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Evaluation of Local Muscular Load on the Forearm in Industry

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ABSTRACT

The paper is focused on the muscular load of the forearm in the case of prede-fined working positions in relation to the handling of different loads. The study was conducted on 51 respondents (male, 20 - 38 years old). The work includes the results of forearm muscle load for shoulder flexion and abduction, the meas-urements were evaluated for the dominant upper limb. The main aim of the study is to demonstrate the relationship between forearm muscle load, working position and load handled. The research will be continued and extended to the female pop-ulation. The research was conducted primarily to define in advance inappropriate working positions that could cause future damage to the upper limbs.

Keywords: Integrated electro-myography, EMG, iEMG, Occupational disseas, Working postures, Ergonomics

INTRODUCTION

In today's era of extensive robotization, it may seem that the role of humans in production is becoming irrelevant, but the opposite is true, because humans will never disappear from the work process completely, but will occupy different jobs than before. Today, there are many laws, standards and regulations that protect workers against overwork, whether it is chemical, biological or physical. There are also standards and regulations that set limits on the physical strain that workers should be subjected to during a work shift; if the limits are not met, workers may develop occu-pational diseases. It is the overload of workers and the possible development of oc-cupational disease that is a major problem today. (Čech, 1978) Both mental and physical aspects affect a person's workload. Both affect the worker in a certain way. The worker may not be efficient enough due to psychologi-cal or physical stress, scrapfulness increases, etc. However, psychological stress is difficult to measure and define, much more difficult to eliminate, but it is completely linked to psychological stress and has a significant impact on workers. These two aspects cannot be separated, but only one is measurable - physical strain. Similar definitions are used by some other authors, for example, Mikuláštík (2015), who refers to workload as synonymous with stress, while indicating that workload can be understood as the demands that are placed on the worker and the way in which the worker handles them and how these demands affect the worker's psyche. It is im-portant to note that the concept of stress is not understood in a clinical sense in this case, although in more extreme working conditions, for example, the workload must be understood as a situation of imbalance and the consequences may also be cumu-lative for the worker and thus have a negative effect on the worker's organism. It is the sum of the requirements and external conditions in a given work sys-tem that affect the physical and mental state of a person. Each activity is a signifi-cant load on the human organism. If the degree of strain exceeds a value that inter-feres with a person's level of well-being at work, it is overload. Workload includes both mental and physical stress, which can be objectively measured in defined units. (Bureš, 2013) Depending on the magnitude (level) of the workload, fatigue will always set in. For a short period of time, fatigue can be overcome by willpower, but sufficient rest and regular breaks from work are needed to eliminate it. (Slamková, 2010) Physical stress causes many health complications, the most common occupational disease until 2021 was carpal tunnel syndrome, which was caused either by unilateral load of the upper limbs or from working with vibrating tools. (Bureš, 2020) Since this is the most common disease in industrial workers, the work focuses on physical stress, especially on the evaluation of forearm muscle stress. Physical load is the work performed by the muscles. It is influenced by the range of muscle groups and their activities as well as energy ex-penditure. It can be divided into static work, which is characterised by the fact that the muscles are contracted and remain in this position for a long time. The muscles are therefore not sufficiently supplied with blood and oxygen and are overloaded. In terms of time, it is a static load if the muscle is contracted for more than 3 seconds. And dynamic work, which in turn is characterized by alternating involvement of muscle groups and thus tension in these groups. (Kačerová, 2019) Dynamic load is less burdensome than static load. After static load is over, the muscles need time to recover. The de-gree of load is of course dependent on the strength capabilities of the person, as well as gender, age and the ability of muscle groups to recover. (Slamková, 2010) Research shows that women's physical strength is about one-third less than that of men. Men have the highest strength around 25 years of age, then there is a gradual decline of 2.5% in strength over a five-year period to 45 years, then the de-cline is much faster, around 5% over a five-year period. (Grime, 2018) The measurements can be performed by integrated electromyography (IEMG) or by strain gauge and computa-tional methods. EMG is nowadays the most accurate method available for measuring local muscle strain, and it is also the method legally permitted for the assessment of physical strain in the workplace. Electromyography is an examination method that allows us to assess the state of the human nervous and musculoskeletal system. The aim of integrated electromyography is to record the electrical activity of a selected muscle, which is induced by the change in the electrical potential resulting from mus-cle activation. The activity is recorded from nerves or muscles. Muscle activity is induced either by stimulation of the proband or by the will of the subject. (Ticháček, 2008) The study was conducted in the Czech Republic; therefore, all limits refer to national legis-lation. The experiments were conducted to determine local muscle loading in industri-al workers. Local muscle load is the load of small muscle groups when performing work with the limbs. The muscle forces exerted, the number of movements of the musculoskeletal structures under consideration and the working positions in relation to the extent of the static and dynamic components of the work are determined and assessed. In the Czech Republic, the EMG Holter from GETA is the only device approved by legislation for measuring local muscle strain. After the examination, it is evaluated whether the work is static or dynam-ic. The static component is defined as a load without movement during muscle contraction lasting 3 seconds or more or as a load associated with movement of muscle structures without rest periods. Predominance of static work means that static tasks are performed in an average eight-hour shift for more than 4 hours. Evaluation of the monthly average Fmax of the work forces for the extensors and flexors of the left and right hand according to NV 68/2010 Coll. The permissible values in % Fmax for men and women when working with a predominantly dynamic component for a monthly average 8-hour shift are 30%. The permissible values in % Fmax for men and women at work with a predominantly static component for an 8-hour shift aver-aged over the whole month are 10%. For the assessment of local muscle strain, it is necessary to assess several criteria in relation to each other, in particular excessive-ness, unilateralness and long-termness.

Longevity can be considered as a period of impairment that excludes an injury mechanism. The criteria of unilateral and exces-sive are always considered in relation to each other and tell us about the ratio of the forces exerted to their time course in terms of load on the same anatomical structures. (Mukhopadhyay, 2007) The main goal of the study is to analyse the connections between position of the upper limbs and the loads handled. The research was conducted primarily to define in advance inappropriate working positions that could cause future damage to the upper limbs.

METHODOLOGY

Subjects

A male group of were selected to perform the measurement. The group was in the age range 20 to 38 years (average age 26, 4, average height 180 cm, average weight 78 Kg, average BMI 24, 1). There were 51 men all completely healthy without any movement disorder, health problems or after hand surgery. The vast majority was university students or administrative workers who have sedentary job and spend most of theirs time working with the computer. Men had a different physiological body structure and a different physique. All of those men were right-handed.

Process of the Measurement

When measuring and assessing local muscle strain, a detailed analysis of the working conditions (job description, time factors of work, rest, work mode, etc.), an assess-ment of the time factors of work (time snapshot of the working day), a description and assessment of the workplace (focusing on the handling plane and movement space, reach distances, tools, implements, etc.), and

Table 1. Differences by flexion 0° – 40°.

Flexion 0° – 40°	Average Fmax [%] flexors	Standard deviation flexors	Average Fmax [%] extensors	Standard deviation extensors
0Kg	1, 958	1,12	1,551	1,234
2Kg	9,129	3,930	5,035	1,934
4Kg	11,048	4,813	7,249	2,271
6 Kg	16,525	5,456	13,139	4,743
8 Kg	21,1525	5,383	16,965	5,755
10 Kg	26,8623	6,720	21,791	8,114

a description and assessment of the working positions (biomechanical analysis of the occurrence of conditionally acceptable and unacceptable working positions, assessment of the suitability of the basic choice of working position) must be carried out. The measurements can be per-formed by means of integrated electromyography (IEMG), or by strain gauge and computational methods. EMG is nowadays the most accurate method available for measuring local muscle load, during the measurement electrophysiological biopoten-tials are sensed from the examined muscle groups of the hands and forearms (elec-trodes are glued to the flexors and extensors). The EMG Holter device is used for the measurements, the data are then processed using special software. The measurement process was identical to the preliminary study which was already conducted (Bureš, 2020) respecting the conditions (Firrell, 1996) and (Mathiowetz, 1985). The measurements were performed using the EMG Holter from GETA. In the evaluation, the average maximum forces of the given tasks were compared according to legislation.

RESULTS

The results of the measurements are the relative values of the exerted muscle forces - % Fmax (MVC). The results were varied depending on the physical condition of the volunteers. Volunteers who are accustomed to using the muscles of their hands and forearms (for example by work out in fitness centre) have had better results than volunteers who have more passive lifestyle. Results of measurements were also af-fected by the place where the electrodes are stacked, amount of hairs on forearm, fat under the skin etc. The working positions were measured according to the methodo-logical instruction and then evaluated by statistical evaluation. A total of 51 meas-urements were evaluated. Since in industry activities are mainly performed with the dominant upper limb, only the right hand was evaluated.

Comparison of arm Flexion

The following tables contain average Fmax and standard deviations for arm flexion.

Extensors demonstrate greater muscle load than flexors, this is mainly due to the fact that all movements were performed overhand. In the event that

Table 2. Differences by flexion 0° – 60°.

Flexion 0° – 40°	Average Fmax [%] flexors	Standard deviation flexors	Average Fmax [%] extensors	Standard deviation extensors
0Kg	2,756	3,154	1,955	2,345
2Kg	10,892	4,368	6,663	3,590
4Kg	13,522	4,378	10.689	4,724
6 Kg	17,639	4,899	13,896	5,028
8 Kg	26,713	6,666	22,508	8,813
10 Kg	28,836	9,764	22,069	8.835

Table 3. Differences by flexion 0° – 80°.

Flexion 0° – 40°	Average Fmax [%] flexors	Standard deviation flexors	Average Fmax [%] extensors	Standard deviation extensors
0Kg	2,905	3,258	2,058	2,445
2Kg	12,102	4,274	8,214	3,158
4Kg	15,921	5,845	12,799	5,105
6 Kg	23,011	4,109	10,710	8,853
8 Kg	30,157	8,295	22,464	8,101
10 Kg	35,337	10,819	25,756	10,462

the movements were performed in an underhanded manner, it is hypothesized that the flexors would ex-hibit greater muscular load than the extensors.

Due to the different physical constitu-tion, it can be seen that the standard deviation increases with increasing mass, caus-ing more variability in the results. Flexors have lower values than extensors. The mean averagce %Fmax (MVC) values for both arms increase gradually. The biggest difference is between 0 and 2 kg, as can be seen in the graph below, the difference is more pronounced in the extensor muscle group due to the load on the upper limbs.Due to the legislative limits (30% Fmax - MVC), the muscle load is close to the limit in the case of shoulder flexion with a 10 kg weight in all tested working positions. The limit is exceeded in the case of the 0 - 80° position and already in the case of handling an 8 kg load, see the results in the graph below.

Comparison of arm Abduction

The following tables contain average Fmax and standard deviations for arm abduction.

In the case of abduction, greater muscle strength is also observed in the extensors of the upper limbs, the difference between extensors and flexors is on average around 6% Fmax. The greatest increase in muscle strength is between 0 and 2 kg. The muscle load limit is exceeded in the case of manipulation with 10 kg weights up to 60° and up to 80°, also in the case of manipulation with 8 kg weights up to 80°. In the case of handling an 8 kg

Table 4. Differences by abduction 0° - 40°.

Flexion 0° – 40°	Average Fmax [%] flexors	Standard deviation flexors	Average Fmax [%] extensors	Standard deviation extensors
0Kg	2,025	2,028	1,304	1,571
2Kg	11,018	4,376	7,561	2,829
4Kg	16,458	5,013	9,926	4,041
6 Kg	22,039	5,668	15,244	6,230
8 Kg	25,140	6,894	18,259	7,208
10 Kg	27,306	7,486	21,039	7,809

Table 5. Differences by abduction 0° – 60°.

Flexion 0° – 40°	Average Fmax [%] flexors	Standard deviation flexors	Average Fmax [%] extensors	Standard deviation extensors
0Kg	2,259	1,491	1,906	1,602
2Kg	13,678	4,716	8,892	4,499
4Kg	18,584	5,727	11,655	5,246
6 Kg	23,768	6,324	16,411	6,933
8 Kg	28,529	7,046	21,669	8,678
10 Kg	31,312	7,425	23,739	9,089

Table 6. Differences by abduction 0° – 80°.

Flexion 0° – 40°	Average Fmax [%] flexors	Standard deviation flexors	Average Fmax [%] extensors	Standard deviation extensors
0Kg	2,899	3,339	1,877	2,794
2Kg	15,198	4,417	8,262	3,453
4Kg	21,032	6,978	13,754	6,436
6 Kg	26,201	8,203	16,537	6,561
8 Kg	32,493	11,016	23,814	10,127
10 Kg	38,355	13,189	26,501	11,686

weight up to 60°, the limit is approached. The muscle load of handling loads up to 80° is shown in the graph below.

Comparison of arm Flexion and Abduction

The muscle load in the case of shoulder abduction is higher than in the case of shoulder flexion in every considered case. There is a greater difference in the extensor muscle group with an average difference of about 3, 5% Fmax (MVC), in the case of the flexor muscle group the average difference is about 1, 2% Fmax (MVC). The difference was observed between all measured positions. The difference between extensor muscle loads for flexion and abduction for all manipulated loads can be seen in the graph below. The biggest difference in the case of manipulation up to 40° was recorded

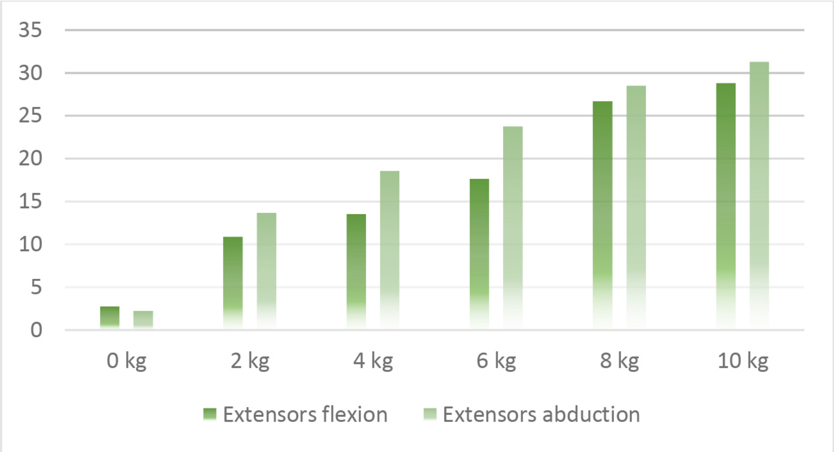

Figure 1: Comparison of flexion/abduction 60°.

in the case of manipulation with a 4 kg weight, while in other positions the biggest difference was recorded with a 6 kg weight. The biggest difference was observed in movement up to 60° and when handling a 6kg load, as you can see in the graph below.

Abduction is an unnatural movement for humans and workers in terms of physiology, and this is one of the reasons that the muscle load on the forearm is higher.

CONCLUSION

On the basis of the conducted research it was found that flexion of the upper limb is less demanding than abduction of the upper limb in terms of muscle load of the forearm (extensors, flexors). The given outcome was obtained by measuring it using integrated electromyography and then evaluating it according to the average muscle force during the given movement. Due to the link to industrial production, only the dominant upper limb was evaluated in the research; the submissive upper limb is minimally used for unilateral load handling. 51 respondents participated in the research. The respondents were selected by random sampling method to ensure variability and reliability of the outcomes. Based on the outputs, it can be confirmed that there is an association between job position and weight of load handled. The paper is focused on specific changes in EMG results which emerge with the shoulder angle. Those results helped for evaluation of the measuring methodology and brought important knowledge on which areas to pay more attention. The research is continuing. More groups will be measured as well as female population. In the final phase our research will bring new information and more detailed outputs on interconnections between shoulder angle, lifting weights and % Fmax (MVC). With these results in mind, it is possible to eliminate inappropriate working positions that could cause workers to suffer an occupational dissease or illness in advance.

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