Measuring muscle fatigue in relation to the workload of health care workers

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Abstract

Number of work related musculoskeletal disorders due to ergonomics risks among workers in Europe, including Latvia, is growing. Employees in health care professions admit physical load and discomfort in various body parts after the shift. According to Eurostat statistical data 60\% of total work related diseases are attributed to musculoskeletal disorders in Latvia. The aim of this study was to determine the muscle fatigue caused by physical load for surgeons, anaesthetists and geneticists in one of the largest Hospitals in Latvia. The research involved 9 surgeons, 9 anaesthetists and 7 geneticists with chronic pain (for four months or more) in the neck, shoulders, arms, hands and legs. All of them agreed to take part in myotonometric measurements. The main results included NMQ-E inquiry data analysis and proved that all participants most frequently complain of feeling discomfort after work, particularly, fatigue or muscle pain in the neck, shoulders, arms, hands and legs. Myotonometric measurement results show that geneticists’ muscle tone at the end of the working week has increased in the shoulder region muscles and slightly in wrist/hands muscles (m. extensor digitorum; m. flexor carpi radialis). Muscle tone of the surgeons increased in wrist, hand and shoulder region, as well as in legs at the end of the working week: m. flexor carpi radialis; m. tibialis anterior; m. gastrocnemius (caput mediale), but anaesthetists’ muscle tone increased in shoulder region and in legs. Hence research participants (surgeons, anaesthetists, geneticists) are subjected to long and intensive work in compulsory work positions, which has impact on fatigue of various muscle groups.

Keywords: Surgeons; Anesthetists; Geneticists; Myotonometry; Fatigue

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1. Introduction

In Latvia, within the recent years number of work-related diseases has drastically grown. This problem refers to health care workers as well. The employees of this branch more frequently than those from other branches are subjected to work in forced position, overload of certain muscular groups, fatigue, lack of time, long working hours, work with complex and fast changing technologies, fast and important decision making and other risks. Regardless of positive changes in health care in recent years (application of modern examination methods and equipment, arrangement of work places proper for patient care) high risk for health still remains in many work places [1]. Lifting and moving of heavy patients, forced work positions, long hours standing at the operation table, often accompanied by static load on arms and shoulder muscles due to holding of crooks and instruments threaten not only nurses but also operation theatre staff, incl. surgeons and anaesthetists [2].

A number of studies have found that the most common musculoskeletal health disturbances manifest as chronic muscular pain, damages of ligaments and tendons [3]. These disorders can be attributed to numerous risk factors, including prolonged static postures, repetitive movements, suboptimal lighting, poor positioning, genetic predisposition, mental stress, physical condition, age and obesity [4].

Researchers have concluded that mechanisms leading to work-related musculoskeletal disorders are multifactorial [5].

From biomechanical viewpoint muscles make the necessary force, then bones, ligaments and joints transfer the force to the load/patient to be handled, the blood circulation and breathing guarantee the provision of energy in cases when loads or patients are handled or other types of physical work are performed [6,7].

Health care employees are also subjected to prolonged sitting since contemporary technologies are computerised. It especially refers to laboratory doctors who spend long working hours at the microscope and computer. Such work postures cause circulation problems in pelvis and legs, which manifests as fatigue of the corresponding muscle groups. Sitting work position promotes muscular tiredness in shoulder area as well. The body does not receive oxygen enough as heart function and breathing are restricted. Therefore these employees often complain about chronic headache or backache [8].

Musculoskeletal health disturbances are found not only in elderly employees, but also in younger employees [9]. It should be noted that both employees and employers are not aware of the risks of physical load, their effect on employees’ health, as well as of preventive activities to avoid ergonomic risks.

Surgeons, anaesthetists and cytogeneticists were chosen for the research since their work is characterized by variable work cycles with differing levels of difficulty in specific work performance, awkward posture and high repetition. All participants were chosen basing on similar work time - 8 hours per day in one working week. The Human Ethics and Institutional Review Board of Riga Stradiņš University approved the study on 23rd of September 2010.

The aim of this study was to determine the muscle fatigue caused by physical load for surgeons, anaesthetists and geneticists in one of the largest Hospitals in Latvia. The research involved 9 surgeons, 9 anaesthetists and 7 geneticists with chronic pain (for four month or more) in the neck, shoulders, arms, hands and legs. All of them agreed to take part in the myotonometry measurements. The employees without health checkups, as well as those with acute pain in certain parts of the body, and those with specific muscular and skeletal diseases were not included in the study. The background factors are shown in Table 1.

### Table 1. Background factors of the subjects: age, height, rest heart rate (RHR).

| Profession            | n  | Mean age±SD | Range | Mean height, cm±SD | Mean weight, kg±SD | Mean RHR, beats/min±SD |
|-----------------------|----|-------------|-------|--------------------|--------------------|------------------------|
| Surgeons (incl.4 fem.,5 m.) | 9  | 38.81±11.07 | 23-60 | 171.19 ±0.08       | 74.96±6.16         | 71.16±8.36             |
| Anaesthetists (incl.2 fem.,7 m.) | 9  | 36.10±13.17 | 23-62 | 169.73±0.14        | 71.42±9.48         | 72.18±7.12             |
| Geneticists (7 females) | 7  | 42.19±13.90 | 35-55 | 165.23±0.11        | 68.27±9.74         | 69.29±8.19             |
2. Methods

The extended version of Standardized Nordic Musculoskeletal Questionnaire (NMQ-E) was used to assess musculoskeletal problems of surgeons, anaesthetists and geneticists (the nature and severity of self-rated musculoskeletal symptoms, including items inquiring about the experience of problems in nine body areas) \[10,11\]. In our study, the extended version of NMQ-E contains some additional questions regarding body postures, job demands and social support (see Figure 1).

Assessment of the functional state of skeletal muscles and muscle fatigue was carried out using myotonometric measurements with the MYOTON-3 device created in Estonia, the University of Tartu. The theoretical concepts of myotonometer and social support (see Figure 1).

Please answer if you have never had trouble in any parts of your body

(one tick for each question using tick boxes)

| 1. Neck | 2. Shoulders | 3. Elbows | 4. Wrist/hands | 5. Upper back | 6. Lower back | 7. Hips/buttocks | 8. One/both knees | 9. One/both legs |
|---------|-------------|-----------|----------------|--------------|--------------|-----------------|---------------------|-----------------|
| No (0)  | Yes (1)     | No (0)    | No (0)         | Yes (1)      | No (0)       | No (0)          | No (0)              | No (0)          |

Have you had trouble during the last 12 months?:

| 10. Neck | 11. Shoulders | 12. Elbows | 13. Wrist/hands | 14. Upper back | 15. Lower back | 16. Hips/buttocks | 17. One/both knees | 18. One/both legs |
|----------|---------------|------------|-----------------|--------------|--------------|-------------------|---------------------|------------------|
| No (0)   | Yes (1)       | No (0)     | No (0)          | Yes (1)      | No (0)       | No (0)            | No (0)              | No (0)          |

During the last 12 months have you been prevented from carrying out relaxation activities (eg. physical activities, hobbies, swimming) because of this trouble:

| 19. Neck | 20. Shoulders | 21. Elbows | 22. Wrist/hands | 23. Upper back | 24. Lower back | 25. Hips/buttocks | 26. One/both knees | 27. One/both legs |
|----------|---------------|------------|-----------------|--------------|--------------|-------------------|---------------------|------------------|
| No (0)   | Yes (1)       | No (0)     | No (0)          | Yes (1)      | No (0)       | No (0)            | No (0)              | No (0)          |

Body Posture

| Question                                                                 | Always (1) | Sometimes (2) | Never (3) |
|--------------------------------------------------------------------------|------------|--------------|----------|
| During my work I keep a good work posture.                               |            |              |          |
| At work I sit for long hours in one position.                            |            |              |          |
| For more than two hours per day I sit with lifted shoulders.             |            |              |          |
| During my work I sit in awkward posture.                                  |            |              |          |
| In work I perform repetitive tasks.                                      |            |              |          |
| I find my job physically exhausting.                                     |            |              |          |
| When I key my hand is placed in a straight line with my lower arm.       |            |              |          |
| When I work my head is bended.                                           |            |              |          |
| Head is twisted towards the left or right.                               |            |              |          |
| Trunk is twisted towards the left or right.                              |            |              |          |
| My Trunk is in asymmetrical position.                                     |            |              |          |

Job demand and social support

| Question                                                                 | Always (1) | Sometimes (2) | Never (3) |
|--------------------------------------------------------------------------|------------|--------------|----------|
| I work under extensive work pressure.                                    |            |              |          |
| I have no enough time to finish my job task.                             |            |              |          |
| At work I speed to finish my tasks on time.                              |            |              |          |
| I find my work tasks difficult.                                          |            |              |          |
| I have too many job tasks.                                               |            |              |          |
| The work flow goes smoothly.                                             |            |              |          |
| I can ask and enquire in my work.                                        |            |              |          |
| My work tasks depend on other colleges.                                  |            |              |          |
| My work atmosphere is comfortable.                                       |            |              |          |
| If I made a mistake in my work I find support from my colleagues.       |            |              |          |
| If I made a mistake in work task I find support from supervisors.       |            |              |          |
| My colleagues are friendly.                                              |            |              |          |

Fig. 1. Musculoskeletal questionnaire (trouble with the locomotive organs and work disposition).
maintenance workers was investigated [14]. The principles of the MYO lies in using acceleration probe to record the reaction of the peripheral skeletal muscle or its part to the mechanical impact (testing end mass 20 grams, duration 15 milliseconds) and the following analysis of the resulting signal. The frequency of the damped oscillations (Hz), measured during the rest period, characterizes the tissue tone. Muscles stiffness (N/m) reflects the resistance of tissue to the force that changes its shape. It was calculated by the measuring device, taking into account the relationship: $m \cdot \frac{\text{am}}{\Delta l}$, where $m$ is the mass of the testing end of device; $\text{am}$ is the maximal amplitude of oscillation, and $\Delta l$ is the depth of the displacement of the testing end. The procedure of NSAH muscles testing was performed in a sitting position, the muscle length was middle; for all measurements the subject took the same position. Thus, it is possible to obtain the most precise results, when estimating muscle fatigue or the ability to restore elastic muscle qualities after the work cycle.

Myotonometric testing of muscles was performed at the beginning and at the end of the work week in relaxed state: $m$. extensor digitorum; $m$. flexor carpi radialis; $m$. gastrocnemius(caput mediale); $m$. tibialis anterior and $m$. trapezius (upper part). According to this method the obtained results can be subdivided into categories, as follows: Category I – subject is able to relax the muscle; Category II – muscle is able to adapt to the work load and to relax partly; Category III – muscle is not able to relax (muscle tone is increased which is associated with muscle fatigue).

The acquired results were processed, using statistical data processing software SPSS.16 (SPSS Inc., Chicago, IL) according to popular descriptive statistical methods. Cohen’s Kappa ($\kappa$) coefficient was determined [21]. This coefficient identifies connectivity of the experimental data, the number of participants and the proportion or correlation of the participants’ acceptance of the experimental data: $\kappa = \frac{P_O - P_C}{1 - P_C}$, where: $P_O$ – correspondence proportion of objective experimental data with respondents’ responses (yes or no), $P_C$ – correspondence proportion of data with number of participants ($P_C = \Sigma p_i^2$, where $p_i$ is acceptance of each participant, expressed in percent or as fractional number).

3. Results and discussion

NMQ-E data show that all participants most frequently complain about feeling discomfort after work, particularly, fatigue or muscle pain in the neck, shoulders, arms, hands and legs. Results of discomfort in different parts of the body of surgeons, anaesthetists, geneticists after work are shown in Table 2.

|                 | Surgeons (n = 9) | Anaesthetists (n = 9) | Geneticists (n = 7) |
|-----------------|------------------|-----------------------|---------------------|
| Neck            | 9 100.00%        | 5 55.56%              | 7 100.00%           |
| Shoulder        | 9 100.00%        | 8 88.89%              | 7 100.00%           |
| Elbow           | 2 22.22%         | 2 22.22%              | 7 100.00%           |
| Wrist/hands     | 8 88.89%         | 3 33.33%              | 6 85.71%            |
| Upper back      | 9 100.00%        | 6 66.67%              | 7 100.00%           |
| Low back        | 8 88.89%         | 6 66.67%              | 6 85.71%            |
| Hip/Thigh       | 8 88.89%         | 0 0.00%               | 6 85.71%            |
| Knee            | 3 33.33%         | 2 22.22%              | 3 42.86%            |
| Ankle/Shank/Foot| 7 77.78%         | 5 55.56%              | 3 42.86%            |
| Awkward posture | 9 100.00%        | 4 44.44%              | 7 100.00%           |
| Physical exhausting | 9 100.00% | 4 44.44% | 7 100.00% |
| Extensive work  | 8 88.89%         | 3 33.33%              | 7 100.00%           |
| High work speed | 8 88.89%         | 3 33.33%              | 5 71.43%            |
| Too many job tasks | 8 88.89% | 0 0.00% | 6 85.71% |
| Colleagues’ support | 3 33.33% | 6 66.67% | 5 28.57% |
| Supervisors’ support | 5 55.56% | 5 55.56% | 2 71.43% |
Statistical data, revealed in the Table 2, suggest that comparing the studied groups of surgeons and anaesthetists, more discomfort in shoulder and neck area is felt by surgeons (100%). Also surgeons’ hand and wrist are more loaded than those of anaesthetists, which is proved by questionnaire data (respectively 88.89% and 33.33%). 88.89% of the surgeons involved in the study complain about discomfort in pelvic and thigh area, but 77.78% - in the ankle, foot and lower leg area. All surgeons work in forced work position. After work, 100% of surgeons feel physical fatigue. As to anaesthetists, only about half of the studied participants admit physical fatigue after work. Anaesthetists, more than surgeons, admit that they do not receive support from colleagues at work (66.67%). Support from the head of the unit in both groups is similar (55.56%). Generally, anaesthetists complain of discomfort after work in the following parts of the body: shoulder girdle (88.89%), in the upper back and lower back (66.67%), while 100% of geneticists admit discomfort after work in the neck area, shoulder girdle, elbows and at the top of the back. They also complain of increased work intensity, physical fatigue, and work in forced posture. Geneticists note that during the work they have to perform a lot of different tasks (85.71%), work tasks have to be performed at accelerated speed and many of them admit insufficient support from the management. It should be noted that 100% of surgeons and anaesthetists answered that, generally, they work in standing position, but 100% of geneticists work in sitting position. As to physical activities after work, doctors gave the following answers: do physical activities – 22.2% of surgeons (doctors residents, males), only 33.3 % of anaesthetists (1 female doctor resident and 2 certifed male anaesthetists), only 22.2% of geneticists. Of all doctors included in the study 32% admitted smoking.

Myotonometric measurements were made in body parts according to the studied doctors-specialists’ complaints in the following muscle groups being in in relaxed and contracted state: m. extensor digitorum, m. flexor carpi radialis, and m. trapezius (upper part), m. tibialis anterior, m. gastrocnemius. According to regression analysis of MYO data, the trend line reflects the condition of the muscles after one week work cycle. It was stated that all studied subjects could be divided into following categories:

- **Category I** – subject is able to relax the muscle;
- **Category II** – muscle is able to adapt to the work load and to relax partly;
- **Category III** – muscle is not able to relax (muscle tone is increased which associates with muscle fatigue).

Myotonometric measurement results show that geneticists’ muscle tone at the end of the working week has increased in the shoulder region muscles (m. trapezius – upper part) and slightly wrist/hands muscles (m. extensor digitorum, m. flexor carpi radialis). Muscle tone of the surgeons increased in wrist, hand and shoulder region, as well as in legs at the end of the working week: m. flexor carpi radialis, m. tibialis anterior, m. gastrocnemius(caput mediale), but anaesthetists’ muscle tone increased in shoulder region and in legs. According to the Myotonometric method geneticists can be referred to the category II-III. It was proved that muscle tone is increased in surgeons and anaesthetists (category III) in similar muscle groups (m. tibialis anterior, m. gastrocnemius), but surgeons’ muscle groups in arms can adjust to the workload (category II), the m. trapecius tone corresponds to category III (in one working week cycle).

Results of myotonometric measurements are shown in Table 3.

MYO testing results reflected in Figure 2 show the frequencies of different muscles at the beginning and at the end of the week work in different muscle groups. These frequencies show changes in the muscle tone of the investigated health care staff who are not adapting to the workload and whose muscle frequency exceeds the norm (11 up to 16 Hz, exist for each muscle individually) after the work week cycle. Therefore, the muscle fatigue is stated, and such workers are related to III MYO category.

The percentage of workers with differences in their muscle tone (MYO categories) after work in one week period is shown in Table 4.

Acquired myotonometric data at confidence level 95 %, revealed in Table 4, show that muscle tone of 22% of the studied surgeons in work week cycle corresponds to II MYO category (muscles are able to adapt to the work load and to relax partly), 78 % - III MYO category (muscles tone is increased which associates with muscle fatigue). 33% of anaesthetists fall into II MYO category, 45% - III MYO category, while in 43% of geneticists muscle tone in work week period corresponds to II MYO category, but 57% - to III MYO category.
Table 3. Comparison of myotonometric parameters of muscles in relaxed and contracted state.

**M. extensor digitorum**

| Parameters | Surgeons | Anaesthetists | Geneticists |
|------------|----------|----------------|-------------|
|            | Left     | Relax          | Left        | Relax          | Left        | Relax          | Right       | Contract      |
| frequency, Hz | 16.6± 2.4 | 16.3± 2.4 | 15.6± 2.4 | 15.6± 2.4 | 17.3± 2.4 | 17.3± 2.4 | 18.7± 2.4 | 27.2± 2.4 |
| stiffness, N/m | 2408± 324 | 2300± 324 | 2400± 324 | 2400± 324 | 2300± 324 | 2300± 324 | 2300± 324 | 2300± 324 |

**M. flexor carpi radialis**

| Parameters | Surgeons | Anaesthetists | Geneticists |
|------------|----------|----------------|-------------|
|            | Left     | Relax          | Left        | Relax          | Left        | Relax          | Right       | Contract      |
| frequency, Hz | 16.3± 2.4 | 16.8± 2.4 | 15.6± 2.4 | 15.6± 2.4 | 17.3± 2.4 | 17.3± 2.4 | 18.7± 2.4 | 27.2± 2.4 |
| stiffness, N/m | 2408± 324 | 2300± 324 | 2400± 324 | 2400± 324 | 2300± 324 | 2300± 324 | 2300± 324 | 2300± 324 |

**M. gastrocnemius**

| Parameters | Surgeons | Anaesthetists | Geneticists |
|------------|----------|----------------|-------------|
|            | Left     | Relax          | Left        | Relax          | Left        | Relax          | Right       | Contract      |
| frequency, Hz | 16.9± 2.4 | 17.8± 2.4 | 17.6± 2.4 | 17.6± 2.4 | 17.9± 2.4 | 17.9± 2.4 | 14.8± 2.4 | 24.0± 2.4 |
| stiffness, N/m | 2408± 324 | 2300± 324 | 2400± 324 | 2400± 324 | 2300± 324 | 2300± 324 | 2300± 324 | 2300± 324 |

**M. tibialis anterior**

| Parameters | Surgeons | Anaesthetists | Geneticists |
|------------|----------|----------------|-------------|
|            | Left     | Relax          | Left        | Relax          | Left        | Relax          | Right       | Contract      |
| frequency, Hz | 16.9± 2.4 | 17.8± 2.4 | 17.6± 2.4 | 17.6± 2.4 | 17.9± 2.4 | 17.9± 2.4 | 14.8± 2.4 | 24.0± 2.4 |
| stiffness, N/m | 2408± 324 | 2300± 324 | 2400± 324 | 2400± 324 | 2300± 324 | 2300± 324 | 2300± 324 | 2300± 324 |

**M. trapezius**

| Parameters | Surgeons | Anaesthetists | Geneticists |
|------------|----------|----------------|-------------|
|            | Left     | Relax          | Left        | Relax          | Left        | Relax          | Right       | Contract      |
| frequency, Hz | 16.4± 2.4 | 17.6± 2.4 | 24.7± 2.4 | 24.7± 2.4 | 27.2± 2.4 | 27.2± 2.4 | 17.8± 2.4 | 26.8± 2.4 |
| stiffness, N/m | 364.1± 527.8 | 384.0± 527.8 | 611.8± 527.8 | 514.1± 527.8 | 572.7± 527.8 | 572.7± 527.8 | 582.3± 527.8 | 591.5± 527.8 |
In the study it was determined that surgeons, anaesthetists and geneticists are subjected to variety of work, where the leading role is played by prolonged work in forced position, which manifests as discomfort in certain muscle groups, muscle fatigue or chronic pain, functional abilities of the employees often decrease, disability can set in. Fatigue is a normal part of life and can occur in all age groups, but it can also be a symptom of a disease, including serious WMSDs (Work related musculoskeletal disorders) [15,16]. Results acquired from the questionnaire correspond to studies of other scientists [17,18] on ergonomic risks in work of geneticists, surgeons and anaesthetists: prolonged sitting or standing for many hours without breaks or interruptions by other tasks, long-lasting surgery or diagnostics, particularly when specifically awkward postures have to be adopted; poor design of the workplace (worktop too high or too low, restricted room for sitting, poor layout causing overreaching, no space for the feet, confined view to the screen, bad lightning), inappropriate work chair (seat height and depth, armrest and backrest not adaptable to the user’s needs). Several epidemiological studies have proved that inappropriate postures and handling techniques are associated with a doubling of number of back, joint and muscle problems requiring treatment and time off the job [19].

Therefore, taking into account survey results, we chose to evaluate those muscle groups about which specialists involved in the study complained. The study proved that within the work week period, in surgeons and anaesthetists, the highest fatigue affects legs, in surgeons – shoulder girdle as well, but in geneticists – arms and shoulder girdle. It could be explained by prolonged forced positions at work of the mentioned specialists (geneticists – sitting position, but surgeons and anaesthetists – standing position), as well as by load of certain muscle groups, performing repeated movements with arms or keeping them in static position. The study managed to prove that surgeons’ arm muscles are able to adapt to work load within a week period and do not exceed the admissible norms (11 up to 16 Hz). It would be interesting to study muscle fatigue in surgeons in different specialities since scientific studies suggest that there exist differences between the load in body parts during work. For example, Ninh et al. have proved in their study of videotaped ergonomic evaluation of surgeons’ axial skeletal and upper extremity movements during

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**Table 4.** Percentage of surgeons (n=9), anaesthetists (n=9) and geneticists (n=7) with differences in their muscle tone after work in one week period, Pearson’s correlation (r), and Cohen’s Kappa (k).

|               | Surgeons (n=9) | Anaesthetists (n=9) | Geneticists (n=7) |
|---------------|---------------|---------------------|------------------|
| Category      | r             | k                   | r                | k               |
| I - 0 %       | 0.95          | 0.69                | 0.73             | 0.95            |
| II - 22 %     | 0.95          | 0.78                | 0.78             | 0.95            |
| III - 78 %    | 0.95          | 0.82                | 0.69             | 0.95            |

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**Fig. 2.** Illustration of frequency changes in separate muscle groups while performing the work at the beginning and at the end of one week in surgeons (n=9), anaesthetists (n=9) and geneticists (n=7) who are not able to adapt to the workload and whose muscle frequency exceeds the norm after one week period.
laparoscopic and open surgery that surgeons, performing laparoscopic surgery, exhibited less lateral neck flexion, less trunk flexion, more internal rotation of the shoulders, more elbow flexion, more wrist supination and wrist ulnar and radial deviation than surgeons performing open surgery; they found also a tendency to more shoulder stiffness after laparoscopic operations than after open operations [20]. In our study we analysed surgeons of one type only – open operations surgeons. Hence, in future investigations, the myotonometric measurements for fatigue determination various surgery types should be taken into account (laparoscopic operations, open operations etc.). In our study, low muscle frequencies were not examined, as MYOTON-3 device does not allow measuring the deep muscle groups.

4. Conclusions

Research participants (surgeons, anaesthesitists, geneticists) are subjected to long and intensive work in compulsory work positions, which has impact on fatigue of various muscle groups. Myometric method is suitable for analysis of skeletal muscle fatigue, except analysis of fatigue of deep muscles. Therefore the investigation will be continued and fatigue of deep muscles will be studied applying electromyography measurements.

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