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THE INFLUENCE OF THE REDUNDANT MOVING ON THE PRESSURE MAGNITUDE VARIATION BY MEN SITTING

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1. Introduction

One of the basic characteristics of the comfortable sitting is the magnitude of the pressure with its distribution in the contact regions. The sitting pressure takes effect to the bulked muscles and long bones. Its influence trough long-time duration can cause changes in soft tissues and skeleton. It is known that magnitude variations of pressure on contacting surfaces have influence on blood circulatory system of sitting surfaces. Human body is provided for moving, but not for resting. Prolonged sitting may lead to swelling of the lower extremities, especially in constrained postures. Oedema results from increased net transcapillary filtration, exceeding removal of fluids by the lymphatics. The dominant factor promoting oedema is increased capillary hydrostatic pressure, caused by increased venous pressure. The vein pressure of the feet in a horizontal position is approximately 660 Pa, increasing to 9,3 - 10,6 kPa in upright position. At passive sitting, the pressure is in the order of 6 - 8 kPa, determined by the height of the blood column from the feet to the heart. When walking, the vein pressure normally decreases to 3,3 - 4 kPa, caused by vein pump mechanisms in the lower extremities [1, 2]. Based on this knowledge, short walking breaks in office work is suggested to reduce the amount of leg/foot oedema [1]. Deep venous thrombosis (DVT) and pulmonary embolism are common complications resulting from prolonged periods of bedrest or immobilization of the limbs [3]. Today it is very present fact, that even young car-drivers who immovable sit during all day, can burden own veins very strongly and it can cause the venous thrombosis. The international diagnosis for this condition is known as the effort thrombosis. Today, the passengers who travel in plane on long-time flights are warned and learned about the possible risk of the venous thrombosis. Suhov [1] was showed in her work that a human during the sitting from the time period of 5 hours changes his position about 1000 times, that response an average once in 18 seconds. The dynamics sitting or the continuous passive motion is a new technique into the ergonomic of sitting. A lot of jobs demand continuous sitting or the standstill position of any body parts. During static measurement of sitting pressure it is noticed that even very small displacements of any human body parts cause significant pressure variation [4]. Therefore, pressure measurements depending on time were performed with the aim to assess the influence of redundant moving on static measurements. Also, the influence of redundant movements on the magnitude and distribution of sitting pressures has been determined as well as the evaluation, which movements lead to the highest variation of sitting pressure magnitude. One can conclude from the pressure shape and magnitude variation, which kind of the body motions were in fact. The recommendations based on the performed investigations can be given to better explain which kind of motions should be favoured in limited conditions to realise much better dynamic sitting.

The measurements of the sitting pressure were performed on the specially developed seat with the pressure transducers in form of an indentor with diameter of 8 mm, Fig. 1.

In the recent studies [1, 6] total displacements of sitting surface during the long time period were measured, free from the places where the displacements were originated. On the ground of such re-

corded data a Fourier frequency analysis of displacements in range of 0-20 cycles/min was performed. The measurements were performed in the area under the sitting bones (tuber ossis ischii) or near this area.
The sitting pressure variation acts also as the dynamic pump that promotes the blood circulation in the vein-pumping systems. The redundant movements activate some muscle groups as agonists or as antagonists and their activities also promote the blood circulation in the vein systems.

2. The force-measuring device (indentor)

For measurements of the forces and sitting pressures the force-measuring device (indentor) is used. The measuring parts of the indentor were: a cylindrical part with diameter of 4 mm, with shell thickness of 0,1 mm and length of 40 mm. On the middle of measuring piece three the strain gauges were placed. The strain gauges were placed in position to make possible determination of values of the action forces from measured strains of the oblique loaded shaft. One-axial strain gauges TML type FLA –3-11, length 3 mm, resistance 120 Ω with the value of k-factor 2,13, are used in test placed in arrangement shown in Fig. 2 and 3. The measurements were performed with three-channels amplifier type KWS 3082A, from firm HBM (Hottinger Baldwin Messtechnik GmbH, Darmstadt, Germany). As an analogous/digital converter Multifunction Board PCI 20428-3A was used.

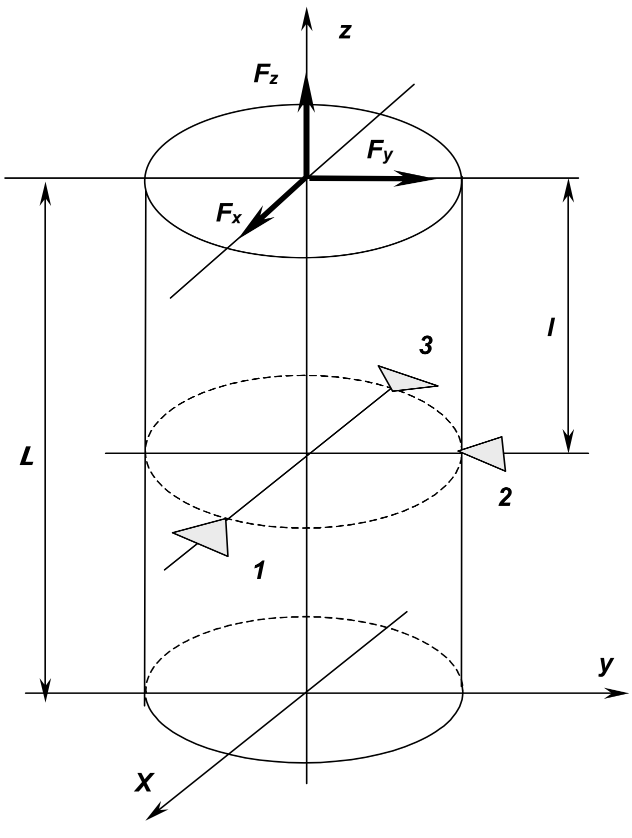

Figure 1. Dispositions of the strain gauges on the force-measuring device (indentor)

The recorded data from the amplifier were fed to PC via A/D converter. Measured forces were determined by applying Microsoft Excel and own developed software application for analysis of the recorded data. The results of the measured force values in dependence of time are shown in Fig. 4. – 19. For recording of sitting forces foam thick 8 mm, from firm "Oriolik" – Oriovac with the impress hardness 4,24 kPa / 40 % (ISO 2439), was placed on the seat. Although used force-measuring device can measure forces in three directions, one normal and two tangential, only the results of the measurements of the normal sitting forces are described in this paper.

Figure 2. Force-measuring device (indentor)

Figure 3. The equipment used to measure sitting pressure

3. Results of measurements and analysis

The measurements of the magnitude variations of sitting pressure caused by movements of arms, legs, head and body even caused by speaking were carried out.

3.1 Magnitude variations of sitting pressure caused by legs movement

Redundant moving of legs is more frequent movement produced by a sitting human, but many controls (e.g. in car) demand limited motion. Therefore pressure magnitude variations by isometric loading of muscles of calf and thigh are measured because that measurement was only possible in this case. The experimental results as function "force-time" are shown in Fig. 4 and 5.

Isometric loading and unloading of the calf muscles is very important in blood circulation of the lower extremities that is based on the principle of a dynamic pump described in [2]. The experimental results are shown in Fig 4. The absolute variation magnitude of the sitting force is very small $\Delta F = 2$ N, but the relative magnitude variation of the sitting pressure is about 20%.

Muscles in the buttocks area are important for isometric loading and unloading of the thigh muscles (Fig. 5). From the results it can be seen that the maximal absolute magnitude variation of sitting force is $\Delta F = 5{,}5$ N, but the relative magnitude variation of sitting pressure is about 50 %.

One of frequent movements in the sitting posture is "forward-backward" moving of legs. Experimental results are shown in Fig. 6. From the results it can be seen that the maximal absolute magnitude variation of the sitting force is $\Delta F = 20$ N and the relative magnitude variation of the sitting pressure is up to 80%.

Sitting space is often limited in front of the seat, causing possibility of moving legs only in back direction under seat. From the experimental results that are shown in Fig. 7 it can be seen that the maximal magnitude variation of the sitting force is $\Delta F = 8$ N and the relative magnitude variation of the sitting pressure is up to 35%

The experimental results of the magnitude variations of the sitting pressure caused by leaning of legs on the floor in a horizontal direction, when legs and knees make angle of 90^{o} are shown in Fig. 8. Results are showing that the maximal magnitude variation of the sitting force is $\Delta F = 40$ N and the relative magnitude variation of the sitting pressure is 80%.

The experimental results of magnitude variation of the sitting pressure caused by putting "leg over leg" in posture when legs and knees make angle of 90^{o} are shown in Fig. 9. From the results it can be seen that the maximal magnitude variation of the sitting force is $\Delta F = 26$ N and the relative magnitude variation of the sitting pressure is 58%.

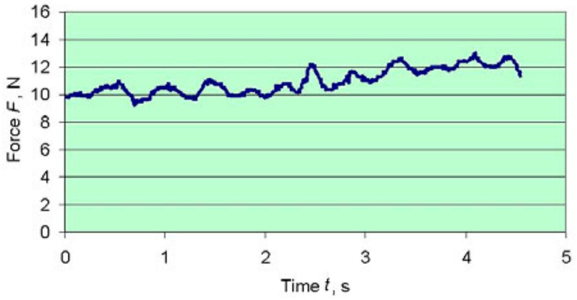

Figure 4. Isometric loading and unloading of the calf muscles

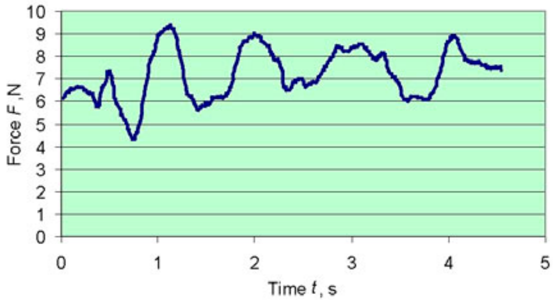

Figure 5. Isometric loading and unloading of the thigh muscles

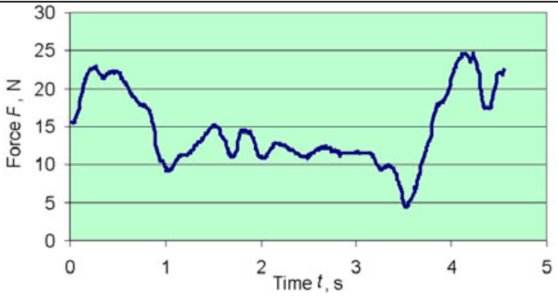

Figure 6. Moving of legs “forward-backward”

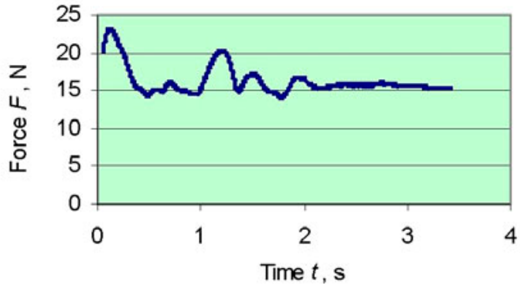

Figure 7. Moving of legs to “under seat”

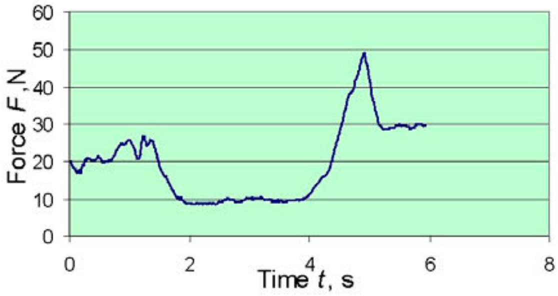

Figure 8. Leaning of legs on the floor in a horizontal direction with backrest

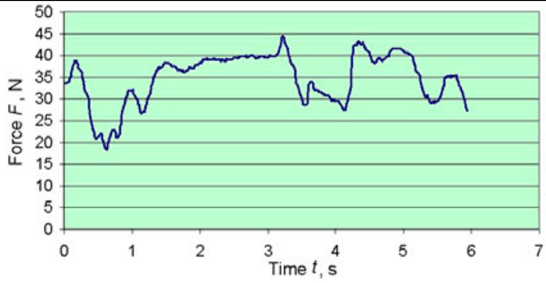

Figure 9. Putting “leg over leg”

3.2 Magnitude variations of sitting pressure caused by movement of arms

In a sitting posture movements of arms often occur, but influence of these displacements onto the magnitude variation of sitting pressure is relatively small. Only in case of the quickly movements of arms in a stretched out posture, the greater magnitude variation of the sitting pressure were measured. The experimental results of the magnitude variations of the sitting pressure caused by movements of arms, when the body was at rest on the backrest of chair are shown in Fig. 10. From the results it can be seen that the maximal magnitude variation of the sitting force is $\Delta F = 10$ N and the relative magnitude variation of the sitting pressure is 20%.

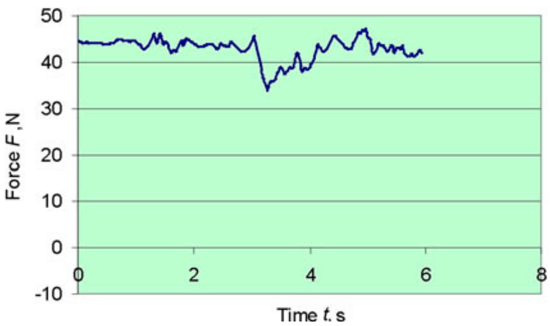

Figure 10. Movements of arms in “forward-backward” direction

3.3 Magnitude variations of sitting pressure caused by head movements

Movement of head are not relatively often and its influence onto the magnitude variation of the sitting pressure is small. The experimental results of the magnitude variations of the sitting pressure caused by head movements in direction "left-right" and "up-down" produced with high intensity are shown in Fig. 11. From these results it can be seen that the maximal magnitude variation of the sitting force is $\Delta F = 4\,\mathrm{N}$ and the relative magnitude variation of the sitting pressure is 10 %.

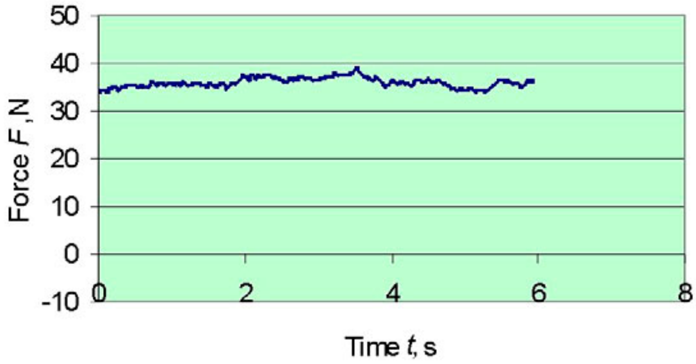

Figure 11. Rotation of head in "left-right" direction

3.4 Magnitude variations of sitting pressure caused by body movements

Moving of men body and head in relation to extremities and its influence onto the sitting pressure is small, but every movement of extremities gives small displacement of body while sitting. On Fig. 12 are shown experimental results of the magnitude variations of the sitting pressure while upper body was moved in "forward-backward" direction with high intensity. Measured results are showing development of completely decreasing areas (Tuber ossis ischii). Different areas took over that loading (Reg. femoris dorsalis). The magnitude variations of the sitting pressure caused by movement of upper body in "left-right" direction are shown on Fig., but in the limits that were allowable by the armrest of the chair. From the results it can be seen that increase of the maximal magnitude variation of the sitting force is $\Delta F = 22\,\mathrm{N}$ and that the relative magnitude variation of the sitting pressure is about 50 %, while maximal magnitude variation of the sitting force decrease was $\Delta F = 32\,\mathrm{N}$ and the relative magnitude variation of the sitting pressure was about 70 %.

Measured results of the magnitude variations of the sitting force during the process of sitting down and getting up are shown on Fig. 14, while experimental results of the magnitude variations of the sitting force caused by isometric loading and unloading of the abdominal muscles are shown on Fig. 15. From these experimental results it can be seen that is the maximal magnitude variation of the sitting force was $\Delta F = 4\,\mathrm{N}$ and the relative magnitude variation of the sitting pressure was about 40 %.

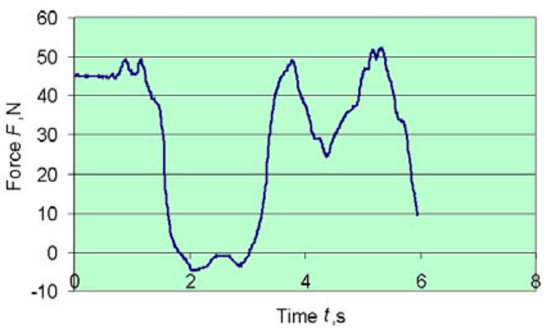

Figure 12. Inclination of the upper body in "forward-backward" direction

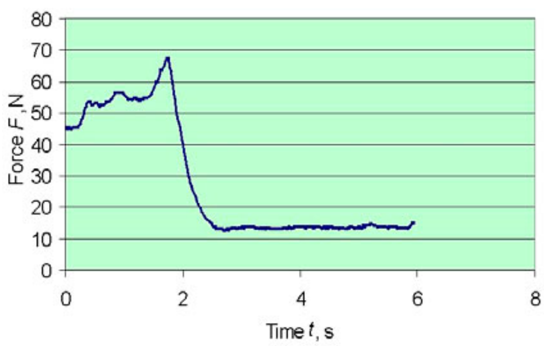

Figure 13. Inclination of the upper body in "left-right" direction

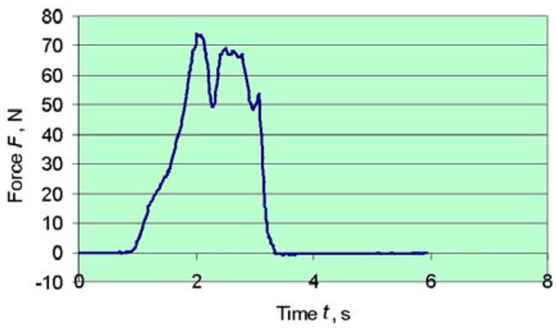

Figure 14. Process of the sitting down and getting up

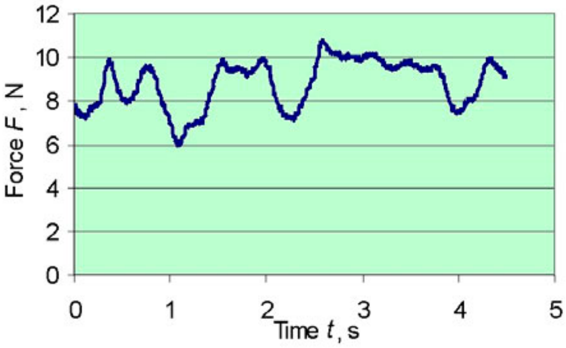

Figure 15. Isometric loading and unloading of the abdominal muscles

3.5 Magnitude variation of sitting pressure caused by speaking

Influence of speaking on the magnitude variation of the sitting force is observed. The magnitude variations of the sitting force caused by pronunciation of words ″dobar dan″ ("good day") are recorded and results are shown on Fig. 16 and 18. These magnitude variations were measured on different places of body. Measured data results of the sitting pressure magnitude variations, Fig 16, are showing that relative magnitude variation of sitting pressure is about 40 % at about 30 % by the maximal sound intensity of 75 dB, Fig. 18. The same experiment was conducted but words ″tik-tak″ was pronounced. The measured results are shown on Fig. 19. The relative magnitude variations of the sitting pressure in this experiment were about 40 % by the maximal sound intensity of 71 dB.

Fig. 17 shows recorded data of the sitting force magnitude variations during the deep respiration. From the experimental results it can be seen that the maximal magnitude variation of the sitting force is $\Delta F = 2\,\mathrm{N}$ and the relative magnitude variation of the sitting pressure is about 30 %.

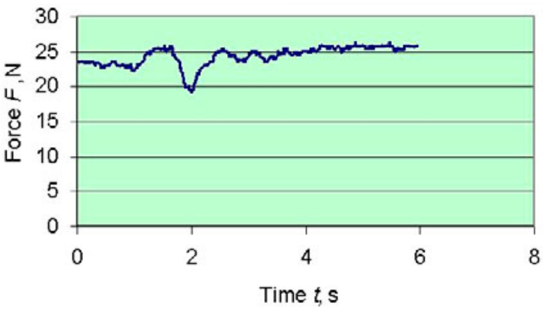

Figure 16. Pronouncing the words ″dobar dan″

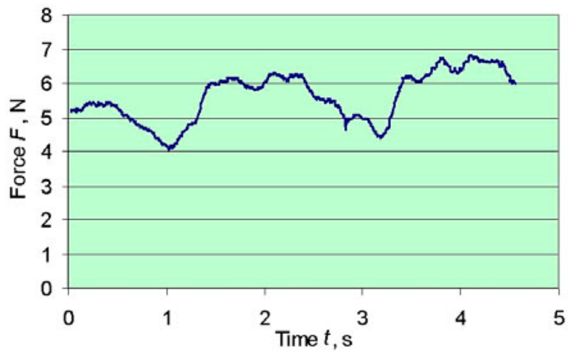

Figure 17. Pronouncing of deep respiration

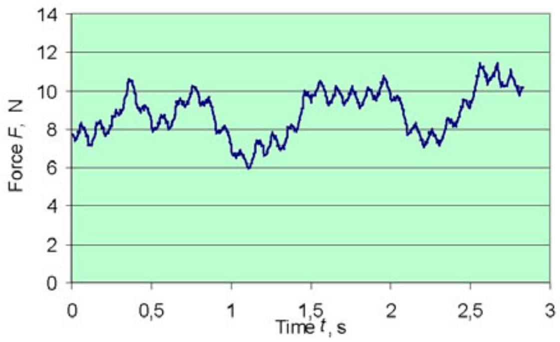

Figure18. Pronouncing the words ″dobar dan″ with sound intensity of max. 75 dB

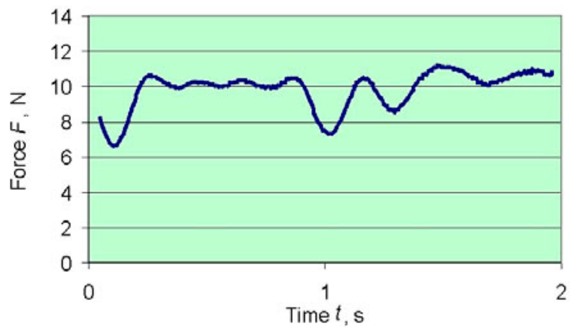

Figure 19. Pronouncing the words ″tik tak″ with sound intensity of max. 71 dB

4. Conclusions

The influence of the redundant moving on the magnitude variations and distribution of sitting pressure should be obtained from the measurements on the full sitting surface. Although it is often difficult to separate the influence of particular motions of body parts, from conducted research and measured results it can be concluded:

The maximal magnitude variations of sitting pressure are obtained from the redundant moving of body parts, and then by moving of legs.

Movements of arms and head have relatively small influences on the magnitude variations of the sitting pressure.

It is very interesting fact that the magnitude variations of the sitting pressure caused by loud speaking and deep respiration were bigger than the magnitude variations of the sitting pressure caused by quickly movements of arms and head.

At passive sitting, the isometric loading of the leg muscles has a significant influence on the magnitude variations of the sitting pressure.

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