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MECHANICAL CHANGES OF THE AXIAL SYSTEM DETECTED BY THE TVS METHOD

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SUMMARY

This experiment is aimed at the analysis of the transfer changes of a vibration load applied to the axial system which were not only affected by a monotonic load during the car ride, but also by the shape, tissue, and weight changes in pregnancy. A vibration load applied to the body parts (spinous processes of C7 and L5) was observed on the segments of the vertebrae (Th1–Th12 and L1–L5) and adjacent tissue of the axial system. The TVS (transfer vibration through spine) was chosen as a detection method. The research results proved the fact that changes caused by the monotonic load influence the way of the waves transfer through the axial system of the observed participant.

Key words: vibrations, monotonic load, mechanical characteristics, axial system, spine, vibrations transfer, vibrations transmission, pregnancy

INTRODUCTION

The rheological tissue changes occur in the axial body system as a result of insufficient physical activity (for example long-term sitting). For instance, a decrease of the physical resistivity of the ligament apparatus to mechanical stress is detected while a long-term monotonic quasi-static tensioning loading is applied. The relevant changes are also measured for the functional segments of the human spine (the intervertebral discs, intervertebral joints, and the ligament apparatus of a particular segment of the axial system) (Johnson, 2001). The results of studies assessing discomfort during the car drive confirm different levels of discomfort perceived by the drivers in different body regions (Jelen, 2007, Zeman, 2007). According to the goniometry, the posture of the driver could contribute to drivers discomfort (Ravnik, 2008).

All the above mentioned changes are underlined by the influence of pregnancy on the shape and tissue characteristics which lead to the changes not only in the areas of abdomen and uterus, but also in other parts of the human body (the position of pelvis, weight of particular body segments) (Fast, 1987). Therefore, the requirements to the human movement system even increase in pregnancy.

METHODS

For detection of the transfer of a vibration stimulus throughout the axial system by the TVS (transfer vibration through spine) were selected three nonpregnant drivers before and after a four-hour car drive. The same measurement of changes of the transfer along the spine was held for a woman who was 16, 27, 32 weeks pregnant. The method is based on the use of a five-msec semi-bandwidth γ pulse stimulus and consequent application of continuously changing harmonic stimuli which periodically differs between 5 Hz and 160 Hz to the vertebrae C7 and L5. This wave is carried through the axial system and its acceleration on the spinous processes between C7 and S1 is scanned with the help of the accelerometric 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

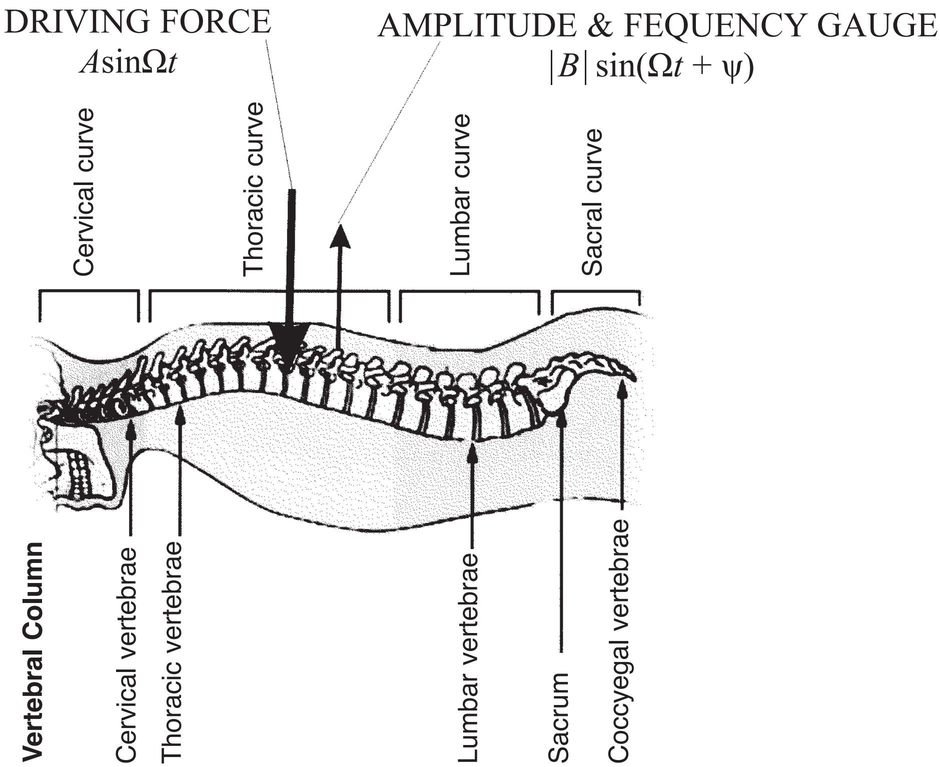

Figure 1. On the figure is the schema of measurement where A is amplitude of driving force, Ω is momentaneous driving frequency, B is the amplitude of the answer, ψ is phase shift. The $A\sin\Omega t$ is the input and the $|B|\sin(\Omega t + \psi)$ is an ouput of the measurement.

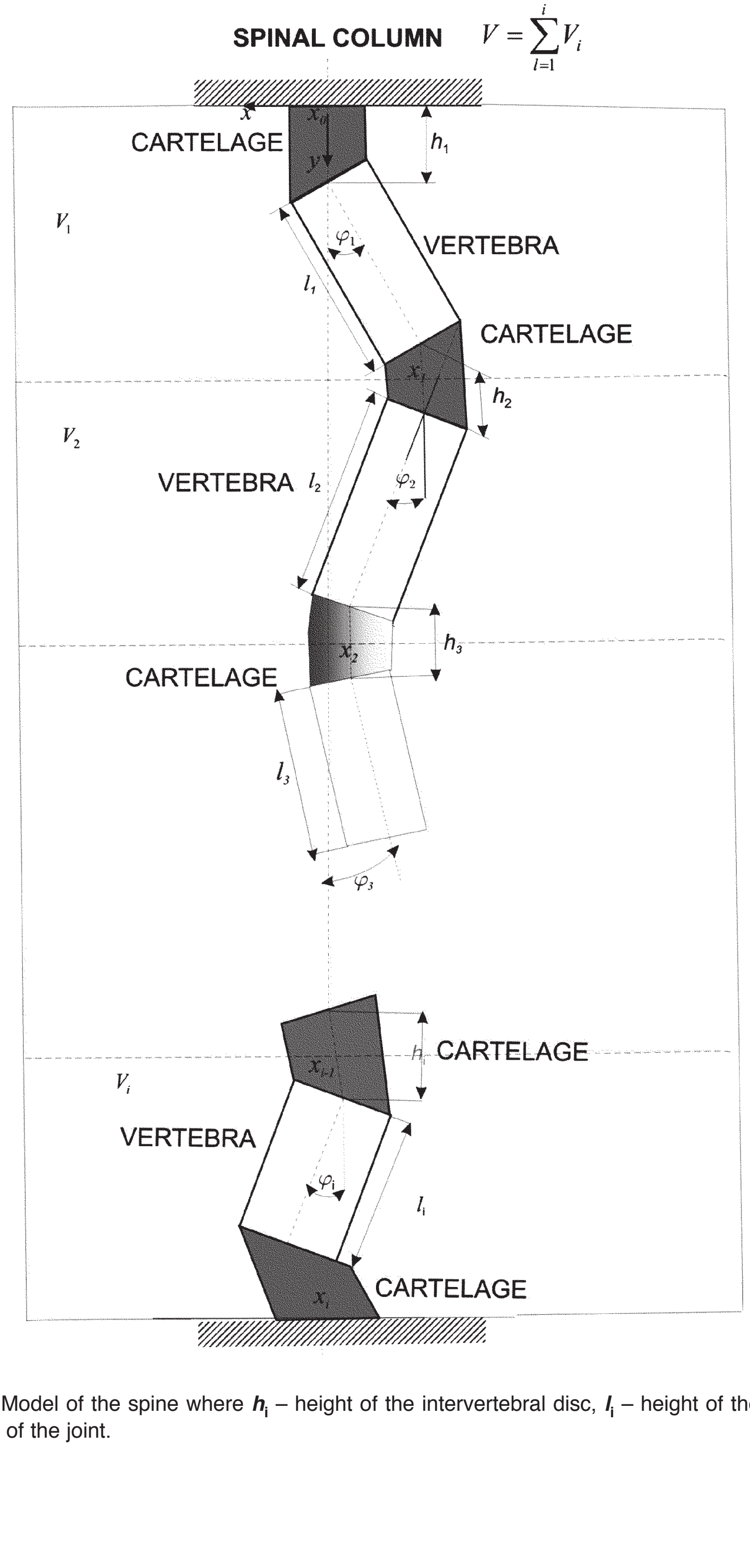

Figure 2. Model of the spine where $\boldsymbol{h}_i$ – height of the intervertebral disc, $\boldsymbol{l}_i$ – height of the vertebra, $\boldsymbol{\varphi}_i$ – angle of the joint.

wave passes through. The mechanical tissue changes are retroactively characterised by a speed of the wave transmission. A simplified model of the human spine which was built in order to analyze the measured data according to the basic characteristics of the measuring system helped to prove the above mentioned expectations (Figure 1 and 2).

According to the measured data (the input stimulus – A and its recorded responses – B, measured on the spinous processes vertebrae) and the geometric features of the human spine (the height – *h*, the radius of the intervertebral discs – a) it is possible to identify changes of the viscoelastic properties of the human spine before and after applying

$$\frac{\pi a^4 E}{\gamma h \Omega} = \pm \frac{\left(\frac{|B|\Omega^2}{A} \pm \cos\psi \right)}{\sin\psi}$$

Equation 1. The relationship between measured data, geometric features and viscoelastic characteristics.

vibration or another type of loading. It was found a relationship between the complete elastic model of the human spine – E and its viscosity γ from the detected response (the rate between the exciting amplitude and the amplitude of a particular vertebra) and the phase shift – ψ of the exciting signal (Equation 1).

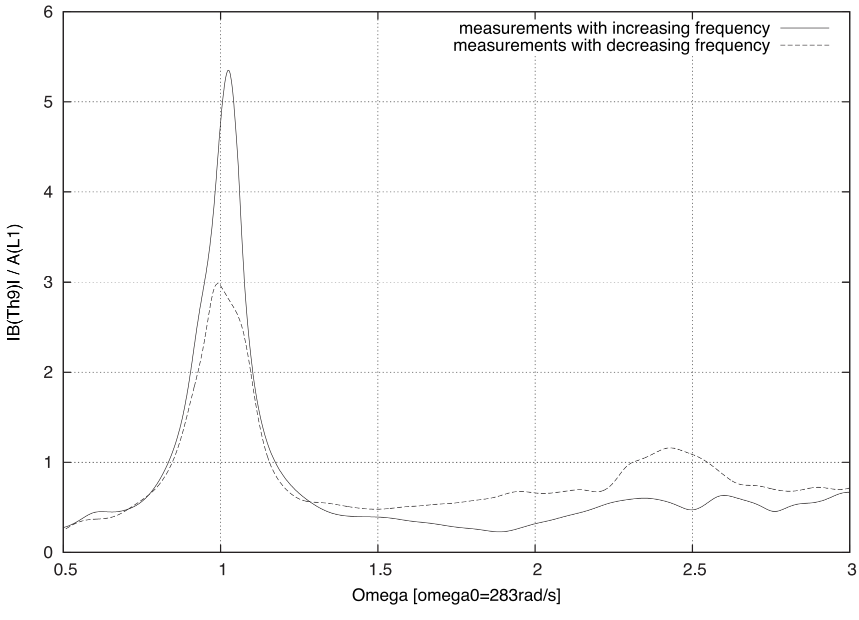

Figure 3. The transmission of the wave between two segments (Th9 and L1) during two measurements going one right after the first one – measurement with increasing and decreasing frequency.
The x axis are multiple of the resonance frequency, 1 correspond to 25 Hz.
The y axis is the ratio of output and input amplitude.

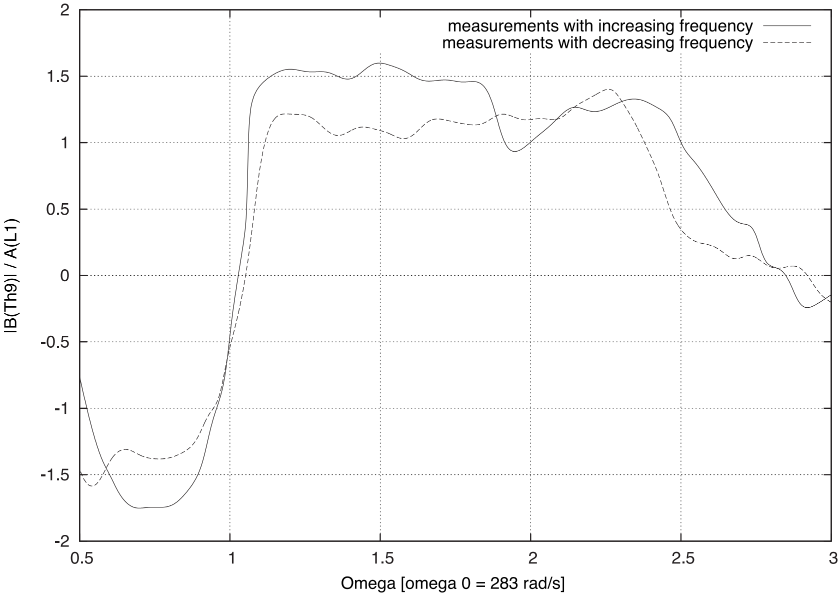

Figure 4. The transmission of the wave between two segments (Th9 and L1) during two measurements going one right after the first one.
The x axis are the multiples of the resonant frequency and the y axis is the phase shift between the two measured segments. The phase shift around resonant frequency (25 Hz) is close to zero.

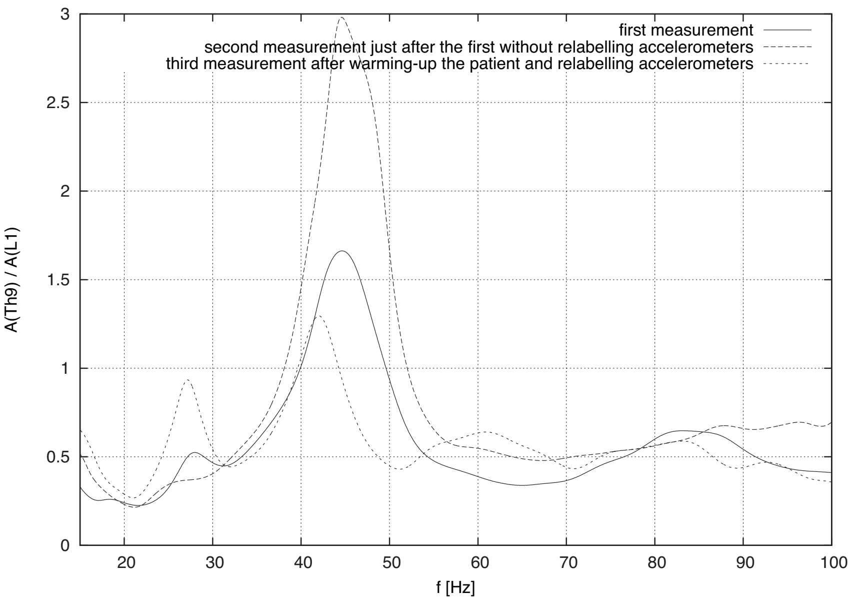

Figure 5. The ratio of amplitudes between the segments Th9 and L1 during the three measurements going in the row. The highest amplitude is when the person was relaxed and the damping was lowest, the lowest amplitude is when the person had some physical activity and the damping was highest.

RESULTS

From the model is clear, that according to the measured data (the input stimulus and its recorded responses measured on the spinous processes vertebrae) and the geometric features of the human spine (the height and radius of the intervertebral discs) it is possible to identify changes of the viscoelastic properties of the human spine before and after applying vibration or another type of loading. A relationship is found between the complete elastic model of the human spine and its viscosity from the detected response (the rate between the exciting amplitude and the amplitude of a particular vertebra) and the phase shift of the exciting signal (Equation 1).

CONCLUSIONS

The research results of non pregnant drivers and pregnant driver show the existence of mechanical properties changes in the observed tissue before and after the loading procedure. Not only is greater absorption of the spine tissue evident, i.e. lower acceleration amplitude, but even the resonant frequency of the tissue moves towards lower frequencies (Figure 5). On the other hand, two successive measurements (the TVS method was used) on the same driver who rested in a horizontal position for 90 minutes show the opposite tendency, i.e. acceleration amplitude increased, the tissue was rested, and the absorption decreased (Figure 3 and 5). The phase shift at the resonant frequency (in this case 25 Hz) approaches zero (Figure 4).

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MECHANICKÉ ZMĚNY OSOVÉHO SYSTÉMU DETEKOVANÉ METODOU TVS

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SOUHRN

V našem experimentu jsme se zabývali určením změny přenosu vibračního zatížení axiálním systémem jednak vlivem monotónního zatížení a dále pak i v důsledku tvarových, tkáňových a hmotnostních změn těla v těhotenství. Zatížení segmentu těla vibracemi bylo na trnových výběžcích obratlů C7 a L5, analyzovaným segmentem byly ostatní obratle hrudní a bederní páteře a přilehlé měkké tkáně axiálního systému. Metodou detekce byla metoda TVS (transfer vibration through spine). Výsledky měření potvrdily, že se vlivem změn v důsledku monotónního zatížení mění I přenos vlnění axiálním systémem sledovaného subjektu.

Klíčová slova: vibrace, monotónní zatížení, mechanické vlastnosti, axiální systém, páteř, přenos vibrací, těhotenství

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