg stance [9]. This finding is confirmed by specific posture of the patients, who assume characteristic leaning position in order to unload the lower extremity, which causes pain.

Table. Comparison of the postural biomechanical parameters in the sick with different pain levels and the control group¹

Parameter	Controls	Patients (moderate state)	Patients (acute atate)
<i>PF1</i> [Hz]	0.58 ± 0.15	0.56 ± 0.13	0.49 ± 0.13
<i>PF2</i> [Hz]	0.71 ± 0.16	0.66 ± 0.11	0.55 ± 0.12**
<i>K1</i> [kg·m ² /s ²]	1137 ± 560	1084 ± 480	966 ± 371
<i>K2</i> [kg·m ² /s ²]	1578 ± 743	1483 ± 574	1056 ± 348*
<i>B1</i> [kg·m ² /s]	122 ± 54	173 ± 59*	165 ± 43*
<i>B2</i> [kg·m ² /s]	84 ± 42	116 ± 44*	125 ± 53*
ξ_1	0.23 ± 0.08	0.29 ± 0.05*	0.32 ± 0.10**
ξ_2	0.13 ± 0.06	0.18 ± 0.06*	0.23 ± 0.08***

¹*PF* – peak frequency, *K* – stiffness, *B* – viscosity, ξ – relative damping, 1 – sagittal plane, 2 – frontal plane.

The level of confidence: * – $P < 0.05$, ** – $P < 0.01$, *** – $P < 0.005$.

The biomechanical properties of the stability system presented in the Table and computed on the basis of the two estimated parameters of the AR model can be helpful in the diagnosis of the instability and/or pain level. The acute patients have increased viscosity and damping ($P < 0.05$) as compared with the control group. Additionally, the frequency of their corrective adjustments generated at the hip level drops substantially: from 0.71 Hz in control group to as low as 0.55 Hz ($P < 0.005$).

4. Discussion

The fundamental advantage of the AR method is the opportunity to distinguish patients in moderate state from healthy subjects. The biomechanical postural parameters derived from the comparison of AR model with the visco-elastic differential model describing the relation between the joint torque and the angular displacement are quite novel indices, having been presented only recently [10]. Although postural stiffness in this group of patients has similar value to that computed in a control group, we can observe a significant increase of viscosity and damping ($P < 0.05$). The increase must have resulted from some constraints imposed on the neuro-muscular system by the disease and pain. As the increased damping in automation systems causes faster elimination of oscillations, this result can be regarded as the defence of the CNS against a troublesome in this case, but otherwise natural, rambling movements of the body's COG in healthy people.

The autoregressive parameters bring forward new information about patients in acute state. As it was indicated earlier, these subjects exhibit pronounced leans in the frontal plane, which indicated a resolute unloading of one side of the body. However, one leg standing, let alone any decrease in the base-of-support, always results in the increase of the frequency of corrective adjustments [9, 10]. It is clearly in contradiction with the drop of the frequency recorded in the group described. We can venture two possible explanations. First, it may be the adaptation connected with a sort of "training" and getting accustomed to the odd body posture. Second, it may be the lowered nervous conductivity, which can result in diminished rate of the nervous signals' circulation, causing the drop in the frequency of the corrective control signal.

The coefficients of correlation between the different parameters in acute patients displayed in the Table are different from those computed in the control group. The most important difference is the decreased relationship between the parameters in both planes. The postural symmetry, which is typical in the healthy population [11], practically disappears. Also, the effect of body mass on postural stiffness and viscosity is lessened, which indicates that the patients seek for and apply individual strategies of maintaining balance.

The results obtained in this study account for the role of AR models in the analysis of human stability system: they are efficient as diagnostic tools and very helpful in developing our knowledge of neurophysiological mechanisms responsible for the proper stability of posture. In the latter case, the patient's motor disorders, if the aeti-

ology is known, may let us understand the functioning of selected parts of our stability system, which practically cannot be done in intact organisms.

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