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DEVELOPMENT TRENDS AND RESULTS IN SPINAL TESTS

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Abstract

Spinal tests have been performed by an ultrasound-based movement test system at the Biomechanical Laboratory of the Department of Applied Mechanics of the Budapest University of Technology and Economics for several years. The system is suitable for rapid tests of the mobility, structure, and deformations of the spine, screening tests, and monitoring. Tests and evaluation take a short time: a complete screening test takes 20 to 25 minutes, a simplified test about 5 minutes. Besides its numerous advantages, it should be noted that the total cost of installing the system – equipment, software, hardware – is only about 8000 €. This article presents the structure and use of a modern ultrasound-based system as well as the results of our investigations.

Keywords: biomechanics, ultrasound, spine tests.

1. Introduction

4 to 6% of school-age children in Hungary suffer from spinal diseases and about 20% have consulted a specialist with spinal complaints. There are several methods for curing diseases depending on their severity. Regardless of the therapy, the first step is to set up an accurate diagnosis of the patient's spine status. There are several options for this, ranging from traditional spinal tests to brand new methods [1]. A common disadvantage of the so-called traditional spinal tests – X-ray tests, magnetic resonance tests, and computer tomography – is that they load the body by harmful radiation, therefore they can be applied in diagnostics and therapeutics at specific intervals and with certain limitations. There are several methods for eliminating harmful effects. There are video-based and ultrasound-based movement test systems. These systems eliminate the harmful effects of traditional tests; and a number of new opportunities are presented in the course of their use. Such a spinal test module was built by Zebris Medizintechnik GmbH, a software called WinSpine operating under a Windows environment.

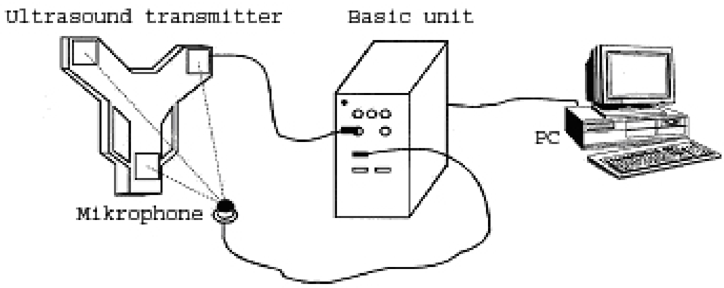


Fig. 1. Outline of system structure

2. Method

The system consists of three parts: a signal source; microphones to be placed on the body, suitable for receiving ultrasound signals; and a central unit.

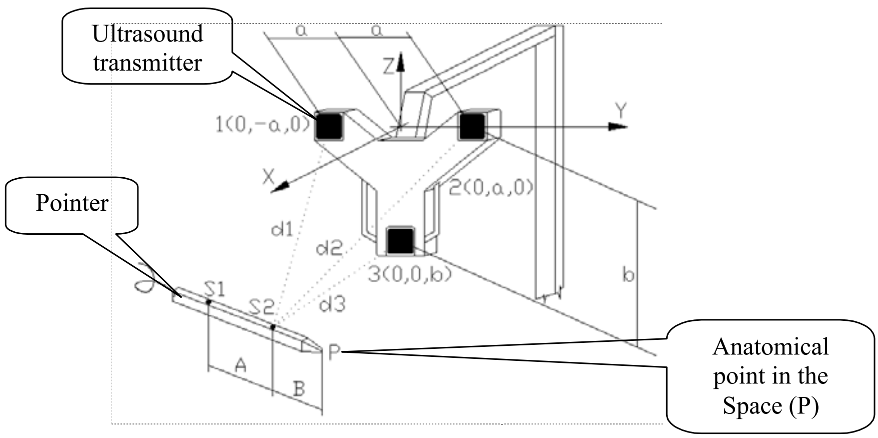
The computer-based signal processing system can determine the position of the microphones with errors of less than a tenth of a millimetre by triangulation. A pointer can be used for associating the microphones with anatomical points that are covered by the body, but their position is required to be specified. The system uses the formulae shown by the following figure to determine the position of the microphones and the anatomical points specified by the pointer [2].

Comparisons of independent measurements performed by two persons were used for verifying the system. A discretional point was specified in space, the location of which was to be determined by the pointer. *Fig.3* shows measurement results. The discrepancy between average measurement results is 0.4 mm.

2.1. Identification of the Shape of the Spine

In the course of the measurement, the patient is located in front of the ultrasound beacon, wearing three microphones fixed rigidly compared to each other – a triplet – on his waist. The doctor performing the test uses the pointer to detect the line of the spine in the knowledge of the position of the spinal processes. The measurement consists of palpating the location of anatomical points, adjusting the tip of the pointer to such a point, and pressing the button on the pointer. Besides, the position of high-priority anatomical points specified by the system (scapula, anterior and posterior edge of the pelvis), as well as of discretional anatomical points are required to be determined [3]. These measurements should be performed in different bodily positions of the patient, e.g. bent forward, backward, and sideways.

There is a report function in the software package to evaluate measurements, displaying – both graphically and numerically – the shape of the spine from various views, the position of vertebrae compared to each other, and the position of



$$Y = \frac{(d_1^2 - d_2^2)}{4 \cdot a};$$

$$Z = \frac{(d_3^2 - 0.5 \cdot (d_1^2 + d_2^2) + a^2 - b^2)}{2 \cdot b};$$

$$X = \sqrt{(d_1^2 - (Y + a)^2 - Z^2)},$$

$$\underline{R}_p = \underline{R}_{S1} + \frac{(a + b)}{a}(\underline{R}_{S2} - \underline{R}_{S1}).$$

Fig. 2. Method for determining anatomical points

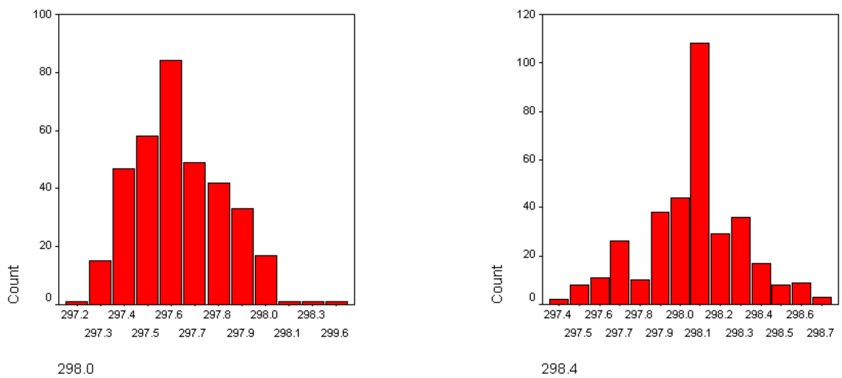


Fig. 3. Results of statistical check

anatomical points compared to each other.

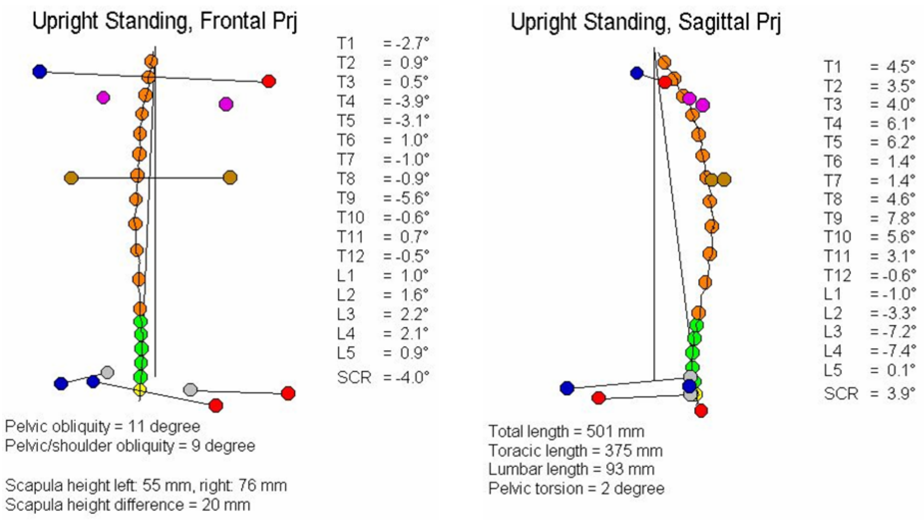


Fig. 4. Spine shape tests, results

2.2. Spine Mobility Tests

The second type of measurement is the analysis of the mobility of the spine. The patient wears two triplets between two discretional sections of the spine; this means that the dynamic characteristics between these two sections of the spine can be specified in the course of the following movements performed by the patient:

- bending the trunk forward and backward
- bending the trunk sideways
- twisting the trunk so that the position of the hip should not change.

Measurement results can be displayed on phase diagrams. In an ideal case, angle/angular velocity diagrams are circular or elliptical, progressing along a single track in the course of repeating the movements, and free from high-frequency signals.

The results measured on bend charts can be compared with ideal data of healthy subjects. The time diagrams of movements represent a traditional mechanical content.

The measurement system is also suitable for measuring muscular activity. Surface Electro-Mio-Graph (EMG) sensors placed on the body can be used for examining surface muscle activity along the cervical, dorsal, and lumbar spine. EMG electrodes can be used for specifying muscle activity characteristics (activity time,

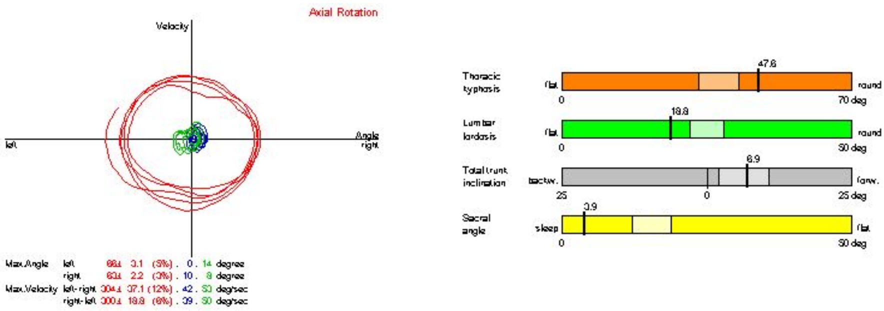


Fig. 5. Phase diagram and comparisons of measured and normative data

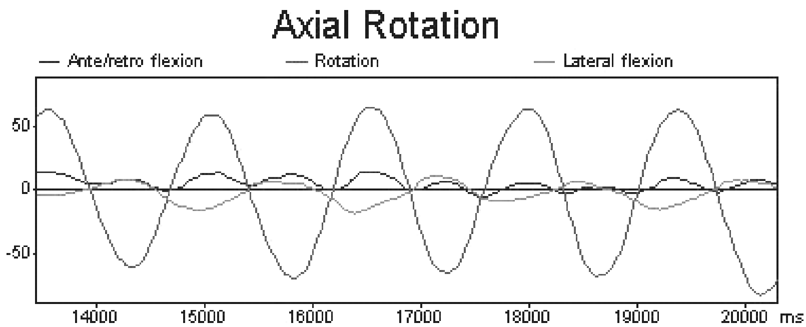


Fig. 6. Movement curves

etc.) (*Fig. 7*). Tests are suitable for checking proper muscular activity as well as for monitoring developments, improvements, and the effectiveness of rehabilitation in the course of the therapy.

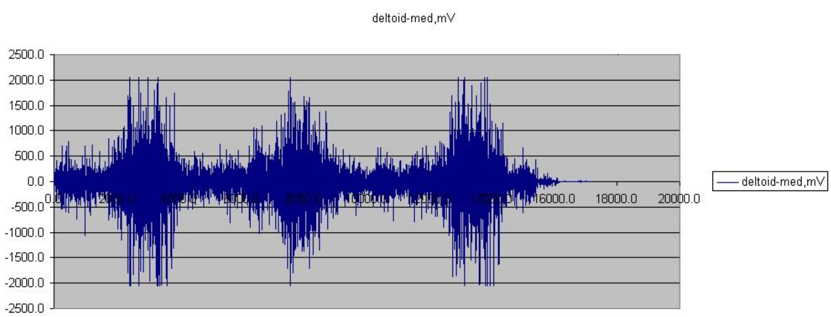


Fig. 7. Muscle activity measurement results, EMG curves

Our patients included school-age children only; therefore we deemed it expedient to perform tests modelling everyday situations at school. We examined the shape of the spine while sitting; determined the correct posture by individual; and studied the impact of schoolbags on the spine. We provided proposals to those suffering from various diseases how to use their schoolbags in order to spare their spine. As a secondary impact, spinal curves can be corrected passively by schoolbags (*Fig. 8*) [4].

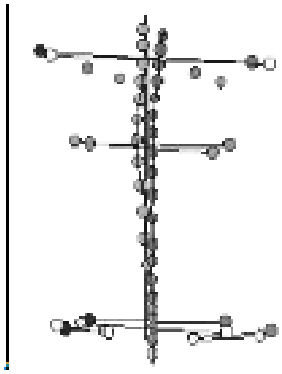


Fig. 8. Comparative tests

Measurements can be supplemented by the results of measurements performed at the Zebris measurement platform (WinPDM) suitable for measuring sole pressure distribution. There is a relationship between the structure of the sole and the pathological deformations of the spine. The health status of the spine can be completely surveyed by processing the data of gait tests performed at the treadmill [3].

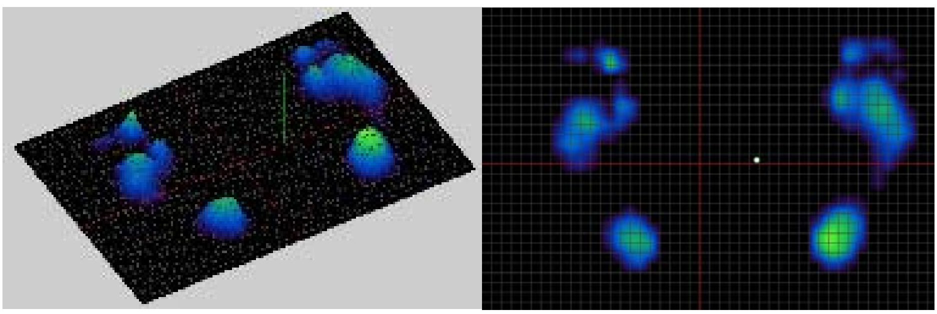


Fig. 9. Sole pressure distribution

The health status of the spine can be clearly surveyed by way of complete tests. Test results can be used for more easily determining the required therapy as well as the method and type of therapeutic gymnastics [5].

3. Results

An advantage of the system is that not only the shape of the spine can be determined but the mobility and movement ranges of the spine as well. Measurement results favourably complement traditional measurements; measurements can be repeated at discretionary intervals without any harmful effect. Due to the on-line measurement system, measurement results can be improved and corrected immediately. Measurement results can be viewed in the report functions, which contain normative data besides displaying various shapes of the spine. They contain the values measured as compared to data recorded in the course of measurements performed on healthy subjects. Results can be printed out and compared with traditional measurement results. Results can be further processed by displaying and processing the measured data in Microsoft Excel format [6].

The system was tested and extended in the framework of a joint project with the Buda Children's Hospital and Outpatient Clinic of the Metropolitan Government of Budapest [1], taking the first step towards introducing, in clinical practice, a bioinformatics system unique both in Hungary and in Europe. The survey covered 52 patients (36 girls, 16 boys), with an average age of 14 ± 3 years, average height of 166 ± 14 cm, and average weight of 49 ± 13 kg. 10 of them were healthy, 26 suffered from the Scheuermann disease, and 16 from Scoliosis [7].

There are biomechanical theories for the research of the SD-Scheuermann disease of unknown pathological origin and Scoliosis. There is a multi-disciplinary approach to this problem, meaning that the cooperation and common considerations of expert orthopaedic specialists and technical professionals lead us closer to clarifying issues at stake, a basic condition for which is the existence of a properly equipped biomechanical laboratory. The 3D ultrasound Zebris device can map the actual topography and the entire movement track of 3D deformations by supplementation of its Winspine programme and the exchange of normal values. It can be properly reproduced and it works with acceptable inter and intra observer error rates. Different measurement systems can be linked (gait analysis, electromyography). Tests can be performed really in 3D, and measurements can be taken in realistic circumstances. On the basis of our surveys it can be established that they provide further information obviously suitable for research and diagnostics. We hope that they are also suitable for tracking patients; therefore our tests are performed with longitudinal follow-up.

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