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Original Article

Evaluation of a Passive Robot Arm for Overhead Work: Experimental Approach

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***Abstract** - Overhead work is an important risk factor for upper extremity musculoskeletal disorders. This paper considers the evaluation of a passive robot arm and an exoskeleton as wearable assistive devices for overhead work. The performance evaluation is to be conducted by the electromyography analysis of the arms, shoulders and backs muscles obtained in experiments.*

***Keywords** - Overhead work, Passive robot arm, Exoskeleton, Payloads, Electromyography.*

I. INTRODUCTION

The problems of shoulders, arms and backs are prevalent in industrial work, mechanics, agriculture and construction today.Musculoskeletal diseases of the arms and back are serious problems. In the United States, the reported number in 2011, the incidence of the musculoskeletal disease:shoulders is 13%, backs is 42%. The shoulders injuries are serious problems, with the average number of days off for shoulder ailments reported as 23 days (compared with 11 days for other injuries). Musculoskeletal diseases often have a repetitive and prolonged element. Studies have shown that heavy lifting tasks at height (i.e., when working with arms at or above the shoulder) have been suggested to be one of the major causes of these diseases in musculoskeletal [10] - [16]. Those jobs that need to lift heavy objects at height are very common in the mechanical manufacturing and construction industries, such as drilling, bolting, and cutting materials...

There have been many scientific studies on these problems in recent years, including both theory and experiment [1]-[9]. Although extensive research has been conducted on prolonged static exertions, and several guidelines for such efforts exist, there is insufficient information for the ergonomic evaluation of intermittent and/or dynamic tasks. A laboratory simulation was conducted of overhead assembly work that was both intermittent and dynamic and which varied the duty cycle (work/rest ratio), arms reach, and hand orientation of a tapping task. Results consisted of endurance times and fatigue onset times as indicated by perceived discomfort and declines in muscle strength. Significant influences of duty cycle were found on both endurance and fatigue times, yet arm reach and hand orientation did not have consistent effects. Distributions of endurance and fatigue times are presented as criteria for preliminary evaluation of overhead work.

This paper presents an experimental study evaluating the effectiveness of a passive robotic arm for tasks requiring overhead lifting. The purpose of the study is to reduce the force exerted on the shoulder and back muscles. A mechanical arm mounted on a skeleton robot body (Figure 1) supports heavy objects such as machine tools and transmits force to the ground, reducing the force exerted on the shoulder and back muscles.This paper estimates the effect of using robotic arms for overhead lifting. It is performed by comparing this situation with the case of lifting objects without the help of the arms through electromyography signals obtained from the shoulder and back muscles. In addition, it is also assessed through the feedback of the experimental participants.

II. CONSTRUCTIONS OF EXPERIMENTAL SYSTEMS

A. Experimental Systems of Passive Robotic Arms When Lifting Objects from the High Position

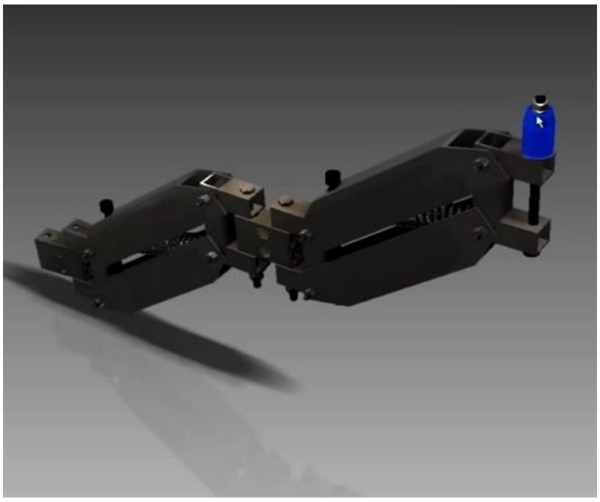


Fig. 1 Passive robotic arms

The experimental system of the passive robot arms consists of a passive robot arm designed according to the principle of balancing the weight of the lifting object and the elastic force of the two springs inside the arm (Fig. 1). The geometrical dimensions of the arms are calculated to be suitable for an adult.

The robot arms can move flexibly according to the operator's movement by hinged joints. The robot arms are linked with a skeleton robot leg system to complete the robot systems that lift heavy objects and transmit the weight of the weight to the ground. Therefore it reduces the robot's force on heavy objects on the person.

B. The Selection and Set of Measuring Sensors

a) Selection of Input Devices and Measuring Devices

Electromyography signal measuring equipment and input devices are produced by Noraxon company, USA. The measuring input device connects to the measuring device by wifi signal, and the measuring device connects to the computer by a Lan wire connection. The measuring input device is attached to the two poles of the electrode sensor, which is glued to the skin's surface. From these, the electromyography signal on the skin's surface can be sent to the computer by the transducer and recorded (see Fig. 2).

Fig. 2 Electromyography signal record system

b) Select Sensor Positions

According to biomechanical studies, the shoulders and back muscles work mainly when we lift the objects. Hence, we chose the position to attach the sensor to the anterior shoulder, middle shoulder, and back muscle (see Fig. 3).

Fig. 3

C. Method of Processing Experiment Results

a) Participants

We considered five participants; all participants were an average height of 1m70 and average weight of 70kg, between ages 18 and 22, and reported moderate physical activity levels with no recent history of musculoskeletal injuries.

b) Experimental Tasks

Each participant performed 6 lifts in 30 seconds, where 3 times lifted without the help of the robotic arm and 3 times with the help of the robotic arm. Lifting loads are light loads (1kg), medium loads (3kg) and heavy loads (6kg), respectively.

c) Stores Data

There have been many methods of recording and processing electromyography signals [17]-[25]. In this research,the electromyography signal data received by the transducer is transmitted to the computer by wifi signal. on the computer, the specialized software NORAXON MR3.8 is installed. The software records each measurement in a record. on the record, 6 signal channels can be obtained corresponding to the locations of the measuring input device, which are the left anterior shoulder muscle, right anterior shoulder muscle, left middle shoulder muscle, right middle shoulder muscle, left-back muscle and right back muscle (see Fig. 4).

Fig. 4 Electromyography signal data by NORAXON MR3.8

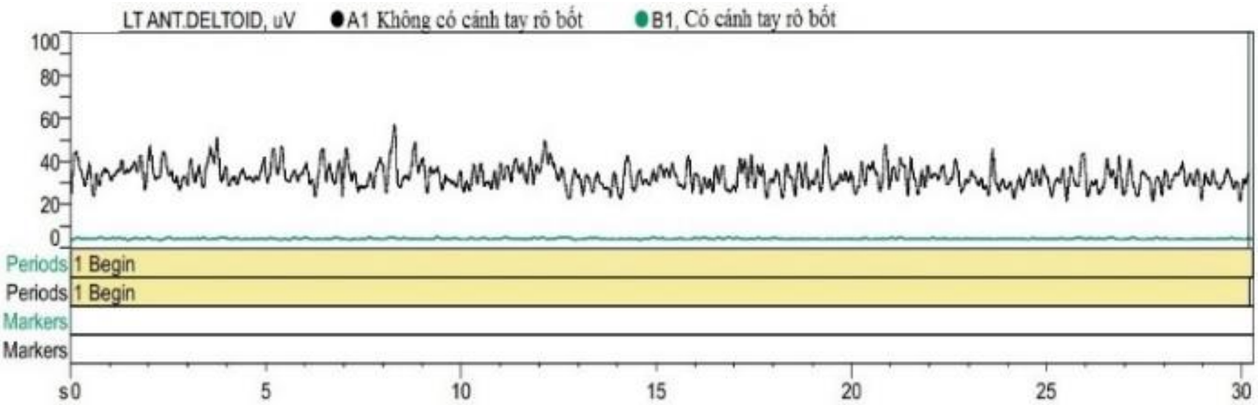
d) Processing experimental data

After receiving the raw signal, it will be processed by NORAXON MR3.8 software through raw signal filtering, rectification, signal smoothing...Then the corresponding electromyography signal between the experimental case with and without the support of the robot arm will be compared with each other on the same graph.

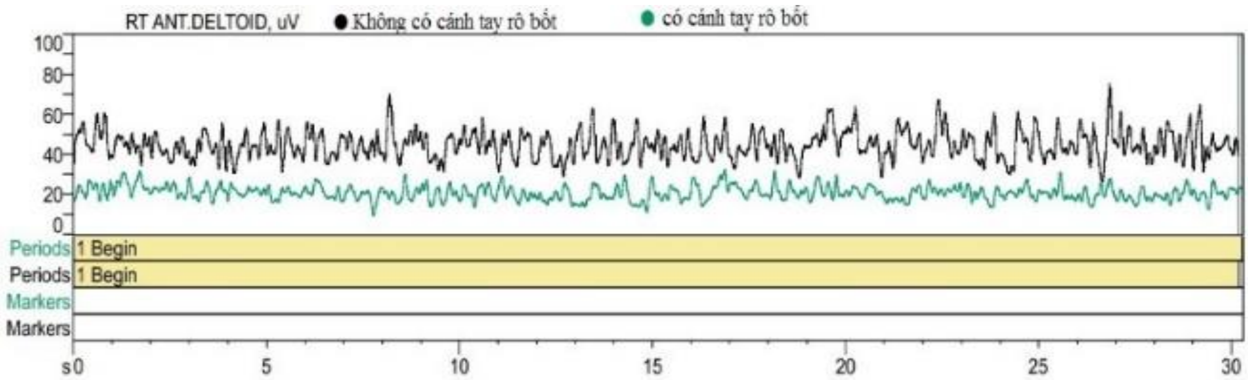
III. RESULTS AND DISCUSSIONS

A. In the case of light lifting load (Q = 1 kg)

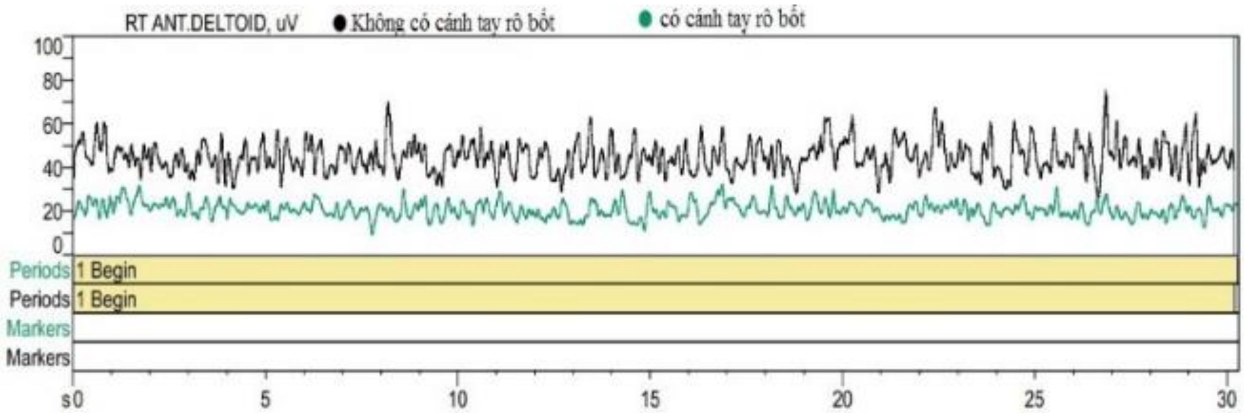
Experimental results with a lightweight lifting object Q = 1kg in the case with and without the robot arm support are shown in the electromyography signal graphs below (in the case of the robotic arm). Blue graph robot, no black graph robot arm):



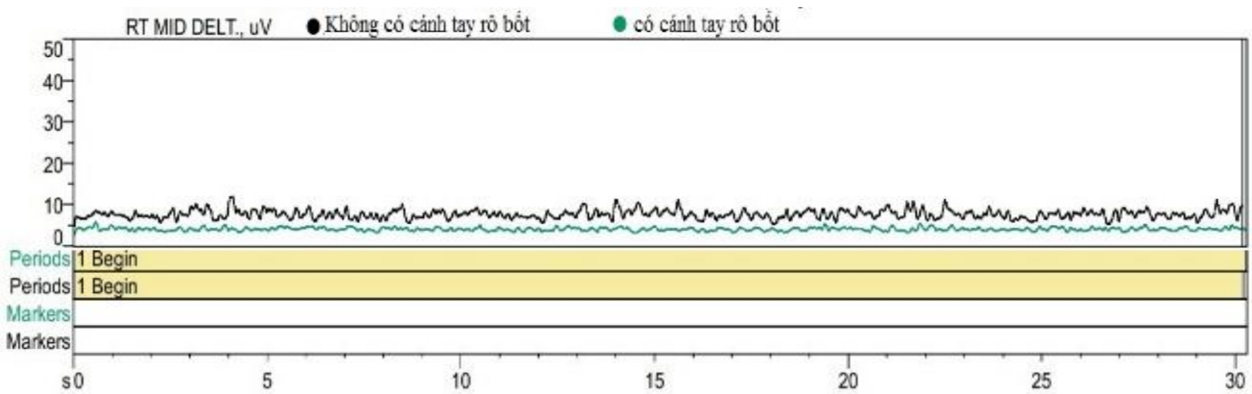
Left anterior shoulder muscle



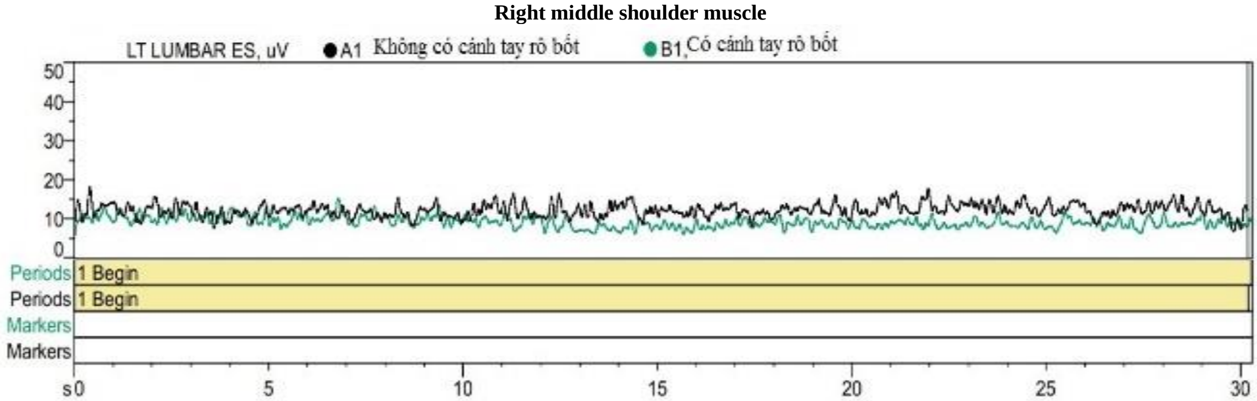
Right anterior shoulder muscle



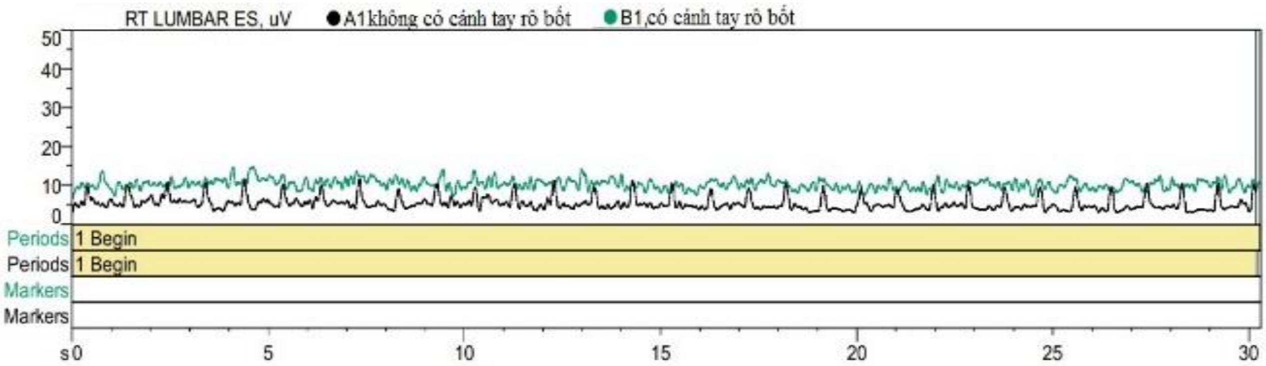
Left middle shoulder muscle



Right middle shoulder muscle



Left-back muscle

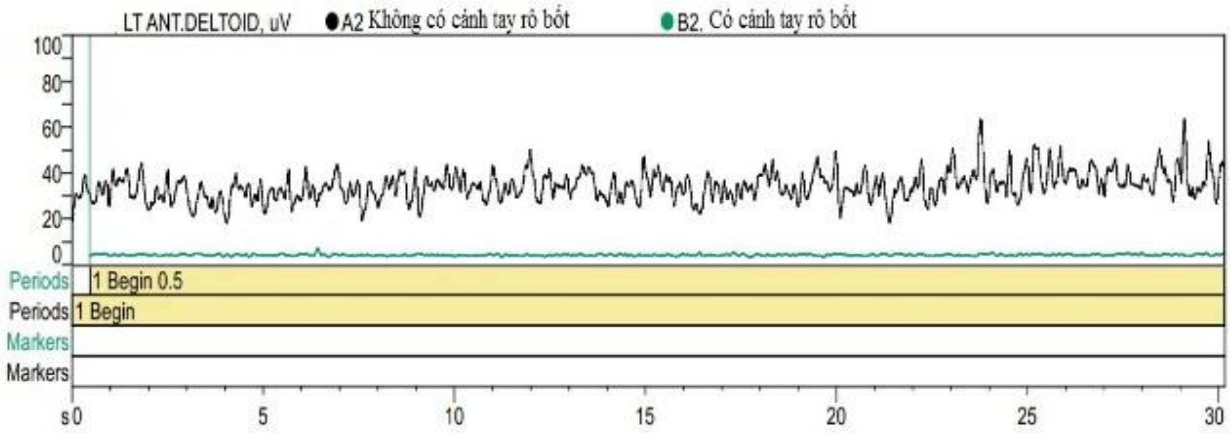


Right-back muscle

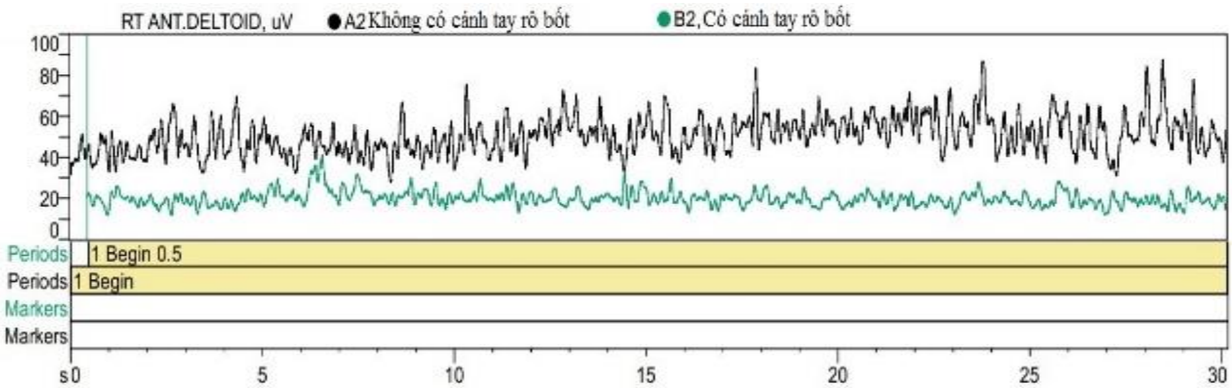
The experimental results show that with the help of the passive robot arm in lifting light objects, the electromyography signal is significantly smaller and smoother, which shows that the muscles do lighter work. Especially with the right and left anterior shoulder muscles, the electromyography signal with the help of the robot arm is reduced by about 50% compared to the case without the robot arm.

B. In the case of average lifting load (Q = 3 kg)

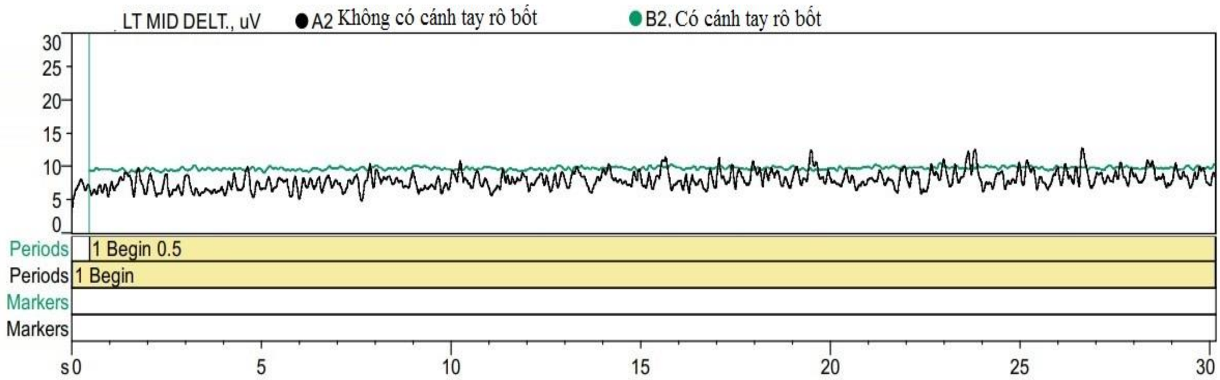
Experimental results with the lifting object with average load Q = 3kg in the case of with and without the help of the robot arm are shown in the following graphs of the electromyography signal:



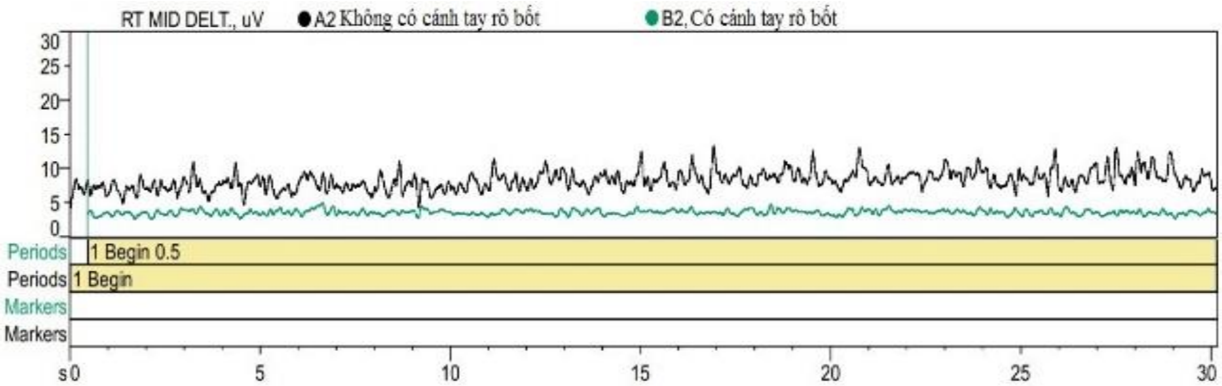
Left anterior shoulder muscle



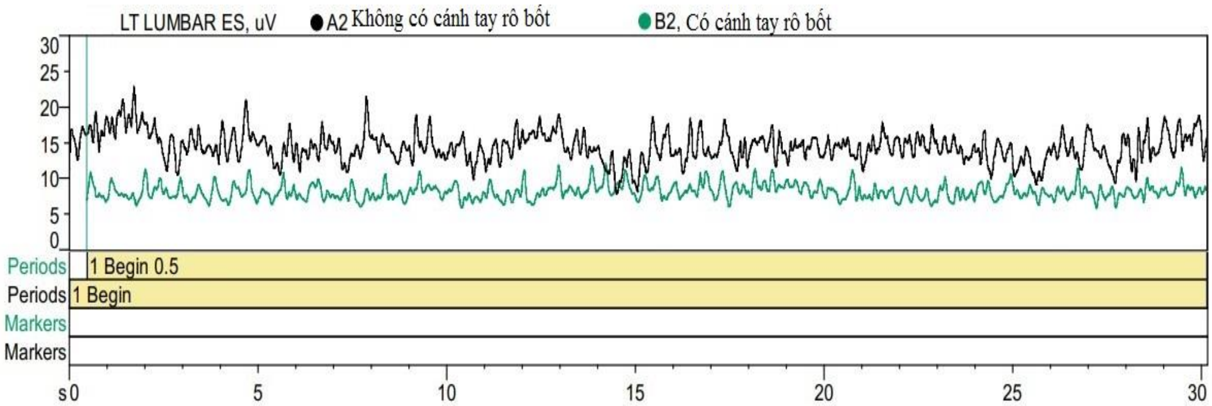
Right anterior shoulder muscle



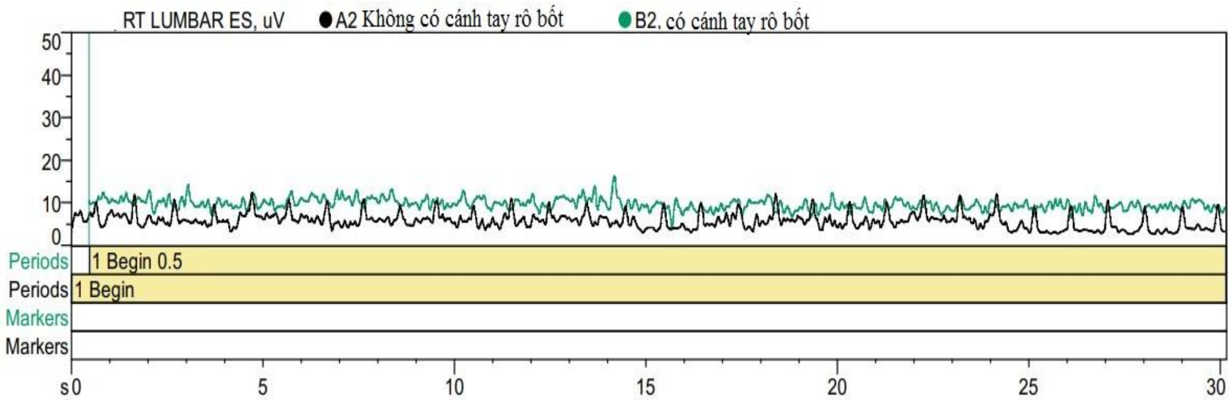
Left middle shoulder muscle



Right middle shoulder muscle



Left-back muscle

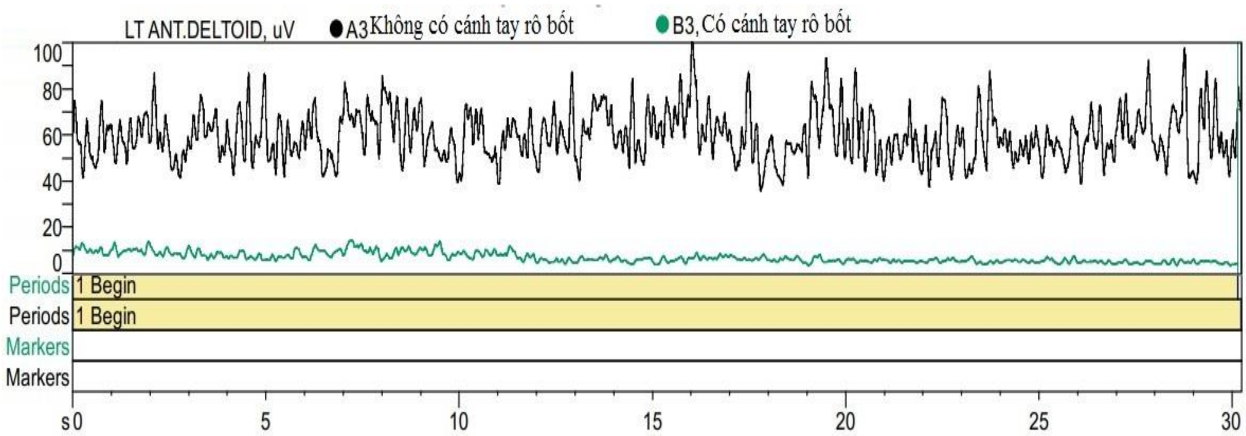


Right-back muscle

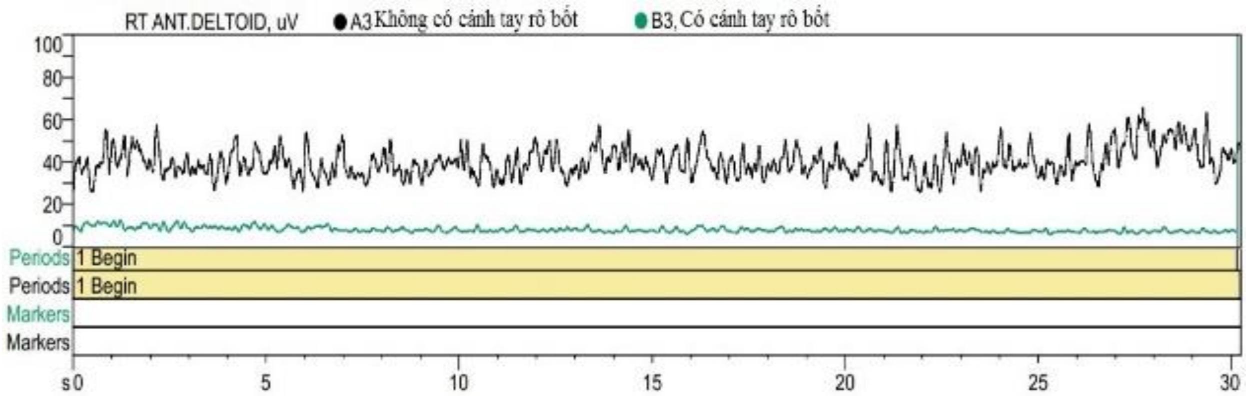
Similarly, to the case of light load, with the average load, the electromyography signal obtained in the case of robot arm support is also lower and smoother than in the case without the robot arm support. Especially with the anterior shoulder muscle, the lower right shoulder and left-back muscles are reduced to more than 50% to 70%.

C. In the case of average lifting load (Q = 6 kg)

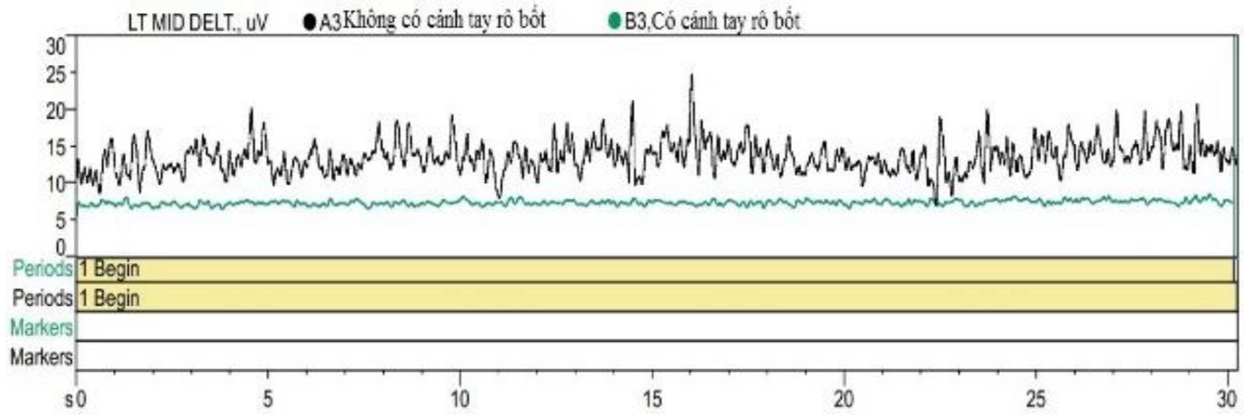
Experimental results with the lifting object with an average load Q = 6kg in the case of with and without the help of the robot arm are shown in the following graphs of the electromyography signal:



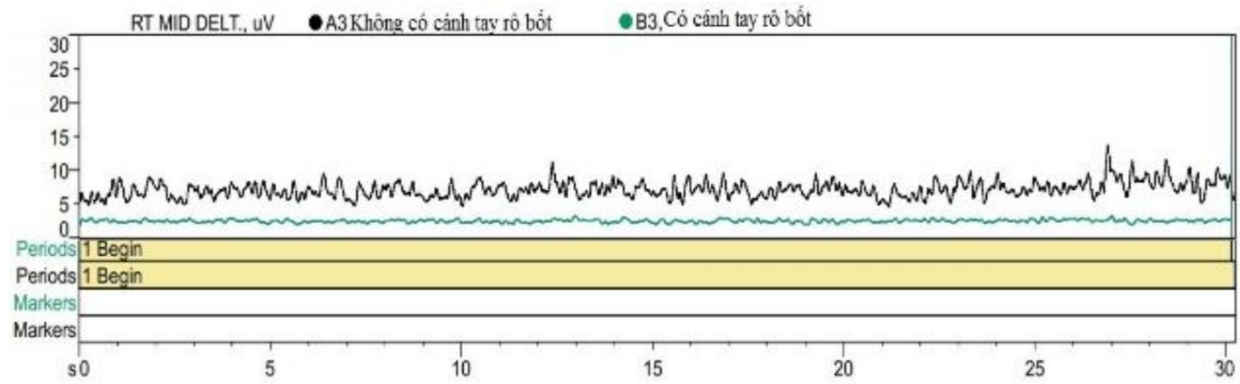
Left anterior shoulder muscle



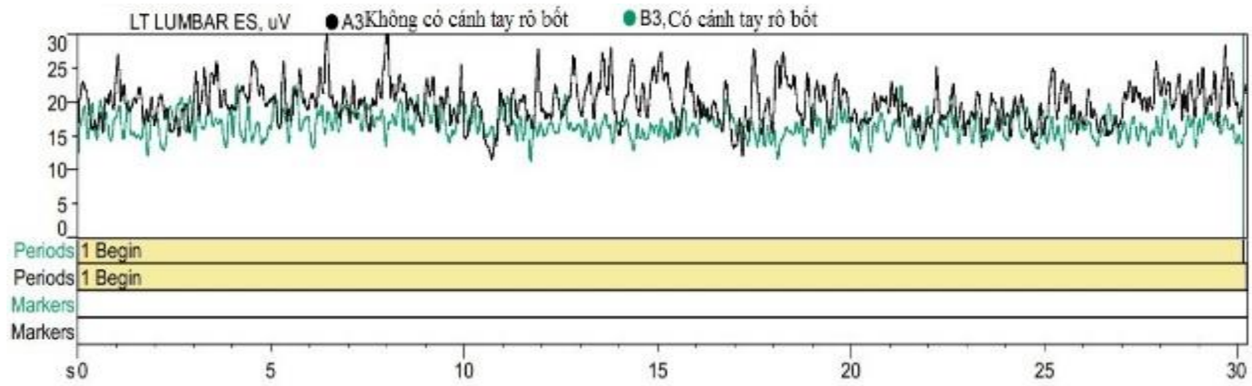
Right anterior shoulder muscle



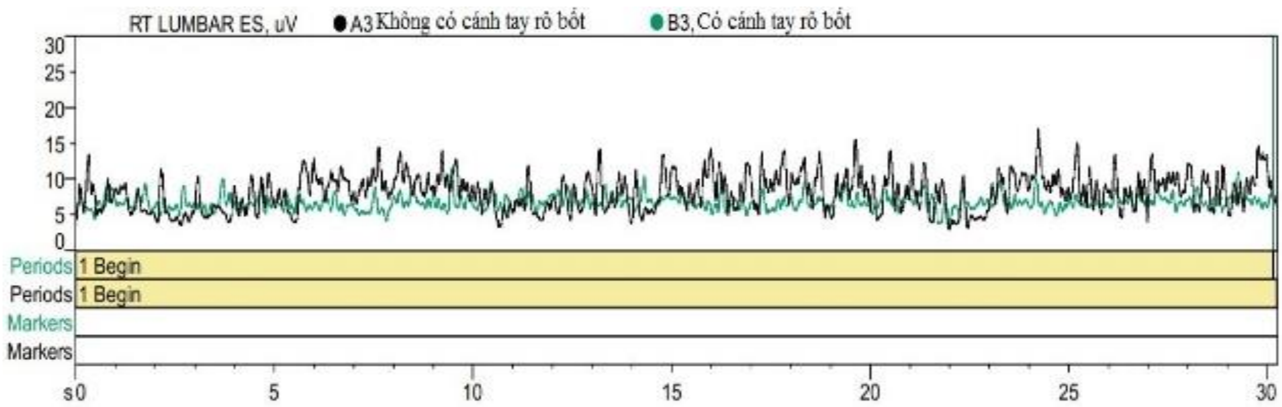
Left middle shoulder muscle



Right middle shoulder muscle

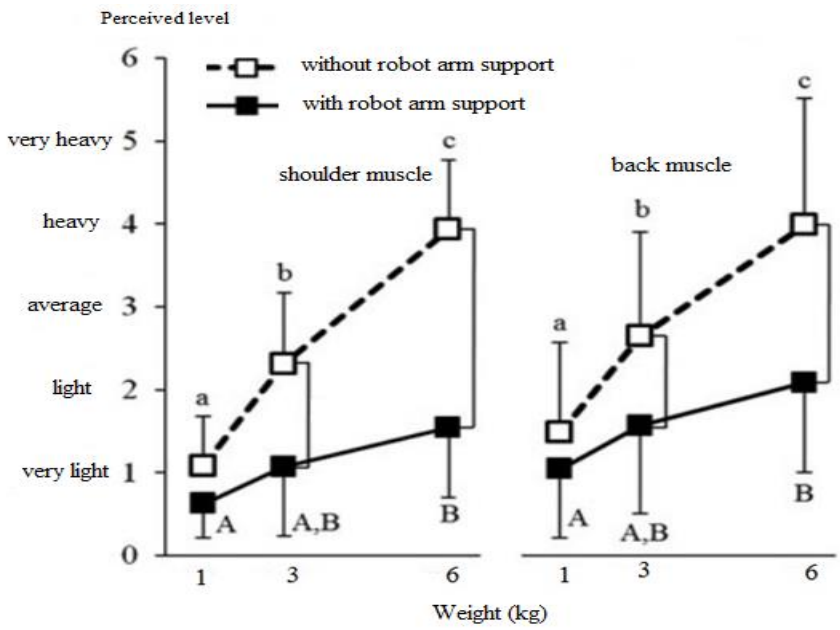


Left-back muscle



Right-back muscle

In the heavy load case Q = 6kg, we see that the electromyography signal of the anterior shoulder muscle in the case of robot arm support is big lower than in the case without arm support(over 70%). In the case of support to a robot arm with light, medium and heavy loads, the electromyography signal is almost equivalent. It implies that with different loads, with the help of the robot arm, the force acting on the hand muscles is very light and comfortable for the user.



IV. CONCLUSION

From the experimental results in the paper, we have some conclusions as follows:

With the help of a passive robotic arm, the force acting on the left-and right-hand muscles is reduced from 50% to 70% compared to the case without the help of the robot arm.

The electromyography signal in the back muscle has a value smaller than in the shoulder muscle. It shows that the force acting on the back muscles is not much when lifting heavy objects overhead. Especially with the help of the robot arm, the value of the received electromyography signal is very small.

The experimental results in the article show that the supporting effect of the passive robot arm on the fatigue level of the hand muscles is very clearly.

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