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Muscle Fatigue for the Health Staff in Hospital Operation Unit

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ABSTRACT

For the research the health sector was selected and it is one of the largest sectors of the economy in Latvia, where more than 6.8% of workers are employed in different professions. Operating block employees from different hospital clinics were selected for the research. The aim of the study was to investigate muscle fatigue and its causes for the operation unit health staff. Such investigation methods were used: survey, determination of the hand muscle strength, muscle fatigue analysis. Survey results prove that operation unit staff indicates discomfort in various body parts after the work shift. That is in accordance with the results of myotonometric measurements that show that during the weekly working cycle, the most loaded muscle groups were in shoulder region and legs, but less loaded were arm muscles. Analysis of the strength of the handgrip muscle shows that the mean handgrip muscle strength of nearly all the employees of the studied professions is in line with the norm before and after a week of performance, for some right-hand grip muscle strength is slightly greater than the strength of the left hand. The research will be continued with motion capture analysis to analyze the awkward movements during operations for surgeons, nurses, and surgeons-residents.

Keywords: Muscles, Fatigue, Operation Unit, Staff, WRMSD

INTRODUCTION

The health sector is one of the largest sectors of the economy in Latvia, where more than 6.8% of workers are employed in different professions (Central Statistical Bureau of Latvia, 2021). Data from the 2019 study shows that the sector has the third highest (12%) number of first-time occupational sufferers, with 66% diagnosed with work-related musculoskeletal disorders (WRMSD) and nervous system diseases. Musculoskeletal and connective tissue disorders are the most common causes of occupational diseases, injuries, and disabilities for various professions, including staff in the operating block. A literature analysis shows that the most common health problems for surgeons in the various sub-specialist sections and nurses in the operating block are associated with muscle, tendon, nerve, and joint overload in certain parts of the body (Centers for Disease Control and Prevention, 2020; Epstein et al. 2018). The most frequently affected parts of the body are the neck, shoulder area, lower back, and often also legs and arms (Janki et al. 2017). The most common diagnoses are carpal tunnel syndrome, lumbar radiculopathy, varicose veins, rotator cuff disease, etc. (Forst et al. 2006; Auerbach et al. 2011).

The musculoskeletal system can be influenced by not only the ergonomic risk factors associated with work, but also by a number of psychosocial risks (Devereux et al. 1999) as well as sedentary lifestyles, congenital posture disorders and injuries. Several studies have demonstrated that WRMSD reduces hand agility, range of movements, strength of grip, and sometimes even coordination, which can directly affect not only the health of surgeons but also successful patient care (Voss et al. 2017). In addition, significant muscle fatigue (discomfort) is affected by the intensity of the procedures to be performed and their direct effects on staff comfort and surgical accuracy. It is often associated with a discrepancy of physical load for the worker's ability to work. It is therefore recommended that, in the same way as for computer operators, temporary rest periods (micro-pauses) are observed, which is an effective means of removing fatigue (Dorion and Darveau, 2013). The same could also be attributed to the daily work of operation nurses, characterised by repeated and frequent hand movements, periodic lifting of heavy loads and patient displacement, awkward work postures, attention, and concentration. Such working conditions are associated with increased psycho-emotional stress (Lelis et al. 2012; Magnano et al. 2009).

Despite the fact that between 50 and 85% of practicing surgeons worldwide, including young employees, are complaining about these problems, the most frequently mentioned problems are overlooked, which may have an adverse effect not only on the health of the staff in the operating block, but also on productivity (Schlussel and Maykel, 2019). This indicates that there is the need for the training of staff in the operating block, including surgeons and nurses, of ergonomic risks at work and possible WRMSD.

The aim of the study was to investigate muscle fatigue and its causes for the operation unit health staff.

It should be noted that for employees in the operating block, the work is organised in shifts. Work in the operation halls lasts for several hours, depending on the type of operation, in long-lasting standing and awkward posture. Work is very responsible, needs increased attention and concentration. Daily, both scheduled and acute operations are carried out. During operations, personnel handle various medical equipment, such as bronchoscope, echocardiograph, microscope, monitors, and hand tools (surgical pliers, tweezers, scalpels, etc.).

Of 39 addressed employees 22 operating block employees from different hospital clinics participated in the research (10 operating surgeons, 9 operation nurses, and 3 surgeons – residents). Their complaints were about pain or discomfort in different parts of the body after work shift. For the study, operating unit employees were selected following these criteria: full-time employees, no acute musculoskeletal symptoms, work experience of at least five years in health care and full consent to participate. All participants were right-handed. The participants were informed on research aim and research methods. The participants gave written consent to participate in the study. The Ethics Commission of the University of Latvia approved the study on November 17, 2020. Table 1 shows the background factors of the participants.

Table 1. Background factors of the subjects: mean age, mean height, mean weight, mean body mass index (BMI).

Profession	n	Mean age (years) ± SN	Mean height, cm ± SN	Mean weight kg ± SN	Mean BMI, kg/m^2 ± SN
Operating surgeons (5 females, 5 males)	10	41.50 ± 7.546	178.10 ± 7.015	82.70 ± 24.176	25.90 ± 7.062
Nurses (only females)	9	46.67 ± 11.136	168.22 ± 6.591	75.56 ± 16.141	26.44 ± 4.586
Surgeons –residents 2 females 1 male)	3	26.67 ± 1.528	177.33 ± 8.083	59.67 ± 4.041	19.00 ± 2.646

MATERIALS AND METHODS

Survey of the Participants

The survey covered 33 issues comprised of 3 question blocks: (1) Demographic indicators and general information on the physical activities of the employee, their frequency, harmful habits, weight and height, etc.). (2) Health-related information focusing on the musculoskeletal system problems related to ergonomic risks at work (awkward posture, workload, working environment and organisation of work, including number of operations in shift, duration of operations, etc.). (3) The opinion of study participants on ergonomic risks at work. The questionnaire contained open and closed questions. The questionnaire response bases on the claim "yes" and "no". Questionnaires were sent electronically to the employees of the operating block to a work email that was filled out on the Internet using the sent link. Questionnaires were analyzed using IBM SPSS 22.0 and Microsoft Excel.

Determination of the Hand Muscle Strength Using a Hand Dynamometer

Due to the use of hand tools by the staff of the operating block in their daily work, an electronic hand dynamometer was used to assess the strength of the hand muscles employed - *Camry Electronic Hand Dynamometer.* In the dynamometer, it is possible to set a number of parameters for the observed person, such as gender and age. The device can be calibrated in kilograms (kg) and pounds (lbs). The maximum possible value is 90 kg and 198 lbs. For the personnel of the operating block, measurements with the dynamometer were performed in the standing position, their hand outstretched at shoulder level maximally compressing the dynamometer equipment. Measurements for the right and left hand were performed 3 times and then averaged. The results obtained were compared with a specially designed dynamometer force table, separately for women and men, depending on age, and the applied force was determined in kilograms (kg). Measurements prior to and after the

workload give an indication of the size of the hand strength when performing a particular work operation. It is also possible to judge the physical fitness of the employee following the acquired hand strength measurements.

Muscle Fatigue Analysis Using Myotonometry Method

The myotonometry method was applied to assess the functional status of individual muscle groups during work and after the working week in the working cycle. Measurements were performed with the "MYOTON – 3" device, which records the frequency, speed and acceleration of the sensor rod's rebound pulse from the surface of the muscle (Vain and Kums, 2002). The operating principles of the facility are described in one of our previous publications (Roja et al. 2006). The myotonometry measurements specify three parameters: (1) a frequency that describes the muscle tonus during natural contractions. The frequency best reflects muscle fatigue. Depending on the type of muscle, the frequency fluctuation ranges from 11 to 16 Hz, but in a contracted state 18 to 40 Hz); (2) decrement value that describes the elasticity of the muscles or the ability to gain initial condition after contraction; (3) a hardness that describes the ability of the muscle to resist changes caused by external forces. Depending on the type of muscle, hardness ranges from 150 to 300 N/m, for contracted muscles, the stiffness value may be higher than 1000 N/m.

A computer program determines the changes in the tonus of the measured muscle groups over a specified period of time, which allows the assessment of their fatigue, as well as the adaptability of the muscle groups studied to the corresponding workload.

The trend lines obtained were classified in 3 categories:

Category I: the trend line decreases, indicating the muscle relaxation capacity and the complete relief after work.

Category II: the trend line is constant, indicating the ability of the muscle to adapt to the workload and only partially relax.

Category III: the trend line is increasing, indicating that the muscles are not able to relax (the muscle tonus is increasing) and this indicates muscle fatigue.

The myotonometry method evaluated the following muscle groups in a relaxed state: *m. extensor digitorum; m. flexor carpi radialis; m.gastrocnemius (caput mediale); m. tibialis anterior and m. trapezius (upper part)*. Myotonometric testing of muscles was performed at the beginning and at the end of the working week cycle. The procedure of muscle testing was performed in a sitting position, the muscle was of medium length.

Data Processing Methods

For data analysis, descriptive statistical methods were used — frequency analysis, cross-column analysis with the Chi-squared test to identify differences between groups if variables are nominal measuring p values that describe the statistical significance $p < 0.01$ and $p < 0.05$. In order to determine the closeness of the coherence, a Pearson correlation test was applied with a strong

correlation of 0.8-0.9, a mean correlation of 0.4-0.7, a weak or no correlation of 0.0 – 0.3. The ANOVA test ($p < 0.05$) was applied to determine the dispersions of two and more samples. SPSS 22 program was used for data analysis. For regression analysis, to determine the "trend lines" of the muscle tonus, where the R^2 or determination coefficient is between 0 and 1, which determines how close the determined parameters are to real data and tables. Microsoft Office Excel was used to arrange tables and graphs.

RESULTS AND DISCUSSION

Survey Results

Analysis of the survey participants by age showed that the majority of respondents entered the age group from 36 to 50 years (41% of operating surgeons and 18% surgical nurses). On the other hand, in the age group from 51 to 65 and over, there were 10% of operating surgeons and 13% of surgical nurses. In the age group from 26 to 35, there were 8% operating surgeons, 3% of nurses and residents.

Analysis of the length of service by profession shows that for 33% of respondents it is 21-35 years (21% operating surgeons and 12% surgical nurses), the length of service is 11-20 years for 23% of the respondents. Of those surveyed, 18% (10% of nurses and 8% of operating surgeons) have the length of service over 35 years. Length of service from 0 to 5 years has been reported by surgeons-residents and 5% of nurses. Statistical data processing shows that there is a statistically significant difference between the length of service and the age of employees ($p = 0.756$), i.e. increase in age also increases length of service in the profession. The analysis of the Body Mass Index indicates that all respondents have elevated weight, with the exception of surgeons — residents for whom it is within normal limits.

The surveyed operating surgeons and surgeons - residents (82%) indicated discomfort in the shoulder and neck areas, arms, legs, and lower back, while surgery nurses (90%) - in the arms, legs, and shoulders, but older nurses – also in the lower back. Similar results have been obtained in other authors' studies on the posture and pain, or feelings of discomfort after work of surgeons and nurses. They indicate that surgeons and nurses mainly work in a standing, awkward posture that causes pain in the back area, arms, legs, neck area, and shoulder girdle. That coincides with the results obtained in our research (Matern and Koneczny, 2007; Tsekoura, 2017).

Of the respondents, 64% indicated that ergonomic working conditions and work equipment were suitable in the working environment, while 31% considered that the working space was unsafe, movements in the room restricted, and the staff were not provided with auxiliary aids for lifting and relocating heavy patients. All respondents involved in the study acknowledged that hand tools were easy usable at work. These results contradict other studies, which highlight the fact that surgeons complained about uncomfortable hand and arm postures when working with hand tools (Matern and Koneczny, 2007). Daily, between 5 and 10 operations are performed in a shift lasting between 2 and 10 hours, depending on the type of operation and its complexity.

Of the surveyed operation block staff, 90% denied smoking, but others smoke 11 to 20 cigarettes a day. Alcohol is not consumed at all by 33% of those surveyed, while the others use it in moderate doses. The staff of the operation block (96%) believe that their daily diets are healthy. Unfortunately, from the survey results it should be concluded that the majority of employees are not engaged in or are very rarely engaged in physical activities in spare time, as only 36% of respondents noted that they are engaged 1-2 times and only a few – 5 times a week. The vast majority (82%) of respondents noted that there were no regulated micro-pauses during work. At the end of the survey, nearly 90% recommended additional improvements in working positions, adjusting table height and providing modern auxiliary aids for lifting and moving patients. Emphasis was placed on the need for micro-pauses during work and on training on ergonomic working techniques.

Results of Analysis of Hand Grip Muscle Strength

The results were compiled for professional groups, calculating the mean values of hand strength, standard deviation (SD), and statistical reliability (p) using the ANOVA test was determined.

Analysis of the strength of the handgrip muscle shows that the mean handgrip muscle strength of nearly all the employees of the studied professions is in line with the norm before and after a week of performance. For operating surgeons and surgeons-residents, the right-hand grip muscle strength is slightly greater than the strength of the left hand, while for surgery nurses, the mean muscle strength of the hand is the same for both hands. The strength of handgrip muscles in the studied groups is higher at the beginning of work than after work in all studied days. Analysis of dispersion showed that there was a statistically significant difference between professional groups and right-hand strength before work ($p = 0.037$) on the first day of measurement and right-hand strength before work ($p = 0.050$) on the last day of the weekly working cycle measurement (see Table 2).

Analysing the obtained results by age and sex, it has been found that for almost all operating surgeons, male (22.5%) handgrip muscle strength before and after work, corresponds to normal and strong strength, with the exception of one doctor (38 years old), whose handgrip muscle was weak in the right hand after work (33.9 kg). Of the 22.5% operating surgeons – females, for 13.2% females handgrip muscle strength before and after work corresponds to normal hand strength, but only two (29 and 31 years old) - it was weak. Before and after weekly work cycle, only 7.3% of nurses had handgrip muscle strength corresponding to normal and strong, while some surgery nurses aged 44 to 64 experienced weak handgrip muscle strength. Generally for surgery nurses, the strength of right-hand grip muscles was greater than the strength of the left hand, except for two (ages 37 and 38), for whom the strength of handgrip muscles in the left hand was greater than that in the right hand. Analyzing the handgrip strength of a 28-year-old surgeon - resident – it was found that the strength of the handgrip muscles in the right hand was greater than in the left hand. The strength of the right-hand grip muscles was weak in all measurements for both surgical residents (25 and 27

Table 2. Handgrip muscle strength (kg) in weekly working day cycle (kg±SD).

	First working day				Fifth working day			
	Before work		After work		Before work		After work	
	Right hand	Left hand	Right hand	Left hand	Right hand	Left hand	Right hand	Left hand
Operating surgeons (n = 10)	37.90 ± 11.958	35.80 ± 11.312	33.80 ± 10.020	32.20 ± 9.693	39.40 ± 12.651	35.0 ± 11.328	36.60 ± 10. 752	33.60 ± 10.895
Surgical nurses (n = 9)	23.67 ± 6.982	23.56 ± 5.897	23.56 ± 8.141	21.78 ± 7.661	24.78 ± 7.694	24.22 ± 6.591	23.89 ± 7.865	23.11 ± 7.079
Surgeons-residents (n = 3)	30.33 ± 18.037	28.33 ± 17.616	32.67 ± 20.744	29.67 ± 15.011	31.67 ± 20. 404	31.00 ± 14.799	31.67 ± 19,757	28.33 ± 14.012
ANOVA F-value	3.924	3.324	2.207	2.849	3.509	3.168	3.152	2.660
ANOVA p	0.037	0.058	0.137	0.083	0.050	0.065	0.066	0.096

$p<0.05$.

years). The results are consistent with the data from the survey on pain or discomfort in the hands following work in similar studies. A study evaluating handgrip strength for 4 specialist groups - surgeons, dentists, physiotherapists and nurses - found that surgeons had highest grip strength followed by Nursing, Physiotherapy and Dental professionals (Zakariya et al., 2016).

Handgrip strength may also vary depending on the position of the hands during the working hours (Richards et.al. 1996). The above literature describes that changing the position of the forearm between neutral, supinated and pronated altered the grip strength. The supinated position produced the strongest force, whereas the force was weakest in the pronated position. This could be attributed to the nurses and female surgeons-residents involved in our study, since, as observed, the hands of the staff in the operation block often need to be adjusted specifically to perform their work successfully.

Results of Muscle Fatigue Analysis

Myotonometric measurements with the MYOTON 3 device were performed to assess muscle fatigue in the operation block staff before and after the weekly working day cycle for the following muscle groups: *m. extensor digitorum, m. flexor carpi radialis, m. trapezius, m. tibialis anterior, m. gastrocnemius.*

The results of myotonometric measurements show that during the weekly working cycle, the most loaded muscle groups were *m. trapezius* and *m. tibialis anterior*, but less loaded were *m. extensor digitorum, m. flexor carpi radialis,* and *m. gastrocnemius*. This coincides with the results of the survey of the staff of operation block on complaints in these muscle groups (see Figures 1 and 2).

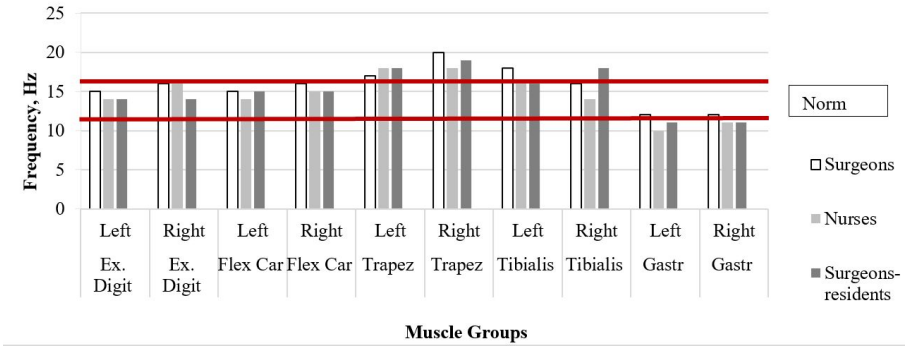

Figure 1: Mean frequency of the right and left side body muscle groups before and after operation.

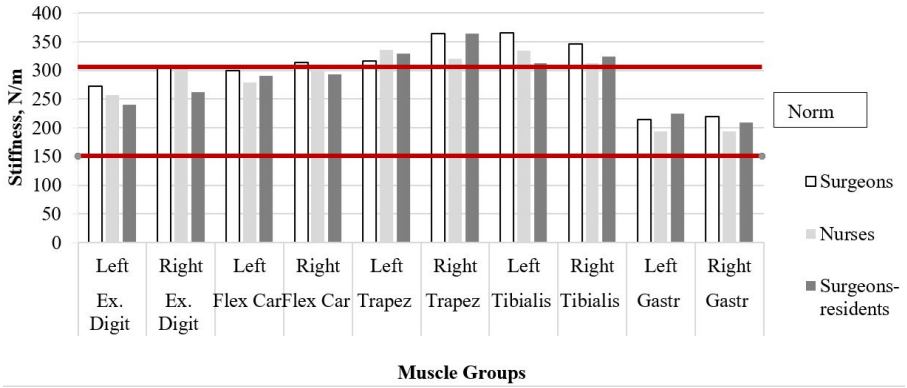

Figure 2: Mean stiffness of the body's right and left side muscle groups during operations.

Despite the fact that the stiffness and frequency indicators for the right hand *m. extensor digitorum* and *m. flexor carpi radialis* do not exceed the permissible levels, the results indicate that the respective muscle groups are loaded during the weekly working cycle.

Analysing the obtained results by professions, it has been found that the operating surgeons have a greater load on the right-side *m. trapezius* and *m. tibialis anterior* of the left leg, as well as on the studied arm muscle groups, and also slightly on the right *m. gastrocnemius*. It should be noted that the body of surgeons is bent during surgery and the head is tilted at more than a 45-degree angle, which often contributes to a variety of health problems, so-called muscle fatigue in the corresponding parts of the body. Studies by other authors have also demonstrated that surgeons' head positions during surgery increase the pressure on the thoracic part of the spine from 4.5 kg in neutral to 27 kg in bent position, which may negatively affect the musculoskeletal system (Hansraj, 2014).

The analysis of the results of myotonometric measurements for surgery nurses showed that, as with surgeons, more loaded are *m. trapezius* and *m. tibialis anterior*. The load is also on *m. extensor digitorum* and *m. flexor*

carpi radialis. The results are consistent with survey data on pain or discomfort in individual parts of the body. The analysis of the integrative literature on WRMSD in nursing profession indicates that nurses most frequently complain about pain in the shoulder girdle, lower back, arms and legs (Lelis et al., 2012) and that it is often associated with physical load, psychosocial risks and poor physical fitness (Fonseca and Fernandes, 2010). The load of individual parts of the body of nurses indicates that nurses, like doctors, spend most of the day standing in operation halls, making frequent bending movements, handing tools, regulating monitors, thereby creating a load on both leg and shoulder muscles. Nurses' duties also include preparation of the operation hall, moving medical equipment, arranging tools between operations, thus creating an increased physical load for all parts of the body, which influences the development of WRMSD.

The increase in the stiffness rate of the left leg *m. tibialis* during the weekly working cycle could be related to the fact that, during surgery, the body weight is often put to the left leg, as the right leg is directed slightly forward. In prolonged time, it could lead to the fatigue of the mentioned leg muscle group.

The results of myotonometry have shown that for operating surgeons and surgeons – residents, *m. trapezius* is not able to relax after workload. It corresponds to category III, indicating the fatigue of this muscle. *M. tibialis anterior*, *m. ext. digitorum* and *m. flex.carpi radialis* are able to adapt to the load and partially relax corresponding to category II, but *m. gastrocnemius* –to category I, indicating that the muscle is also relaxed after work. Results from myotonometry have shown that for surgery nurses *m. trapezius* and *m.flex. carpi radialis* cannot relax after workload thus corresponding to category III, but *m. tibialis anterior* and *m. ext. digitorum* are capable of adjusting to the load and partly relax, corresponding to category II. *M. gastrocnemius*, similarly to that of surgeons, corresponds to category I, which indicates that the muscle is able to relax after workload. The results of the study coincide with our previous research results that health staff (surgeons, anaesthetists, geneticists) are subjected to long and intensive work in compulsory work positions, which has impact on fatigue of various muscle groups (Roja et al. 2015). The research will be continued with investigation of deep muscles fatigue applying electromyography measurements.

CONCLUSION

It was concluded that in the studied occupational groups during the weekly work cycles muscle fatigue increases mainly in two muscle groups - m. trapezius and m. tibialis anterior. When analysing the handgrip muscle strength, it was found that generally it is within normal limits for all the groups studied and it indicates that hand muscle groups are not overloaded. In order to clarify these results, the authors consider that additional studies will be needed to compare changes in hand positions during operations in relation to length of service, gender, and age. The research will also be continued with motion capture analysis to analyze the awkward movements during operations for surgeons, nurses, and surgeons-residents.

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