EMG measurements of thumb muscles of nurses and caregivers

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Abstract. The number of ageing people in Estonia is increasing. Convenience for personnel in the nursing homes for the elderly and enabling high-quality care is essential. This includes new work methods to relieve the physical burden of nursing workers and the mental stress decreasing interventions. In the theoretical part of the paper, the physical and psychosocial risk factors of nurses and caregivers are dealt with. **The aim** of the study is to measure the *m. abductor pollicis brevis* fatigue in connection with the physical stress of nurses and caregivers. The experimental part of the paper concentrates on the physical stress factors. Electromyography (eMotion EMG) is used as the method for the determination of the nursing workers' thumb muscle's (*m. abductor pollicis brevis)* fatigue. The results show the linear dependences between the level of fatigue of the thumb muscles at the beginning and at the end of an 8-hour workday; between the EMG signals from the muscles in the resting state and after a 5-minute strained state. The interviews with the nurses showed that the renewal of equipment and rooms in the nursing homes is the main factor to prevent the physiological stress at workplaces (pain in the hands, low back pain etc.). In the newly built nursing homes with modern equipment, the workers are satisfied and no physiological stress was noticed.

Key words: psychological stress, fatigue, nursing homes, nurses working conditions, job satisfaction.

INTRODUCTION AND THEORETICAL BASIS

Nursing and caregiving are considered both physically and psychologically demanding jobs (Kim et al., 2010). The main risk factors may lead to the musculoskeletal disorders (MSDs). The work of nurses and caregivers in the Estonian hospitals and nursing homes is considered physically and mentally stressful. The number of ageing people and nursing homes in Estonia is increasing. There is a need for new work methods to relieve both the physical burden of nursing workers and for interventions decreasing the mental stress (Põlluste et al., 2007; Risk…, 2007; Merisalu et al., 2011; Freimann et al., 2013). According to the studies on the relationship between nurses' working conditions and musculoskeletal disorders, the focus is placed mainly on these physical and ergonomic conditions (Karasek & Theorell, 1994; Trinkoff et. al., 2003; Kim et. al, 2010). In addition, high physical workload, workplace demands and lack of control over work could lead to a stress and illnesses (Leijon et al., 2007). The main health problems

for the medical staff (Anon., 2007) were reported as follows: stress, pain in the lower back, aching shoulders and feet, and the heart rhythm disorders.

Studies of gerontology and nursing (Zimmermann, et al., 2005; Noelker et al., 2006; Saarnio et al., 2012; Woodhead et al., 2014) emphasize the stress and burnout of the nursing staff; the need for the social support and to find the possibilities to enhance the job satisfaction for workers in the nursing homes. The relationship and the conflicts between the nursing staff and the residents' families were investigated by Abrahamson et al. (2009).

Long-term care nursing staff (Woodhead et al., 2014) are subject to considerable occupational stress and report high levels of burnout, yet little is known about how stress and social support are associated with burnout in this population. The results of the study showed that the greater occupational stress was associated with more emotional exhaustion, more depersonalization, and less with the personal accomplishment. They demonstrated that the support from the supervisors and friends or family members, reassurance of worth, opportunity for nurturing were associated with less emotional exhaustion and higher levels of personal accomplishment. The survey data from personal interviews with 338 nursing assistants employed at 22 skilled nursing facilities showed that the nurses' personal stressors require careful attention from supervision. Employee Assistance programs and training for supervisors in team building, communication, and motivational skills are needed to promote more positive relationships among nurses (Woodhead et al., 2014).

A Finnish study (Saarnio et al., 2012) showed that the nursing staff mostly felt that they did not have enough time to provide good care to the patients, and that gave them a troubled conscience. They also felt that the demanding work taxed their energy, a conscience being that they could not give their own families and loved ones the attention they would have liked.

A summarized report on safety risks in the Estonian nursing homes in the capital area was carried out by Peeker (2012).

To measure the physical risk factors, electromyography (EMG) has been used as a valuable tool for many years (Kumar & Mital, 1996), mainly for the investigation of the muscles' fatigue. It is a technique for evaluating and recording the electrical activity produced by skeletal muscles. According to previous studies (Westgaard et al., 1996), the use of EMG is based on the problem of musculoskeletal complaints in the workplace. EMG was used both for intentional muscular efforts and at electrostimulation and reflectory induced muscle contractions' conditions in order to estimate muscle activity (internal exposure) and thereby provide an estimation of the risk of a future development of a health problem (Fig. 1).

Physical burden is a part of the conceptual model presented here for possible influences that various factors (individual and in the working environment) may play in the development of musculoskeletal disorders, it includes processes that could occur within a person and possible outcomes, which may be influenced by individual factors, such as psychological stress. The working environment domain includes the following parts: organizational factors (working hours and shift, and type of ward), and physical/ ergonomic and psychosocial working conditions (Fig. 1).
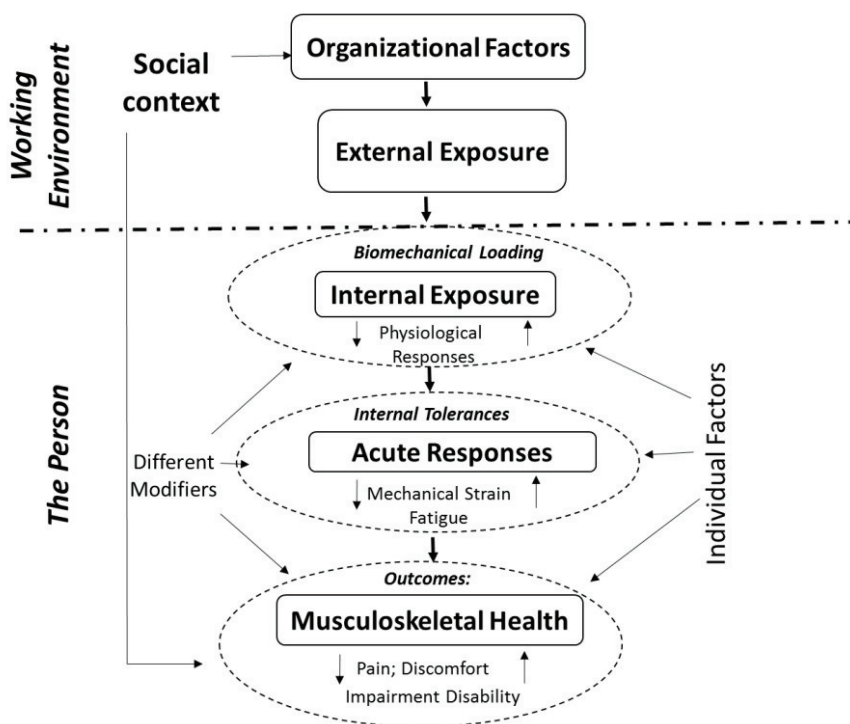
Figure 1. A conceptual model of the possible roles and influences that various factors may play in the development of the musculoskeletal disorders (adapted from Westgaard et al., 1996; National Research Council, 2001).

In light of the above theoretical discussion of the literature survey, the research questions are:

1. Is there any difference in workplace ergonomics *(fatigue of m. abductor pollicis brevis, some additional questions in the course of the interview of the workers)* in different nursing homes in Estonia depending on the state of the building and/or equipment for the ageing people staying there and accordingly in the working conditions?

2. How high is the physical fatigue of nurses and caregivers (EMG measurements)?

3. Are there any other problems that stress the workers connected with the character of their work (consistent care of people with dementia)?

The article proceeds as follows: the next section outlines the materials and methods used in the research. The results of the electromyography measurements and some additional problems in the workplace ergonomics of nursing homes staff are presented. The authors' recommendations and arguments conclude with a view of implications of the new work methods to relieve the physical burden of nursing workers.

MATERIAL AND METHODS

The study group

The study covers four different nursing homes (A, B, C, D) in Estonia (the number of nurses involved in the study was: institution A – 12; B – 6; C – 6; D – 10). Most of the nurses and caregivers (total number of investigated persons n = 34) were female (only 2 male persons). The average age of the nurses (n = 25) and caregivers (n = 7) was 46 years. Participation in the investigation was voluntary.

The working conditions of nurses depend substantially on the building where the nursing home is situated (on the building state, the existence of the aids, the temperature of the air).

Nursing home A is located in a new building, which is operating from September 2014. All equipment there is new in contrast to the previous home near the new building. Therefore, the nurses were very satisfied with the working conditions.

Nursing home B is located in a 2-storey house built in 1965; the latest repair work was done two years ago (in 2012). The rooms for patients are clean, warm, but the possibilities to move from their rooms to the corridor or to the restroom or balcony with wheelchairs are restricted by the doorframes. The house was not built for the nursing home needs. One male caregiver (45 years old) who lives in the same nursing home makes the hardest work (for example, lifting of patients). Even though the working conditions for nurses are poor, they were not complaining, as the nursing home is located in the rural region where it is very difficult to find a job.

Nursing home C is located in a small and quiet town in Estonia and the main complaints of the personnel were connected with the pace of work, lack of support from the side of the leadership etc. Their old building was repaired in the 1980s, but in the process of reconstruction it was impossible to consider the nursing needs of the ageing people.

Nursing home D is located in the capital of Estonia. The building was repaired in 2012. The rooms are clean; the transpired interviews revealed the inconveniences of the nurses and the caregivers. Labor turnover there is very high. One of the nurses interviewed was on her 2nd workday, the other had been working only for 4 months, but there were also some workers who had been working for 12 years and had collected all their work experience in the health care area.

Air temperature measurements of the work environment

Temperature measurements of the air in the nursing homes were done by the multi-function instrument TESTO 435-2 intended for the indoor air quality measurements.

The standards for the temperature measurements were as follows:
- BS EN ISO 7726:2001. Ergonomics of the thermal environment. Instruments for measuring physical quantities.
- CSN- EN 15251:2007. Indoor environmental input parameters for design and assessment of energy performance of buildings, addressing indoor air quality, thermal environment, lighting, and acoustics.

Muscle fatigue measurement equipment

A 2-channel electromyograph eMotion EMG (Mega Electronics, 2014) connected to the computer was used. The computer software allows the determination of the frequency spectrum as well as the indicators of the EMG amplitude and integral. eMotion EMG is a fully automatic system for quick muscle testing, biofeedback and free-mode measurements. It is also possible to measure the fatigue of the muscle. The measurements are based on the scientifically validated analysis of frequency change in the electromyographic signal of muscles (*m. abductor pollicis brevis)* (Anon., 1992; Soderberg & Knutsen, 2000; Tuulik et al., 2000; Mewett et al., 2004). The duration of each recording was 120 sec. The length of the time cycle of the thumb muscle (*m. abductor pollicis brevis)* in the strain state was 5 minutes before the recording of the EMG signal.

Fatigue measurements

The following measurements were carried out:

1. In the nursing homes A and B, the fatigue of the thumb muscle (*m. abductor pollicis brevis)* in the resting state was measured at the beginning (8.00) and at the end of the 8-hour workday (at 17.00);

2. In the nursing homes B, C and D, the starting point was the measurement of the thumb muscle (m. abductor pollicis brevis) fatigue in the resting position and then after a 5-minute strained state of the same muscle. The fatigue of muscles was measured on the working hand (right or left).

There are two outcomes from the EMG results: 1) strength of the EMG signal (µV) and 2) per cent of the muscle fatigue (max 100).

The statistics

The correlation between the results of the beginning and the end of the workday and in the resting state and after a 5-minute strained state is presented. The ANOVA-test and t-test were used for the statistical assessment of the results.

Additional investigations

In connection with the fatigue measurements, the interviews with the working staff were carried out to solve additional problems of the workplace ergonomics. Three questions connected with the work based on 'The stress of conscience' (Saarnio et al., 2012) were presented to the workers. Each item had a 10-point scale (1–10), where higher scores indicated very much so/ certain or well.

The interviews were carried out with 34 nursing home' workers. The investigation with the eMotion EMG involved 22 workers (65% of all the investigated persons).

RESULTS AND DISCUSSION

The temperature in the nursing homes was > 22 ± 0.6 °C.

The number of the nurses with school education for health care of ageing workers was 5 (16%). The other nurses and caregivers were educated mainly for ergonomics of lifting the patients at the workplace (in the nursing homes).

The eMotion EMG system allows us to measure the signal from the muscles *(m. abductor pollicis brevis)* and the fatigue of the muscles only in the time range. It does not allow us to determine directly the coming from the muscles signals' frequency, but it is possible to measure the signals' amplitude by the electromyograms. The procedure takes max. 15 minutes per person, which is very important, as the nursing home workers have really very little time. The results of the measurements of fatigue at the beginning and at the end of the workday are presented in Table 1. The muscle is tiring during the day. The dependence between the thumb muscle *(m. abductor pollicis brevis)* signal and fatigue at the beginning and at the end of the workday is considered to be significant (Table 1; $p = 0.004$). The correlation between the thumb muscle's *(m. abductor pollicis brevis)* fatigue at the beginning and after a 8-hour workday ($n = 10$, Table 1) is shown in Fig. 2.

Table 1. The results of the *m. abductor pollicis brevis* EMG of the nurses and caregivers at the beginning and at the end of a 8-hour workday

Nurse identification/ the mean age	The strength of the EMG signal at the beginning of the workday $E1_{mean}$, μV	SD of $E1_{mean}$	Muscle fatigue at the be-ginning of the workday % of 100 max.	The strength of the EMG signal after a 8-hour workday, $E2_{mean}$, μV	SD of $E2_{mean}$	Muscle fatigue after a 8-hour workday, % of 100 max.
A1-A5*/53.5	503.0	10.2	11.5	290.0	7.7	34.5
B1-B5*/45.5	415.5	140	16.0	299.5	6.4	38.0

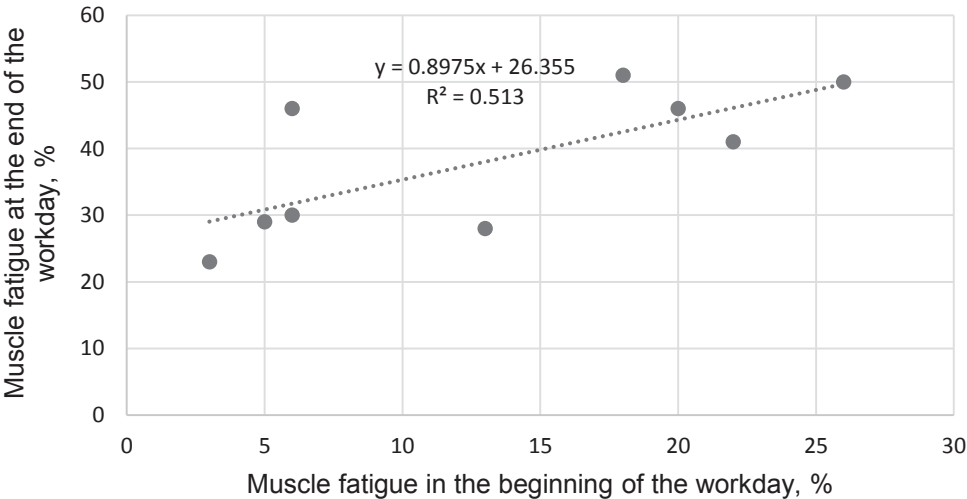*A1, A2, A3, A4, A5; B1, B2, B3, B4, B5 – investigated workers.

Figure 2. The correlation between *m. abductor pollicis brevis* thumb muscle fatigue at the beginning (x) and at the end of the workday (y), nursing home A&B (Table 1, $n = 10$).

In the nursing homes B, C, D, the EMG signal from the thumb muscles and the fatigue of the muscle were measured (n = 17, Table 2). The correlation between the thumb muscle's signal strength in the free state and after the 5-minute strained state is presented in Fig. 3 (p value of the results 0.002).

Table 2. The results of the *m. abductor pollicis brevis* EMG of the nurses and caregivers in the resting position and after a 5-minute strained state

Nurse identification/the mean age	The strength of the EMG signal in the free state $E1_{mean}$, μV	SD of $E1_{mean}$	The thumb muscle fatigue, %	The strength of the EMG signal in a 5-min. strained state, $E3_{mean}$, μV	SD of $E3_{mean}$	The thumb muscle fatigue, %
B1-B5/45.5	415.5	14.0	16.0	344.5	5.7	28
C1-C5/49.5	309	3.1	33.0	322	6.4	42.5
D1-D7/46.5	291.5	6.6	31.0	269.5	6.9	33.5

The data were statistically analyzed with the ANOVA-test (single factor) and t-test (two-sample assuming equal variances). P-value in both tests was between 0.004 and 0.002. This means that the dependence between the thumb muscle signal and fatigue at the beginning and at the end of the workday is considered to be significant (Table 1) as the dependence between the EMG signal in the free state and after a 5-minute strained state (Table 2).
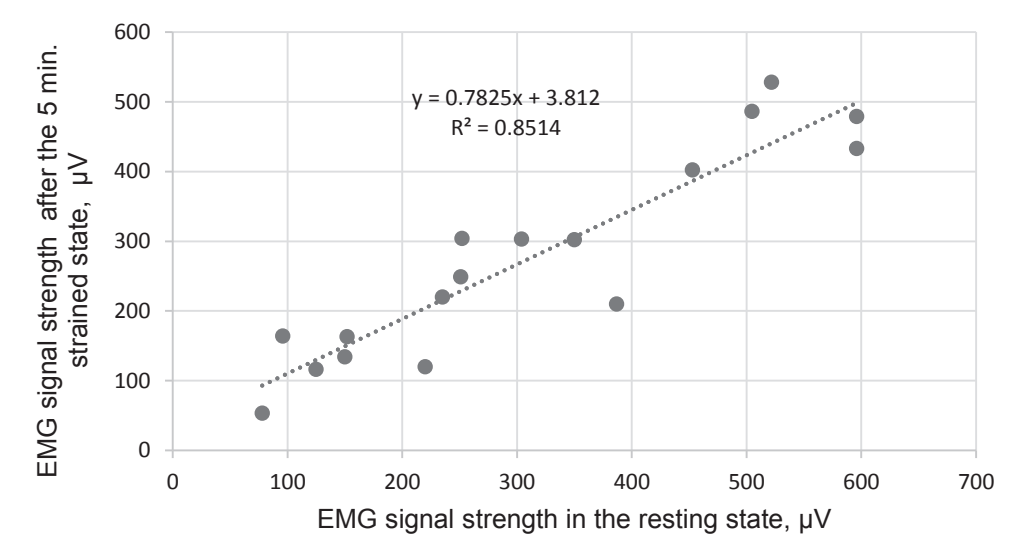

Figure 3. The *m. abductor pollicis brevis* EMG signal strength in the resting position (x) and after a 5-minute strained state (y), μV (Table 2, n = 17).

The workers were very interested in the results of electromyography. The fatigue prevention possibilities were presented to the workers after the measurements.

The results covering the three questions from the interviews that the authors considered important for the workers in the nursing homes (the assessments are given in the 10-point system) are as follows:

1. How often do you lack time to provide the care the patient needs? – 7.1
2. Do you ever have to deal with incompatible demands in your work? – 6.7
3. Is your work in health care ever so demanding that you do not have energy to devote yourself to your family as you would like? – 6.1.

The nurses are too tired to deal with their own families as they would want to; sometimes they have to deal with incompatible demands in their work. In every nursing home the nurses were interviewed at the absence of the employer. They could speak about the main important problems they have.

According to the results from the self-reported questionnaires, Estonian nurses and caregivers in all investigated nursing homes did not consider their work as physically (usually the patients are lifted by two or more persons) demanding. Nurses and caregivers usually have high workloads because of staff shortage. For instance, the question '*is the workday of 10 hours too long for you*', was answered such that time is flying so fast for themselves, because they are constantly occupied as the patients' bells are ringing all the time. Most nurses in the capital were also dissatisfied with inflexible work schedule, shift work and low salary. Nurses in the rural area did not mentioned these facts, as the nursing home is one of the few possibilities to get work in these areas.

Modern patients' lifting equipment is available in most of the nursing homes (A, C, D). Arrangements connected with lifting of physically very weak persons take time and therefore lifting equipment is not always used by the nurses and caregivers. Professional training in this field from the side of the employers is needed.

Comparisons with other studies in Estonia

An extensive study including the risk assessment of the nurses was carried out by Kadanik (2012) in SA Läänemaa Haigla (hospital in the West of Estonia). The risk assessment covered the area of the psychological and physical risk factors and was connected with the employees' job satisfaction. The subjects of the study were the risk factors of the nurses and caregivers arising from their psychosocial environment. Work overload, lack of tools and work organization were the most problematic issues of job satisfaction (Kadanik, 2012). The health of the nursing staff was influenced by the excessive workload, which was caused by the extremely intensive work (high work pace). The static posture, bad quality of tools and the lack of modern tools, as well as too short rest periods, were considered to be the most important factors that had a damaging effect on the nurses' health.

The authors suggest that the working conditions in the nursing homes have been improved during the last two years. More nurses should be employed as a prerequisite for the flexible working shifts adjusted to nurses' and caregivers' individual needs and their family demands. These activities, along with improving physical and psychosocial working conditions, could increase nurses' and caregivers' job satisfaction, wellbeing and work efficiency and would lead to increased quality of health care in the nursing homes.

The *m. abductor pollicis brevis* fatigue decreases the workability of the nurses and caregivers and increases the possibilities for developing the musculoskeletal disorders (MSDs). The changes in the EMG signal of *m. abductor pollicis brevis* give the data for prevention of MSDs to the medical doctors in the beginning stage. At present the MSDs are diagnosed only in the last stage of the disease, when the work is already disabled and very seldom it is possible to recover the workability of the muscles.

CONCLUSIONS

The measurements of the *m. abductor pollicis brevis* by electromyography showed that the muscles are tiring during the workday. The mean results in the EMG signal were: from 415.5 µV to 269.5 µV. The fatigue of *m. abductor pollicis brevis* developed from 11.5% to 42.5%.

The work of nurses and caregivers in the ageing people nursing homes is generally considered as physically demanding with a high risk for musculoskeletal disorders. The muscles are tiring and therefore the MSDs are possible. The other risk factors were as follows: work intensity, lack of time, social environment, social support, and psychological problems in the patient communication. Nurses and caregivers have high workloads because of the staff shortage.

The results from the study revealed differences in the feeling and perception of psychological stress in different nursing homes in Estonia depending on the state of the building and equipment for the ageing people staying there and accordingly the working conditions of the nurses and the caregivers.

Future research is needed to determine the fatigue in other muscles of the workers that are involved in the lifting process.

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