UPPER LIMB MUSCULAR ASSESSMENT IN A WORKSHOP OF WELDING WORKERS - CASE STUDY

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Abstract

Welding has one of the highest prevalence of musculoskeletal disorders (MDS) and clinical diagnosis. According to some studies, the disorders related to the activity are in the shoulders, neck, and low back, primarily by work in static load in postures above the shoulders. This study is focused on welding in joints and prefabs workshops in real working conditions. After an ergonomic diagnosis, and according to the literature, a muscle evaluation was performed using surface electromyography (sEMG) in a sample of three subjects without any upper limb diagnosis. The muscles evaluated were trapezius, deltoids, extensor carpi ulnaris and radialis, flexor carpi ulnaris and radialis in the dominant arm. The measures were 30-60 minutes, depending on the welding piece. The equipment used was the Biometrics DataLOG (MWX8) and six EMG sensors (SX230). The data processing was following the SENIAM standardized norm. As a result of the assessment, the trapezius and the flexor carpi radialis presented the highest mean muscular activity, 20.92% and 24.43%, respectively, according to the maximum voluntary contraction (MVC) evaluation. The static load should not exceed 15% of the muscular activity; if it is exceeded, it could lead to the development of musculoskeletal disorders. It was found that the muscular activity associated with welding is risky, especially in the cervical region. To improve the working conditions in a workshop for muscular activity and the postural condition, it is recommended to implement a hydraulic press to adjust the working height.

Keywords: *ergonomics, assessment, welding, electromyography, workshop*

1. INTRODUCTION

Welding work is one of the jobs with forced extended postures (FEP), which generates illnesses, absenteeism, disabilities, and forced retirement from work. Muscle fatigue causes a reduction in the capacity of the muscle during the development of the activity. This fatigue induces inadequate postures and changes in the transmission force in the joints, which can cause damage to these and the ligaments [1]. Surface Electromyography (sEMG) has been widely used to assess muscular activity and identify if there is potential muscular fatigue. sEMG measures muscle activation quantitatively with no invasive methods [2].

The welding activity is presented in different workplaces: according to the International Labor Office (ILO), musculoskeletal disorders are presented in this activity, the cause it is fatigue due to standing for long periods, sprains due to lifting heavy machinery or metal products, and cramping due to working in vertical, horizontal, or overhead positions. The affected parts of the body are the wrist, elbow, shoulder joint, and back pain.[3]. During 2020 in Colombia, 2.550 welders were affiliated at the safety system, and two diseases were reported. Welders usually work in mines, manufacturing, and construction industrial sectors according to the minister of health and social protection, the illness reported were 199,10, 196,63, and 41,13 per 100.000 workers [4].

This problem has been studied around the world. The result of the study developed by Zhan and others of a simulation of ergonomics revealed recommended conditions for Chinese welders for operating distances, operation heights, and neck angle rotation [5]. The working conditions have been evaluated in other studies, but they also were performed in simulated scenarios, e.g., an experiment developed with 14 welders, seven of them were in physical activity training conditions and the others seven were

inactive, the results showed that the active groups had lower muscular activity[1]. Another example of it was the test of a prototype design in welding in construction, where thirty welders between apprentices and experts performed a test of a prototype design. From biomechanics, postural issues and muscle activity were evaluated. Facing posture was assessed in the trunk and muscle activity in the forearm flexors and extensors, upper trapezius, erector thoracic spinae. A decrease was found in most muscles with the prototype except for the trapezius. Regarding the postural issue, it goes from flexion of 79° to 9.6° on average, and the difference in both posture and muscles is statistically significant [6]. Finally, another study was developed; this study aimed to evaluate the effect of one workday on pain and perceived exertion, muscular strength, and electromyographic activity of the erector spinae muscles in welders with and without low back pain (LBP). They used a lumbar dynamometer, a sEMG and an EGNM. The evaluations were conducted in a welding laboratory, where the three welding positions (standing with horizontal trunk flexion, semi kneeling, and kneeling with both knees on the floor with flexion of the trunk) were re-produced as men welded steel sheets. Allowing them to confirm that low back pain is a condition that does not allow the proper development of the activity [7].

All the scenarios presented, had something in common, they were all simulated tasks or were made in a laboratory in controlled situations. Real conditions for welding activity were not evaluated. Perhaps, in a systematic review of work above shoulders, just seven of them used direct measures to evaluated condition, but they just used inclinometers. Moreover, there were also found risk assessments of upper limb muscular activity. Those studies were a diagnosis of the conditions in real environment in different economic sectors: Coffee harvesting [8], [9] and flower industry [10], [11]. The aim of this case study was to evaluate the muscular activity of welders in real conditions.

2. METHODS

2.1. Study design

The main objective of the case study was to assess the muscular activity by surface electromyography (sEMG) during the real conditions in welding activity. To achieve the aim of this study, welding activity was observed to identify relevant working conditions and muscles of interest for the sMEG. Surface electrodes were placed according to SENIAM and anatomical guidelines (Perotto y Hermens). Before placing the electrodes, skin was cleaned with alcohol and cotton. Also, all covid-19 protocols were considered.

To calculate the percentage of muscle usage during the execution of welding task, the maximum voluntary contraction (MVC) was considered. Standardized maneuvers were performed according to the book anatomical guide for the Electromyographer: The Limbs and Trunk [12]. MVC makes possible to normalize signals and perform analysis between subjects. Workers were instructed to execute their maximum strength. Data was gathered 3 times for each muscle with a 1-minute pause between each and they maintained each contraction for 10 seconds. Recordings had durations of 30 minutes.

Data collection was performed at the beginning of the working day in real welding conditions. The muscles that were measure in the activity were the trapeze, deltoid, extensor carpi radial, extensor carpi ulnar, flexor carpi radial and flexor carpi ulnar.

2.2. Subjects

3 Welders who worked in the same company were recruited. All participants were experienced with gas tungsten arc welding (GTAW). Informed consent was provided. Acute or chronic disease in the upper body was considered as exclusion criteria. The age ranged from 28 to 54. Neither of them referred practicing physical activity. No incentives were given for participation in this study.

2.3. Equipment

The equipment used was the Biometrics Data LOG (MWX8) and six EMG sensors (SX230). The raw sEMG voltage signals were wirelessly sampled at 1000 Hz. The signals were encoded and transmitted in the American Standard Code for Information Interchange (ASCII) format and processed using algorithms in the Matlab R2013a/R2018a program (United States), the root mean square (RMS) signal was estimated from

a 200 msec moving window and normalized with the maximum voluntary contractions (MVC) recorded for each muscle at the 5% and 95% static, mean, and dynamic levels were estimated in the amplitude probability distribution function (APDF).

3. RESULTS

During the observation of the working conditions, it was seen that the workers usually adopt awkward postures because it is not possible to move or rotate the pieces they need to weld because of their complex structure, height or the welding type. Also, the working surface is fixed at 77 cm form the floor. This situation also forces them to perform the activity mostly in extended forced postures with static load. Further, argon welding requires the maintenance of the welding filler at a specific angle to ensure the quality of the process. It was identified neck flexion, arm rotation, elbow flexion and wrist extension. Welders reported that those postures were necessary for the visualization of the parts and the manipulation of the welding tool or electrode. Also, this electrode is used for approximately 5 continuous minutes in argon welding.

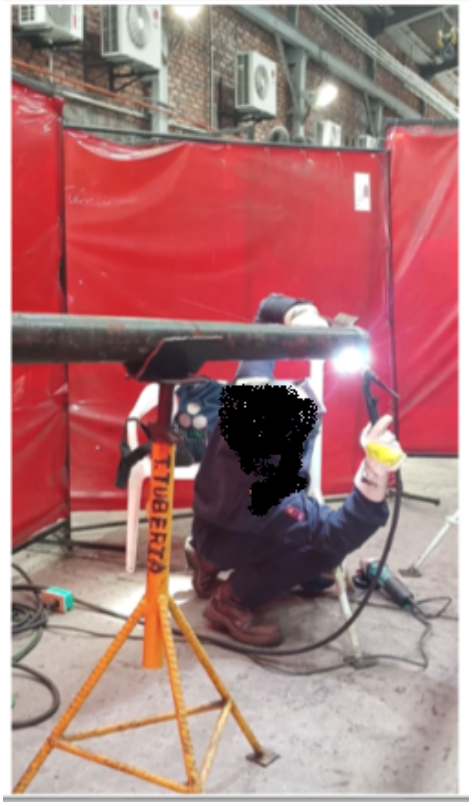


Fig. 1. Welding activity

In the working area they have, as mechanical facilitator, a bridge crane and arms but they don´t fit properly with the working surface so the worker has to ask one of his/her coworkers to lift the pipelines from the floor. It is not possible for only one person to lift it because of the pipeline's dimensions and weight.



Fig. 2. (a) Bridge crane (b) Arm

For the muscular activity measured in the process, the most strained muscle during the activity of welding were the muscles that allow the extension for the forearm (ECU and ECR), also the trapezius and the flexor carpi radialis which presented a mean value over the 20% of the MVC. If it is considered an eight-hour working shift, those muscles will be at a high risk. Studies suggest that the muscle activity must not exceed 5% of the MVC during statics loads (Jonsson, 1978). The fatigue will appear if 5% MVC is maintained for an hour or more (Sjogaard et all, 1986). Then again, the literature suggests that the limit of muscular endurance is 15% of the MVC in periods shorter than one hour and 8% in periods longer than one hour (Rohmert,1973).

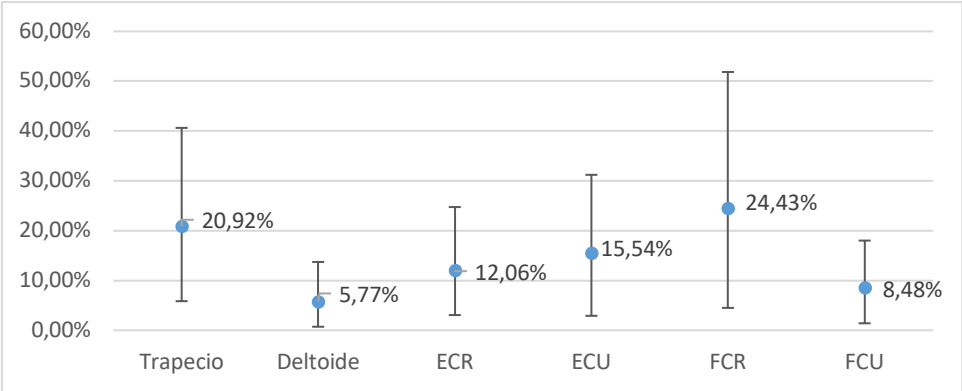


Fig. 3. Muscular activity (Percentile 5, Mean, Percentile 90)

Considering the described above, it mainly affects muscles of the neck and forearm. However, it is also important to carry out interventions to reduce the muscular load of the deltoid. Observing the activity, it is evident that at different times the workers acquire awkward postures which contributes to this increase in muscle load. Work postures were found at a height higher than the shoulder and performing wrist flexions and extensions together with radial and ulnar deviations.

4. DISCUSSION

The identified risk factors during the observation of working conditions revealed high static load on the shoulders, neck an arms as it was reported in other studies [13] where they said this could be an explanation of the high prevalence of neck and shoulder problems among welders. Moreover, other studies also found high prevalence of self-reported low back pain [14]. Furthermore, another study in welders revealed that the long standing during the shift provokes podiatric disorders. It would be recommended to include back and low back muscles in future studies and podiatric studies. Additionally, it's important to consider the shoulders' kinematics, specially the scapulohumeral rhythm, which allows the position of the shoulder over the head by an adequate interaction between the scapula and clavicle with the glenohumeral joint.

Also, other studies have found that upper portion of the trapezius will be loaded the most in welding when the arm is flexed and abducted as the postures observed [15]. Moreover, a study found that strength trained subjects reported less exertion during welding compared to untrained. They defined relative muscle load as the ratio of absolute muscle load, in this case the welding tool, and the muscle strength capacity. They registered a reduction in relative muscular activation during the welding experimental test after training which suggests an improvement of muscular strength [1]. In this study, all evaluated subjects reported no physical activity. Including physical activity training may help the workers to keep the welding tool in the required position improving also the quality of the process.

Another study recommended regularly adjusting the work site making encouraging welders to change the posture of the welding filler [16]. Nowadays, this isn't possible in the actual working conditions because the height of the working surface is fixed and GTAW welding demands specific working angles. One recommendation after this study is to implement height adjustable working surfaces. This decision could be supported by a laboratory electromyographic investigation where they found that none of the arm and back muscles they studied gave sufficient high levels in low vertical welding [15].

Also, another study revealed that it is not recommended for welders to use a welding torch weighing more than 6 kg in order to prevent lower back pressure, upper limb force and to promote comfort value [16]. The tools used for GTAW welding weight between 5.2 and 8.4 kg depending on the reference. Thus, all of them work as good as the others, it is recommended to gradually change to the lighter ones.

Thus, this study was based on muscular activation, it is recommended in future studies to evaluate the mechanical demand, combining the measurement with the postural evaluation in the same study segments.

5. CONCLUSIONS AND FUTURE WORKS

This study examined the muscular activity of GTAW welding process in 6 different upper limb muscles. GTAW was selected for being the most used procedure in the company. The results showed the highest muscle activation (Mean= 20.92% of the MVC) in the trapezius followed by FCR (Mean= 24.43% of the MVC).

As a result of this study, it is easy to identify that it is needed an improvement of working postures and in the equipment. It was found that working conditions are characterized for awkward postures, manual material handling static load in upper limbs and sustained flexion in elbow postures primarily as a consequence of the working surface because it doesn't have adjustable height. This condition combined with the required position of the welding filler at certain angles of the pipelines to ensure the quality of the process for GTAW welding increases postural risk. Thus, it is recommended to have adjustable working surfaces to improve working postures.

It is expected that implementing the height adjustable working surface may decrease muscular activity in trapezius, deltoids and forearm muscles because workers won't be forced to maintain static postures overhead and they also can improve radial and ulnar wrist deviations.

The implementation of the adequate bridge crane and arms to lift the pipelines would improve working conditions for the welders by reducing lifting effort when carrying them. Also, manual material handling

in this activity forces the worker to adopt awkward postures in upper limbs and this may lead to back, shoulder, neck or arms injuries. As a complementary study, it would be desirable to evaluate postural conditions using direct measures methodologies.

Improvement in working postures and equipment will increase welders' productivity, reduce injuries and contribute to economics in business.

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