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A Device for Preventing Occupational Diseases of Lower Legs

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A Device for Preventing Occupational Diseases of Lower Legs

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Physiological processes characteristic of the fatigue of legs mainly appear when the worker's activity requires standing. If the processes are intensive and regular, various diseases of legs, such as varicose veins and musculoskeletal disorders of legs and feet, can develop. Therefore, methods of reducing the fatigue of legs are important in occupational health protection. Air jet massage technology was developed and an appropriate massage device was built by the authors. The massage head turning around the lower leg and moving up and down gradually covers the leg's surface. To determine the efficiency of the massage, fatigue processes were studied. These studies showed that jet massage effectively reduces both the subjective and objective fatigue symptoms. The device is convenient for use in industry, services, and at home.

air jet massage lower leg fatigue

1. INTRODUCTION

Most people working in the standing position feel the fatigue of legs at the end of the workshift or in the evening. This is particularly true in industrially developed countries because work is highly intensive there and, consequently, there are fewer possibilities to sit down. Fatigue of the lower limbs and of the low back are the most common. Simple measures like mechanical massage, periodic brief sitting down, physical exercise in special open canvass footwear with special inner soles, and so on, have not had sufficient physiological and psychological effect. Hydromassage (water jet) devices have sometimes been used (Polyakova, Ryzhov, Minyayeva, & Komin, 1990). They are effective but expensive, they require much room, water is splashed, and the devices may spread infectious diseases of the skin. Therefore, they are not popular with workers. To avoid these shortcomings, an air jet massage (pneumomassage) device was developed.

2. AIR JET MASSAGE DEVICE

The massage device developed by the authors is similar to a chair, in which a person sits and stretches his or her leg at a convenient 45° angle. The shoe is left on and the

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sole rests on a special support, restricting its sideways movements. The moving head, equipped with air nozzles, automatically turns 270° around the lower leg and moves up and down (Figure 1).

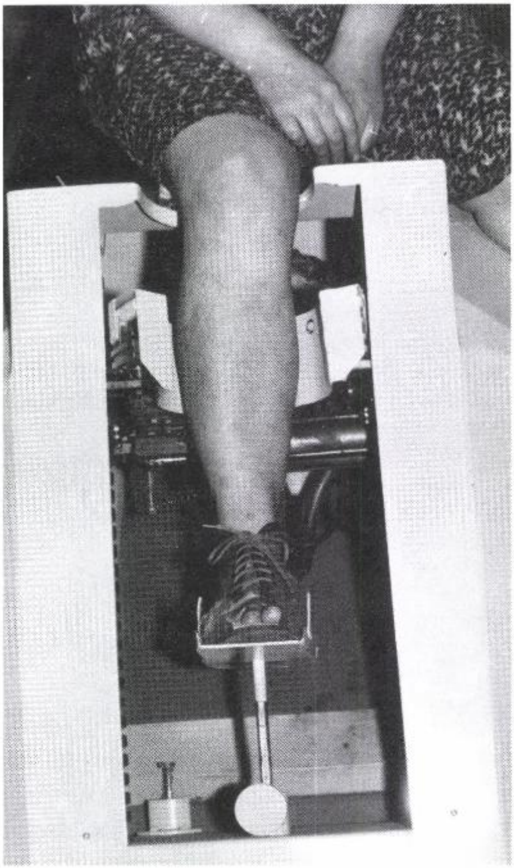

Figure 1. Air jet massage.

The whole surface of the calf is gradually covered by the action of the air jet, making it possible to combine effectively the cooling and massage effects of the air jet with the physiological characteristics of the human body. The full massage cycle (up and down) takes approximately 1 min and it can be stopped and continued in any position of the massage head. The device has to be connected to a workshop compressed air system or have its own air supply. In designing the moving head of the experimental device, special attention was paid to safety measures.

3. AERO- AND THERMODYNAMICS OF MASSAGE

To determine the optimal parameters of the massage jet—diameter of nozzle, air pressure, temperature, and so on—thorough research was conducted to control aero- and thermodynamic processes in the massage depression. Mathematical modeling of aerodynamic processes was undertaken using a finite-volume method of computational fluid dynamics to determine the relationships for the control of these processes. The maximum pressure level was determined by the tolerable sensation for female participants and it is about 0.09 MPa. Furthermore, the massage depression parameters in different calf regions were determined, using a group of female and male participants of different ages and tissue structure. On the basis of the maximum ratio of massage depression volume and supplied energy, the optimal diameter of the massage jet was determined to be about 4 mm. Air velocity and pressure distribution in the massage depression were experimentally investigated for the massage depression with average dimensions.

4. METHODOLOGY OF EVALUATING FATIGUE SYMPTOMS

We used a test for rating fatigue symptoms in various body regions for the quantitative assessment of fatigue processes in the lower limbs. The participants of the investigation had to note the intensity of fatigue sensations in different regions of the lower limb, using an analog 100-mm scale (100 mm = 100% intensity) and a special chart (Kristjuhan, 1992b). In designing the chart, the peculiarities of these sensations in different body regions, pathology symptoms of the musculoskeletal system, and the spatial threshold of discomfort sensations were taken into account, making the distinction between regions easy for workers (Figure 2). Fatigue sensations were assessed in the right lower leg and foot.

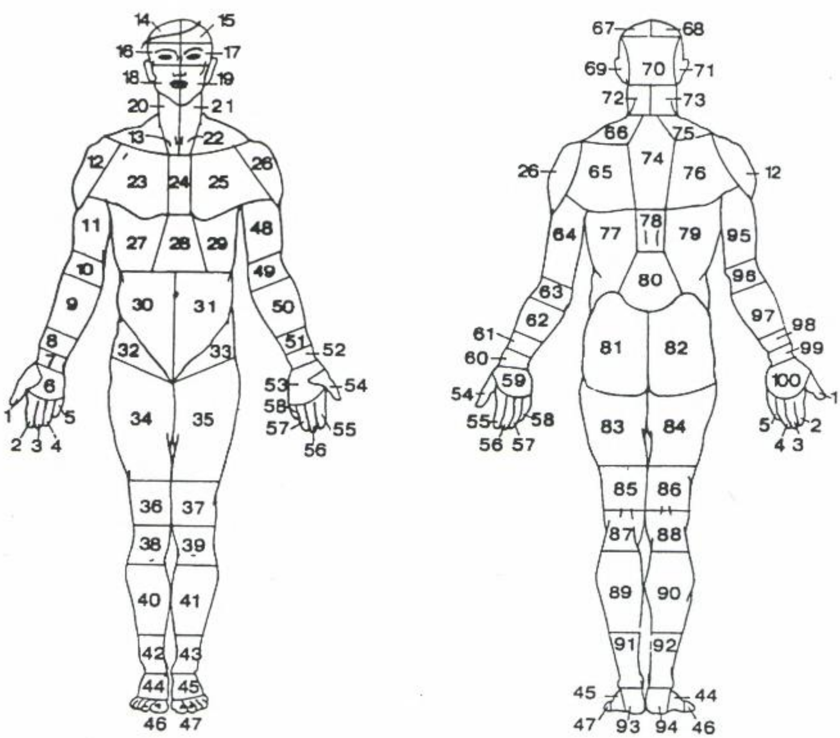

Figure 2. Body regions.

For an objective evaluation of the intensity of physiological processes of fatigue in legs, we used precise measuring (to within 0.2 mm) of the girths of human limbs with perimeter gauges that consist of measuring tapes with loads and calibrated rulers. The width of the measuring tapes was 2–3 mm and there were 5- or 10-g loads at their ends (Kristjuhan, 1992a). The perimeter of the lower leg was measured in its middle part, near the maximum diameter. The tape position was marked on the lower leg to avoid displacement at different measurements. As during air jet massage the participant is sitting, the importance of 2-min passive sitting (absence of muscle pump) in changing the perimeters was also determined. Because the perimeters of lower legs vary greatly from individual to individual, it was appropriate to express the measurement results not as absolute values of perimeters but as their changes in millimeters or as percentages.

We studied fatigue symptoms and limb perimeters before and after massage in 48 practically healthy female textile workers. The participants (weavers and spinners) worked in the standing position. Workers who said that they had chronic diseases with persistent complaints were excluded from the study. The mean age of the participants was 32 (17–54). Air jet massage was carried out in the sitting position using 0.09 and 0.06 MPa air pressure for 2 min. The temperature of the air jet in the massage device supply pressure collector was 24 °C but the air cooled down due to the expansion of the jet. The device was used 1–1.5 hrs before the end of the shift when the workers felt intensive fatigue. After the massage the participants returned to their workplaces.

Fatigue ratings and limb perimeter measurements were made before the massage and immediately after it in a separate room not far (10–50 m) from the participant's workplace. Fatigue ratings were carried out also 50 min after the massage. Wilcoxon's matched pairs test was used in the case of fatigue sensations and the *t*-test was used to assess the differences of perimeters.

5. RESULTS OF AIR JET MASSAGE

The intensity of fatigue symptoms decreased significantly ($p < .05$) in every studied region of the foot and lower leg after air jet massage (Table 1). When the air pressure was 0.06 MPa, the decrease of the fatigue symptoms was even more noticeable. Changes in the average perimeter of the lower leg as a result of the pneumomassage and passive sitting are presented in Table 2. It is evident that massage significantly ($p < .05$) decreases the perimeter of the lower leg, compensating also for its increase due to passive sitting. The results are better in the case of air pressure 0.06 MPa. Studies of fatigue sensations 50 min after the pneumomassage showed that their intensity in the lower legs and feet was not restored: On the contrary, it was significantly ($p < .05$) lower at 73% of the value before the massage.

TABLE 1. Intensity of Fatigue Sensations in the Foot and Lower Leg After Pneumomassage (100% = Intensity Before Massage)

	Fatigue Sensation Intensity (%)				
Operating pressure	Toes	Midfoot	Ankle	Heel	Lower Leg
Air pressure 0.09 MPa	26	33	23	9	8
Air pressure 0.06 MPa	0	18	2	0	2

TABLE 2. Changes in the Lower Leg Perimeter as a Result of Pneumomassage and Passive Sitting

	Perimeter Change	
Operating pressure	mm	%
Air pressure 0.09 MPa	−0.4	−0.11
Air pressure 0.06 MPa	−0.6	−0.16
Passive sitting	1.2	0.34

6. DISCUSSION

After an air jet massage, the intensity of fatigue decreases essentially, especially at the supplied air pressure of 0.06 MPa. Its effect lasts more than 50 min. We did not aim to study thoroughly the physiological mechanisms of pneumomassage in tissue. These physiological processes are probably analogous to the mechanisms of water jet massage, which has been used (mainly in the textile industry) in practice and studied in laboratories. It is interesting to note that in the case of pneumomassage, the subjective fatigue symptoms practically disappeared in toes and heels, which had less direct contact with the air jets. Therefore, the reduction of the discomfort cannot be explained by the diminished sensitivity of the receptors that provide information about discomfort. Some neural mechanisms are probably involved in the decrease of the fatigue symptoms.

Massage may mechanically cause a more homogenous distribution of substances in the interstitial space and improve peripheral circulation (Sjøgaard, Savard, & Juel, 1988). As increased skin temperature promotes edema and fatigue, cooling the skin acts as a fatigue-diminishing factor. The influence of massage through the nervous system may be important. Some data (Maspers, Ekelund, Björnberg, & Mellander, 1991) suggest that sympathetic nerve activity provides effective protection against excessive work-induced rise of capillary pressure and harmful plasma fluid loss into the extravascular space of working muscles. It is possible that analogous physiological mechanisms also function in the case of air jet massage.

7. CONCLUSIONS AND RECOMMENDATIONS

The investigation of the developed air jet massage device in the textile industry showed it to be effective as it reduces subjective and objective fatigue symptoms in lower legs and feet. Different versions of these devices may be developed and used in light, machine-building, and other industries, in department stores, supermarkets, and at home.

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