SUBACOUSTICAL TRANSFER IN SPINAL SEGMENTS AND ITS POSSIBLE USE IN DIAGNOSTICS

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Abstract: This article discusses the possibility of determining the frequency transfer characteristics of the human spine in vivo. We have used the experimental method described herein when attempting to identify the state of the intervertebral junction using subacoustic and low-frequency acoustic vibrations. We believe that this method can be potentially used in the diagnosis and can complement the currently available imaging techniques, as it is capable of recording changes in materials before the occurrence of changes in shape. We use the frequency range from 2 to 200 Hz for examinations. We have successfully identified several resonance frequencies characteristic for different types of mechanical junctions of spine elements. These frequencies are variable for different persons and different regions of the spine. We have familiarized ourselves with this method to such an extent that we are sure our measurements are reproducible. In other words, two measurements performed on the same element of the spine in a given person will give identical results, while measurements on another spinal element or in another person will give different results.

Keywords: Spine, Intervertebral Disc, *in vivo* measurement, Transfer Characteristics, Subacoustic Vibrations, Diagnostics

Introduction

This article discusses the possibility of determining the frequency transfer characteristics of the human spine in vivo. According to [3] we tried to develop similar vibration technique and its modofications but with its application to *in vivo* condition.

Materials and Methods

There were six probads, three women and three men, between 16 and 30 years old with no anamnesy of any back pain or any spine injury. During the measurements, the subjects lie on their abdomen on a hard pad and the vibration exciter and two or three accelerometers are pressed onto their vertebral processes (fig. 1) using a non-invasive force of approximately 50 N. This force generates pressure of approximately 150 kPa, which is sufficient to establish good contact between the sensor or exciter and the vertebra.

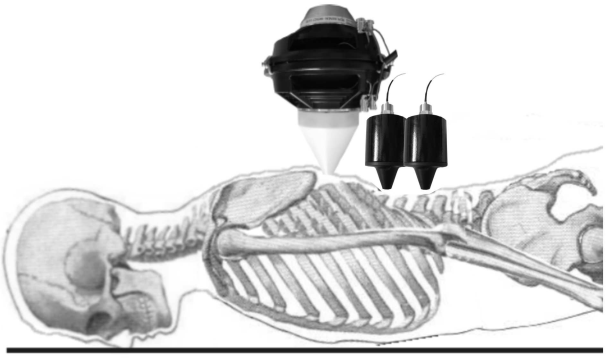

Figure 1: Scheme of senzor application.

To induce measurable oscillations in this frequency area, the oscillating mass must have a weight at least in the order of hundreds of grams, with amplitudes in the order of millimeters. Originally, we used electromagnetic geophones for the detection, but since their resonance frequency lies within the area of our interest, thus rendering the analysis of the signal more difficult, we are now using a very sensitive piezoelectric accelerometer with a crystal stressed by shear forces. Despite this more suitable method of crystal loading, the signal from the sensor is temperature-dependent, and it must therefore be adapted to the proper temperature before each measurement. The reconstruction of motion velocity and of the sensor position by integrating the acceleration measured seems to be a relatively complex task. To differentiate random events occurring in the body of the examined person (fig. 2) and manifesting as vibrations, from the useful signals, we must repeat the measurements several times, but the length of the entire measurement must not exceed a certain acceptable limit.

The entire frequency spectrum must be measured during the measurements. We use two different techniques of excitation. The first method is based on measuring the response to a δ pulse, while the second method is based on inducing vibrations using a continuously changing frequency. When using the first method, we excite the δ pulse by hitting a neurological hammer against the vibration exciter. Although this method is easily inter-

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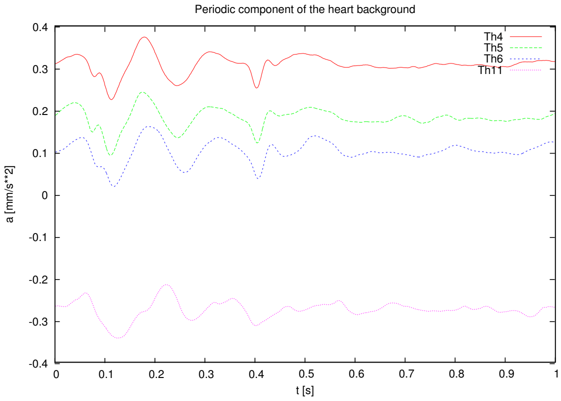

Figure 2: Periodic component part of the heart background.

pretable, we should consider that the main task of the spine is to attenuate vibrations and we can easily conclude that the vibrations thus excited will be attenuated soon. This will always happen within 10 msec after excitation. The second method is performed using an electromagnetic exchanger. The exchanger is excited by the programmable DA transducer ProgGen from PaPouch, s.r.o., by a consistently variable pseudosinus waveform, which is steadily repeated with the periodicity of 200 sec. In both cases, the motion is detected by type SV162 accelerometers from the firm SMS, s.r.o. The signal from these meters is conducted through a charge amplifier of our own design into the 4-input differential synchronous 16 bit AD transducer DRAK5 from the firm PaPouch, s.r.o., and then detected 5,000 times per second and recorded on a PC.

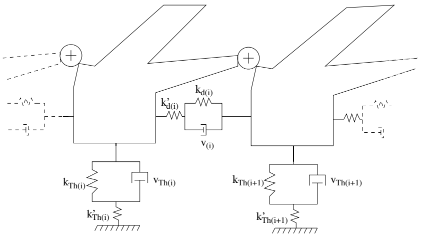

Figure 3: Model of spine mechanical relations designed on the basis of first results.

Results

At least 16 records for a given vertebra junction must always be made for both the impact and harmonic excitation. We have 16 values for each time point and we should calculate their derivatives. To determine the mean value for further processing, we must use only those values which are close to the mode both for the derivative and for the value itself in the given point. In this way, we can obtain the time course suitable for analysis. The first information about this time course can be obtained by comparing the individual measuring channels, provided the time courses were previously standardized in terms of amplitude, because it is not possible to conclude anything from absolute values of the amplitude. Interesting information can be obtained from the correlation function of individual channels. However, the main objective of each evaluation is to find a coefficient of the model shown in the figure such that the given excitation results in the time course are as similar to that actually measured as possible. The figure shows the typical spinal response to excitation by δ pulses. The figure shows the typical response to harmonic excitation.
On the basis of first results we tried to construct the model of spine mechanical relations (3).

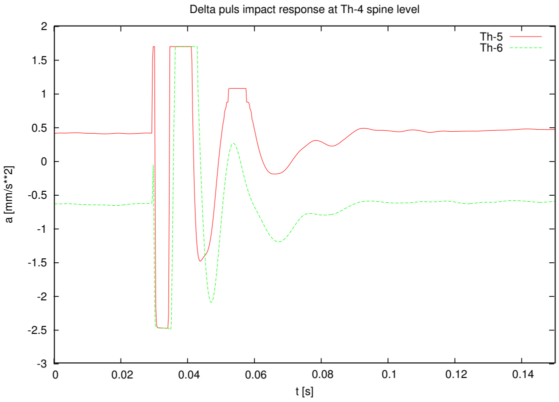

Figure 4: Delta puls impact response at Th-4 spine level.

Conclusion

This contribution provides the first information on the investigated diagnostic method, which already seems to be applicable, as it meets the two basic requirements for measuring techniques, differentiation ability and reproducibility.

Discussion

It was revealed that the impact hammer method or analysis of response to δ pulses having the energy of $0.1[J]$ can provide structural information on the spine elements using currently available techniques. When modifying this method using harmonic excitation, the specific shape of the excitation curve should still be improved, so that the analysis of response can be performed more easily. The figure shows the correlation diagram of the signal from the Th8-9 region during harmonic excitation (fig. 5).

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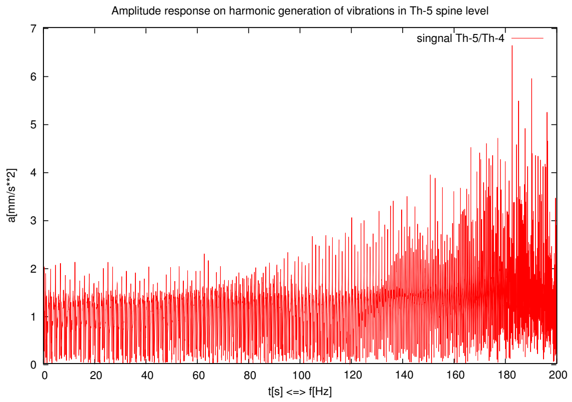

Figure 5: The correlation diagram of the signal from the Th8-9 spine level during harmonic excitation.

References

[1] IATRIDIS, J. C., SETTON, L. A. WEIDENBAUM M., MOW V. C.: The viscoelastic behavior of the non-degenerate human lumbar nucleus pulposus in shear. *Journal of Biomechanics* 1997, vol. 30, no. 10, pp. 1005-1013

[2] WHITE A, PANJABI M.: *Clinical Biomechanics of the Spine.* Second edition. Philadelphia, PA: J.B. Lippincott Co., 1990. ISBN 0-7216-9337-7.

[3] ZEMANOVA, P.: *Popis struktury a viskoelastickych vlastnosti meziobratlove plotenky.* Praha 2001, 92 pp. Dissertation thesis FTVS UK, Department of Anatomy and Biomechanics. Praha 2004. Supevisor of Dissertation thesis Stanislav Otahal.