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IDENTIFICATION AND DYNAMICS OF THE RHEOLOGICAL PROPERTIES OF THE HUMAN AXIAL SYSTEM BY THE TRANSFER VIBRATION THROUGH SPINE (TVS) METHOD.

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SUMMARY

The human musculoskeletal system interacts with other objects in the environment. The hypo or/and hyperkinetic character of interactions causes changes of the rheological properties in connective tissue. This paper shows case studies that indicate the advantages of using TVS method for the identification and classification of the human axial system changes in different physical activities. The investigated activities and their influence on the axial system were mainly monotonous vibration loading while driving, extreme training loading among rhythmic gymnasts and ageing. The TVS method is based on the fact that the speed of mechanical wave and the quantity of mechanical energy transmitted through connective tissue depend on the characteristics of passing tissues. The difference between the input and output accelerations measured on the spinous processes reflects the tissue characteristics. The TVS method is very suitable for all the classification and regulation of extreme and normal physical activities, ageing prevention, quantification of the human axial system among particular groups of people and also for the diagnosis of surgical and therapeutic interventions.

INTRODUCTION

Responses of the joins to the well-defined dynamic load picture the biomechanical properties of the joint components (at the spine mainly nucleus pulposus, annulus fibrosus and endplates) that vary due to the chemical modifications, for example the amount of collagen, GAGs, etc. [6]. The usage of modern imaging methods [5], instruments of continuum mechanics and thermodynamics enables one to develop the mathematical definitions of the material characteristics of connective tissue [1, 8]. The single joint components, i.e. vertebrae, intervertebral discs (IVD) and menisci in particular are usually described through the laws of mechanics as visco-elastic-plastic materials. The computer algorithm for the numerical simulation is designed to imitate the dynamical behaviour of joints, for example a knee, spine, etc. in vivo. The changes of the IVD's material characteristics and of the whole axial complex are possible to determine thanks to the analysis of mechanical wave transfer through the spine – the TVS method. The detection of mechanical energy transferred through the body is discussed worldwide by plenty of authors [2]. However, the conclusions of the studies about the positive or negative effect of vibrations on human tissue are not homogenous. It usually depends on the frequency, amplitude and acceleration and furthermore on the affected parts of the body (whole-body vibrations, etc.). A minor number of studies have examined the effect of vibration transfer through the human body. A study that would have adopted the approach of the transfer of vibrations as a diagnostic method has not been found. A new developing TVS [3,7] method benefits from the favourable feature of matter to transfer pulses that carry some form of energy. It is generally mechanical energy. Since the energy of a mechanical wave is superimposed onto mechanical energy stored in a unit of matter, the speed and inhibition of energy transfer is connected to those characteristics that describe the density and mechanical properties of matter (for example elastic modulus, viscosity or plasticity). The TVS method was used to conduct several experiments among pregnant car drivers. The drivers were examined before and after a ride in a different stage of pregnancy [4]. The main task is to develop a diagnostic method based on a physical model of the craniospinal complex that is able to discover the pathological deformations or the degeneration of a spinal segment.

METHODS

The transfer of vibrations through the axial system was employed to detect the changes of the rheological properties of the system in this study. The TVS method consists of the application of the 5ms semi-bandwidth γ pulse stimulus and consequent application of continuously changing harmonic stimuli which periodically differs between 5Hz and 160Hz to the vertebrae C7 and L5. This wave is carried through the axial system and its acceleration on the spinous processes is scanned with the help of the accelerometer sensors. It is expected that the wave transfer speed and its loss while detecting the responses of the human spine to the stimuli is dependent on the characteristics of tissue in which the wave passes through. The mechanical tissue changes are retroactively characterised by the speed of the wave transmission. There is a relationship between the elastic modulus, viscosity of the spine and the phase shift of the excitation stimuli that are detected on each vertebra (the ratio of the amplitude on a vertebra and the excitation amplitude). The changes of the axial system characteristics were observed among pregnant drivers who were displayed to vibration loading (a 45 minute monotonous drive and 120 minute monotonous drive). Furthermore, the experiment was also performed on two top rhythmic gymnasts at the age of 12. The detection was done before and two hours after the gymnastic practice (impacts, different jumps, and loading of the axial system in flexion, extension and lateroflexion). The method was also used for the investigation among people of different age (three participants born in 1934, 1943 and 1995 were measured).

RESULTS AND DISCUSSION

The results have showed that a different type of loading and also ageing causes some changes of mechanical properties of tissue in the axial system. A smaller reaction of the axial system after the 45 minute drive was observed among the pregnant drivers of the monotonous vibration loading. The larger differentiated reaction was detected after the 120 minute drive [4]. The pregnant drivers displayed higher spine absorption, i.e. lower amplitude of acceleration, after vibration loading. The resonant frequency of the tissues is also moved to the lower frequencies. The opposite tendency was discovered in the case of gymnasts. The absorption abilities of the spine are lower after the practice (Figure 1).

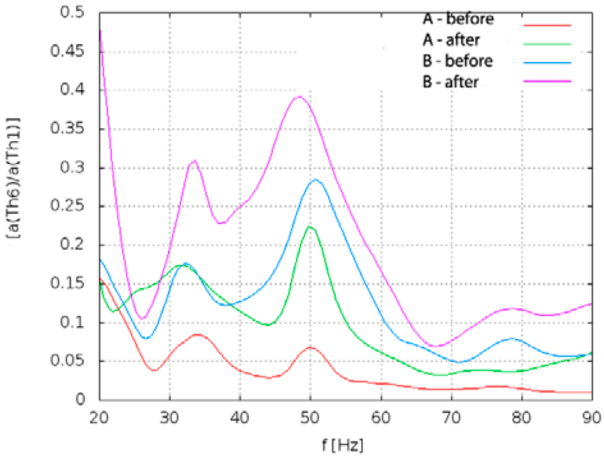

Figure1: The TVS method – the curve of the frequency spectrum absorption between Th1 – Th6 among the rhythmic gymnasts.

The obtained data showed the changes of elastic properties of the spinal corset due to increasing age (Figure 2).

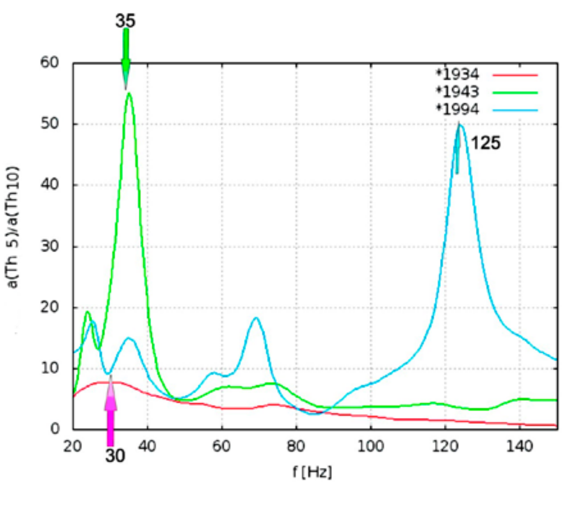

Figure 2: The effect of aging on the differences of elastic properties of the spine.

The magnitude of the resonant frequency and the length of the excited spine indicate elastic properties. According to a great difference of elasticity between the spine and surrounded connective tissue, the high frequencies are mainly transfer by the spine, and therefore the only significant frequency is the mostly amplified one, the resonant frequency. This was confirmed by the youngest participant whose spinal corset showed the highest value of elastic characteristic which means the best ability to transfer mechanical loading. On the other hand the oldest participant had the lowest value.

CONCLUSIONS

The above mentioned TVS method presents a diagnostic apparatus that enables one to classify the characteristics and changes of the spinal system and its parts qualitatively and quantitatively. The TVS method can be used for classification, prevention and therapy of consequences of extreme activities. In addition the TVS method is ideal for checking the condition of the axial system during therapeutic, recovery, training, ergonomic and other regimes.

ACKNOWLEDGEMENTS

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REFERENCES

1. Demirell, Y. (2007). Nonequilibrium Thermodynamics (2nd ed. ed.). Amsterdam: Elsevier Science B. V.
2. Desmoulin, G. T., Yasin, N. I., & Chen, D. W. (2007). Spinal mechanisms of pain control. *Clin J Pain*, **23**(7), 576-585.
3. Jelen, K., Zeman, J., Kubový, P., Drahorádová, R., & Holub, T. (2010). Dynamic of Transfer Characteristic of Driver´s Body Biocomponents During Vehicle Driving. In S. Otáhal, Konvičková, S., Denk, F., Holub, O. (Ed.), *Spinal complexity and its biomechanical reflection* (1st. ed. ed., pp. 131-141). Brno.
4. Jelen, K., Kloučková, K., Zeman, J., Kubový, P., & Fanta, O. (2012). Changes in attenuation charakteristics of axial system of pregnant drivers detected by the TVS method. *Neuroendocrinology letters*, **33**(4).
5. Kuželka, J., Otáhal, M., Heralt, P., Jiran, L., Moravec, M., & Kubový, P. (2012). Experimental determination of spinal segment kinematics. *Acta universitatis carolinae - kinanthropologica*, **47**(2), 166-172.
6. Magnier, C., Boiron, O., Wendling-Mansuy, S., Chabrand, P., & Deplano, V. (2009). Nutrient distribution and metabolism in the intervertebral disc in the unloaded state: a parametric study. *J Biomech*, **42**(2), 100-108.
7. Machač, D. (2011). *Modeling of spinal chord under dynamical loading. [Modelování dynamicky zatěžované páteře]*. Praha: Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Department of Mathematics.
8. Maršík, F., Dvořák, I. (1998). *Biotermodynamika* (2nd revised edition ed.). Praha.