IDENTIFICATION OF ACTIVE HUMAN UPPER LIMB MUSCLE FOR INTENTION DETECTION ACTIVITY

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ABSTRACT

The upper limb comprises various muscle groups that control movement through contraction and extension. These actions, which help in the joint movement of the human upper limb, can be used for intention detection activities. Intention detection is a method of extracting the information from the muscle movement of the upper limb that will help in classifying the type of muscle group for each different type of movement of the upper limb. This study investigates the use of Electromyography (EMG) to identify the muscle groups activated during specific upper limb movements based on their electrical activity. During this experiment, the participant wore a Bitalino sensor kit sequentially on the Biceps, Triceps, Trapezius and Deltoideus muscles. For each muscle group, they performed a series of upper limb movements, allowing data collection on muscle activity for each muscle individually. The captured signal was processed and visualized using software to identify the activated muscles. The experiment was then repeated with an additional weight of 5 kg to analyze the effect of load on muscle activation. The results demonstrate that distinct upper limb movements activate different muscle groups. For instance, flexion primarily activates the biceps brachii, while the triceps brachii remains inactive. Furthermore, the study reveals increased muscle activity during movements with added load compared to unloaded movements.

Keywords: *Electromyography (EMG), Intention detection, Upper limb movement, Muscle activation*

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1.0 INTRODUCTION

The human body upper limb consists of 34 muscle groups as well as 32 pieces of skeleton and tendons which connect the bones. The parts of human body upper limb are the shoulder, elbow, wrist, and fingers. Each part of the human upper limbs has joints that help in controlling the movement of the limbs. The contraction and extension of muscle groups (Trapezius, Acromion of scapula, Deltoid, Triceps brachii, Biceps brachii and insertion of deltoid) will help in joint movement of the human upper limb [1]. By extracting the information from the hands and arms, a variety of information can be obtained such as information on the human's physical movements and physiological status. This will help in creating a device for intention detection. Intention detection devices are devices capable of determining the intent of the users, requiring communication between the devices and the users.

It is well known that sensitive tissues such as the brain, nerves and muscles produce electrical signals and transmit signals. Different muscles are activated to perform different activities. Hence, there is a need to correctly identify which muscle is crucial for certain activities so that the use of sensor during human detection activities can be optimized. This study will investigate the relationship between the upper limb movement and muscle activation patterns.

1.1 Human Intention Detection Technique

Intention detection is a technique to determine the user's different forms of intent that requires a few channels of communication that exist between the human and the device. The term intention refers to the act of wanting to do something. There are two types of intentions, i.e., explicit intention and implicit intention [2]. The act of purposely transferring of information is explicit intention while implicit is the event when the act of the transferring of information about contextual and emotional states such as the emotional expression which is done involuntarily. The main goal of intention detection collaborating system is to determine or predict human action and emotion. Eventually, when the devices are able to understand and interpret the information, the extracted information can be used as a means of communication between a human and a robot.

The signals utilized for intention detection can be categorized as biological signals (bio signals). Bio signals are recordings of biological events, such as a beating heart or a contracting muscle, captured across various domains like space, time, or space-time [3]. These events generate electrical [4-6] and mechanical activity [7-8], resulting in measurable and analyzable signals. Bio signals offer valuable insights into the physiological mechanisms underlying specific biological events or systems. This information proves crucial for medical diagnosis and can be harnessed for various applications, including intention detection.

In the field of human motion analysis, various sensors have been explored for detecting muscle activation signals. Electromyography (EMG) remains the gold standard, offering the most direct measure of muscle activity through electrical signal detection [6]. However, EMG requires skin preparation and can be uncomfortable for extended wear. Inertial Measurement Units (IMUs) and inertial sensors offer a less invasive alternative, estimating muscle activity through complex algorithms [9]. Strain sensors have also been investigated for motion analysis [10-11]. These sensors primarily detect physical deformations or touch and may not provide the necessary resolution or specificity for accurate muscle activity recognition.

Information from the surrounding may also provide the necessary input form human detection such as through the use of motion capture sensor and tactile sensor [12]. Motion captures are used to capture the motion of the upper limb; tactile sensor are used to obtain the information about the external environment.

Overall, the choice of sensor depends on the specific application and desired level of detail. EMG offers the most accurate information on muscle activation, while IMUs and other sensors offer less invasive alternatives with varying degrees of accuracy and suitability depending on the application.

2.0 METHODOLOGY

An experimental investigation was conducted to test the output signal of the muscle action of the human upper limb by using the EMG sensor from the BITalino (R)evolution kit. In this project, a male subject, aged 24, had participated in this study. The subject has no known history of any neuromuscular or joint diseases. In this work, only one subject is used to assess the feasibility of this study. EMG sensor was deployed at different upper limb muscles (Biceps, Triceps, Trapezius and Deltoideus muscles) as shown in Figure 1 until Figure 3. All three pre-gelled electrodes were placed contiguously, lengthwise along the muscle, on the surface of the skin. The dominant arm of the subject was used when collecting EMG sensor data.

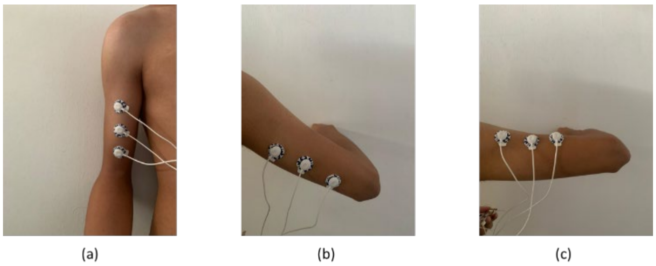

Figure 1: Bitalino EMG sensor placement (a) Biceps brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head)

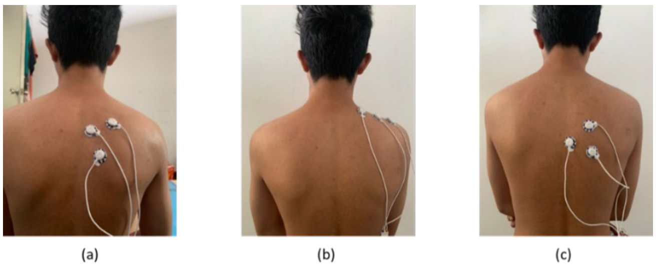

Figure 2: Bitalino EMG sensor placement (a) Trapezius Transversalis (middle) (b) Trapezius Descendens (upper) (c) Trapezius Ascendens (lower)

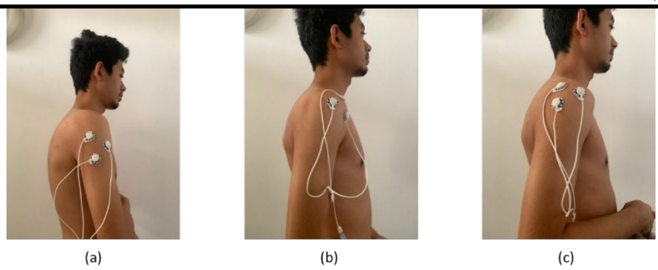

Figure 3: Bitalino EMG sensor Placement (a) Deltoideus Medius (b) Deltoideus Anterior (c) Deltoideus Posterior

In the experiment, the subject performed 4 movements in a way that felt normal and repeated each gesture 5 times. Each gesture was made every 2-3 seconds by the subject. Each session should last no more than a few minutes. As a result, 20 gesture samples were obtained in each of the three sensor placement sites, totaling 180 gesture samples. Since the sensor's ability to quantify muscular activity is highly dependent on the position of the sensor, the samples taken at each of the various sensor placement locations are treated as three independent experiments.

The subject's only instructions for the experiments were to replicate the motion for each session every 2-3 seconds but not to hurry. The aim was to capture a sample of electromyographic behaviour as realistic as possible when performing these movements. Figures 4 and 5 were the movements made by the subject arm extension/flexion, arm pronation/supination, and hand rest.

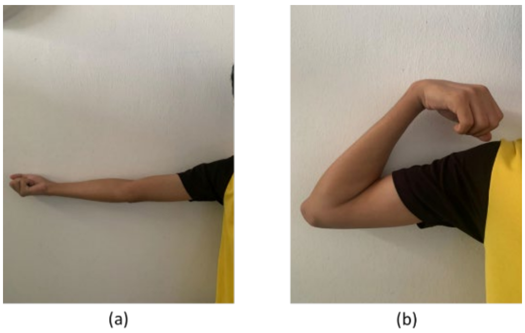

Figure 1: upper limb movement (a) extension (b) flexion

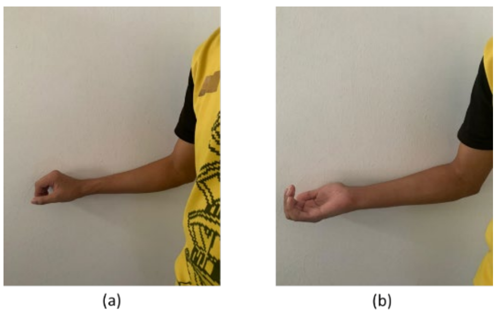

Figure 5: upper limb movement (a) pronation (b) supination

Another experiment was also performed by adding a weight 5 kg during upper limb movement, shown in Figure 6. The subject performed the same movement as in the previous experiment. The step from the previous experiment was repeated while the subject was lifting a 5kg dumbbell. As a result, another 180 samples were obtained. The aim is to study the relationship between the effect of electromyographic behavior when extra force is done during the upper limb movement.

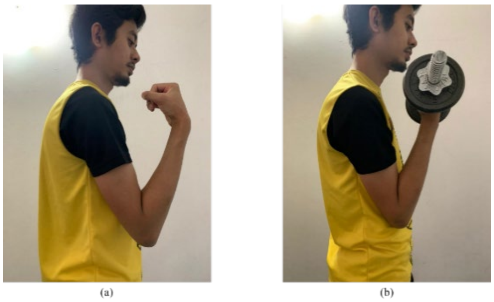

Figure 6: Flexion Movement (a) Without load (b) With load

3.0 RESULTS AND DISCUSSION

3.1 Identification of Active Muscles for Arm Flexion, Extension, Pronation and Supination (Unloaded)

Figures 7 - 10 show all of the EMG recording for the different upper limb muscles by the electrodes of the EMG sensors. The four class of movements (flexion, extension, pronation, supination) can be visually distinguished by observing the EMG reading. The EMG signal graph of different muscles varies in the amplitude of the graph according to the type of upper limb movement made by the subject. This shows that the muscles contracted for each of the muscle types differ for each upper limb movement. During each movement, the EMG signal graph seems different in the amplitude, varying with each different movement. Comparatively, there are movements that can cause a higher rise in amplitude than the other movement.

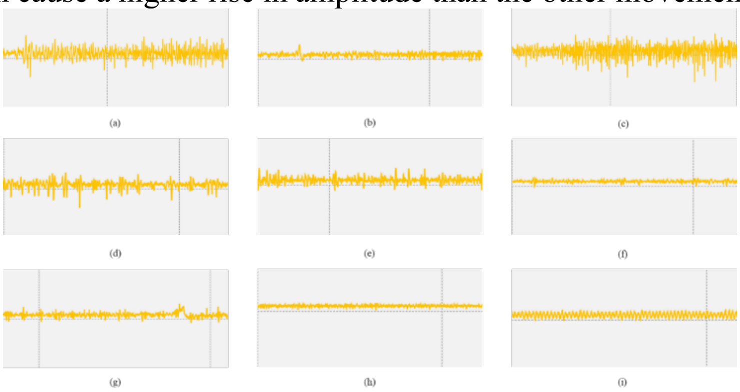

Figure 7: EMG graph for flexion movement (without load) (a) Biceps Brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head) (d) Trapezius Ascendens (lower) (e) Trapezius Transversalis (middle) (f) Trapezius Descendens (upper) (g) Deltoideus Anterior (h) Deltoideus Medius (i) Deltoideus Posterior

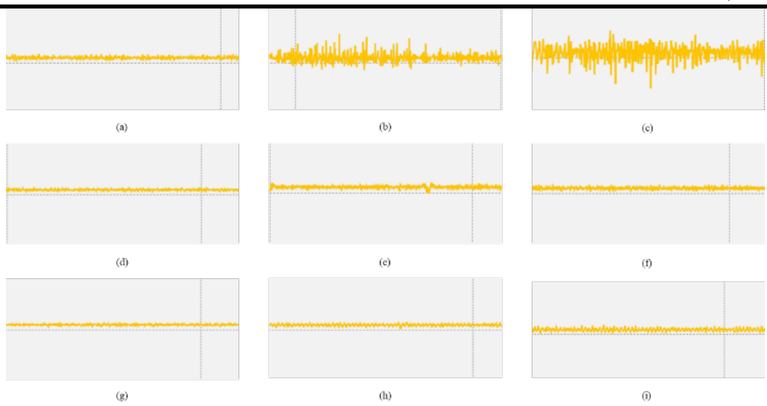

Figure 2: EMG graph for extension movement (without load) (a) Biceps Brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head) (d) Trapezius Ascendens (lower) (e) Trapezius Transversalis (middle) (f) Trapezius Descendens (upper) (g) Deltoideus Anterior (h) Deltoideus Medius (i) Deltoideus Posterior

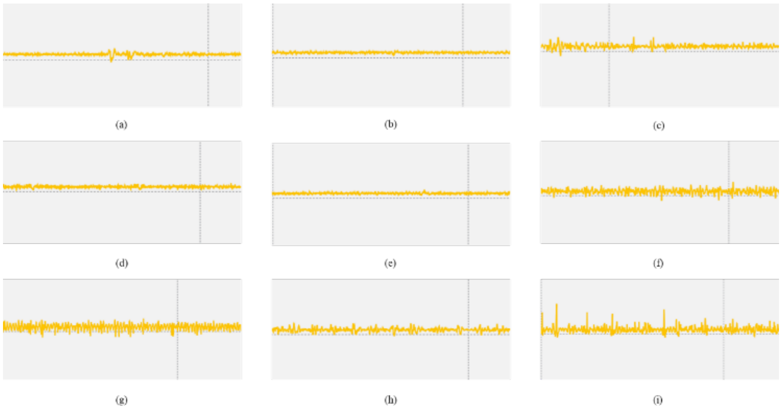

Figure 9: EMG graph for pronation movement (without load) (a) Biceps Brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head) (d) Trapezius Ascendens (lower) (e) Trapezius Transversalis (middle) (f) Trapezius Descendens (upper) (g) Deltoideus Anterior (h) Deltoideus Medius (i) Deltoideus Posterior

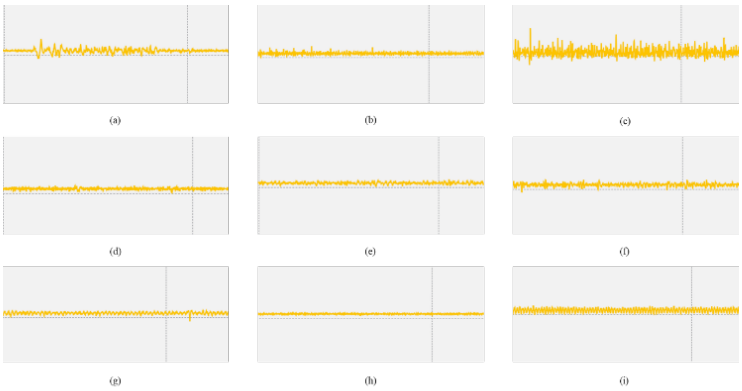

Figure 10: EMG graph for supination movement (without load) (a) Biceps Brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head) (d) Trapezius Ascendens (lower) (e) Trapezius Transversalis (middle) (f) Trapezius Descendens (upper) (g) Deltoideus Anterior (h) Deltoideus Medius (i) Deltoideus Posterior

To identify the muscles that contracted during upper limb movement, the effect of different electrodes placement on each muscle was analyzed. Nine different muscles region for the electrode placement and four different muscle movement for each muscle region as shown in Figures 4 – 6 was analyzed. Each muscle movement was repeated for five times separately for each muscle region. From the result, each muscle activated during the upper limb movement is classified in Table 1 and 2, which summarize the findings for each muscle. All muscles show a significant effect of intention in the EMG signal graph.

Table 1: Active arm/ hand muscle during normal upper limb routine (without load)

Activity	Arm/hand		
	Biceps Brachii	Triceps Brachii (Long Head)	Triceps Brachii (Lateral Head)
Flexion	/	x	/
Extension	x	/	/
Pronation	x	/	/
Supination	/	x	/

Table 2: Active shoulder muscle during normal upper limb routine (without load)

Activity	Shoulder					
	Trapizius Transversalis	Trapezius Descendens	Trapezius Ascendens	Deltoideus Medius	Deltodius Anterior	Deltodeus Posterior
Flexion	/	x	x	x	/	x
Extension	x	x	x	x	x	x
Pronation	x	x	x	/	/	/
Supination	x	x	x	x	x	x

There are several distinctive qualities that can be seen in the result. Firstly, biceps brachii and triceps brachii (lateral head) can be seen very active during the elbow flexion movement. Trapezius Transversalis and Deltoideus Anterior also show a significant movement in the graph that shows that they are also active during this movement. It can also be seen that triceps brachii is inactive during elbow flexion as the graph does not show any significant change. Secondly, during elbow extension movement, both Triceps brachii long head and lateral head is active while the biceps brachii is inactive. All of the other shoulder muscles also do not show any changes in the graph activity during the extension phase. As for the pronunciation phase, both Triceps brachii long head and lateral shows an active change during the movement although Triceps brachii lateral head only has a little significant in the graph as compared to Triceps brachii long head.

PERINTIS eJournal, 2024, Vol. 14, No. 1, pp. 67-78

Deltoideus anterior, Deltoideus Medius and Deltoideus posterior also show some changes in the graph that shows that these muscles also activated during pronation. Also, during supination, the muscles that are active during this movement are the biceps brachii and triceps brachii lateral head. Only these two muscles show an active change during the movement while the other muscles are inactive.

Comparatively, it can be seen from the figures that the more movement of the upper limb, the greater the signal amplitude of the EMG. From Figures 7 – 10, elbow flexion signals have the largest amplitude when compared to the rest of the signals.

3.2 Identification of Active Muscles for Arm Flexion, Extension, Pronation and Supination (With Load)

Figures 11 - 14 show all of the EMG recording signal for each of the muscles (biceps, triceps, and shoulder) by the electrodes of the EMG sensors when additional force (holding a 5kg dumbbell) is applied to the upper limb muscles. From the figures, it can be seen that there are distinct differences in the EMG recording signal for the four class of movements (flexion, extension, pronation, supination) when force is applied to the upper limb. The differences can be visually distinguished by observing both of the EMG signal graph before and after force is applied. The EMG signal graph shows an increase in the amplitude of the graph from the upper limb movement made by the subject when force is applied to the upper limb muscles. Moreover, even some of the upper limb muscles that do not have any respond during the active movement from Figures 7 – 10, do show some respond in the EMG signal graph when additional force is applied to the muscles. This shows that the muscles contracted for each of the muscle type differ for the upper limb movement when force is applied. During each movement, the EMG signal graph seems to increase in amplitude, due to the muscle being contracted to allow enough force for the upper limb to lift the dumbbell. Table 3 and 4 show the active muscle for different upper limb movements.

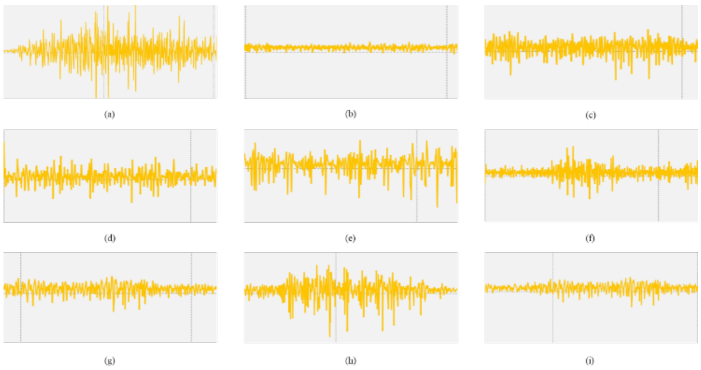

Figure 11: EMG graph for flexion movement (with load) (a) Biceps Brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head) (d) Trapezius Ascendens (lower) (e) Trapezius Transversalis (middle) (f) Trapezius Descendens (upper) (g) Deltoideus Anterior (h) Deltoideus Medius (i) Deltoideus Posterior

PERINTIS eJournal, 2024, Vol. 14, No. 1, pp. 67-78

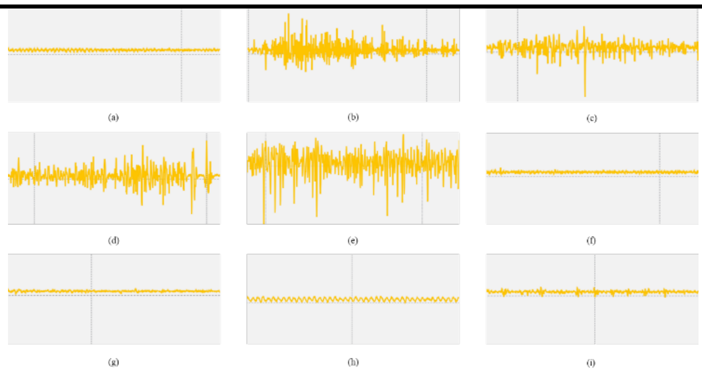

Figure 3: EMG graph for extension movement (with load) (a) Biceps Brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head) (d) Trapezius Ascendens (lower) (e) Trapezius Transversalis (middle) (f) Trapezius Descendens (upper) (g) Deltoideus Anterior (h) Deltoideus Medius (i) Deltoideus Posterior

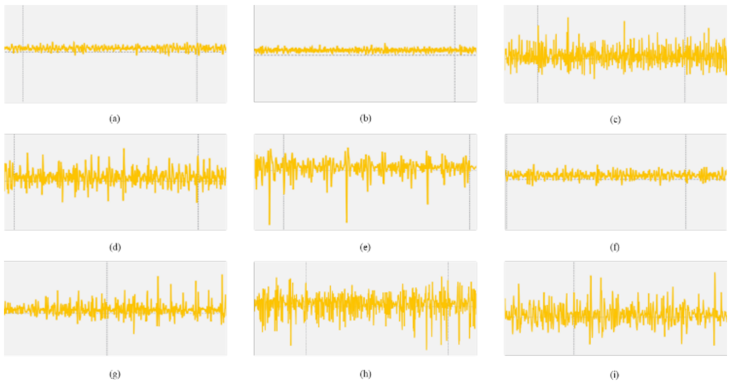

Figure 4: EMG graph for pronation movement (with load) (a) Biceps Brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head) (d) Trapezius Ascendens (lower) (e) Trapezius Transversalis (middle) (f) Trapezius Descendens (upper) (g) Deltoideus Anterior (h) Deltoideus Medius (i) Deltoideus Posterior

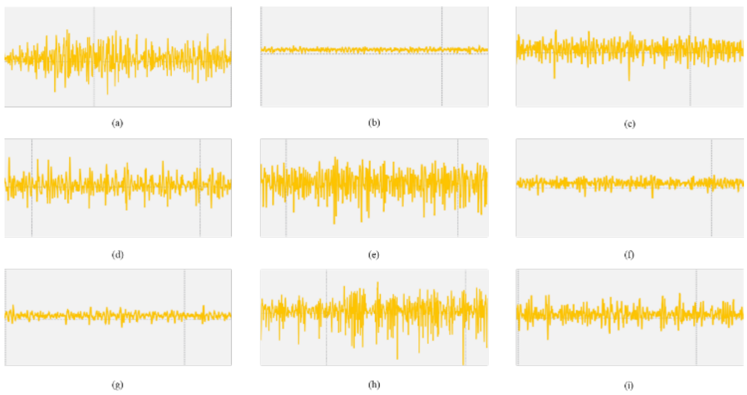

Figure 14: EMG graph for supination movement (with load) (a) Biceps Brachii (b) Triceps Brachii (Long Head) (c) Triceps Brachii (Lateral Head) (d) Trapezius Ascendens (lower) (e) Trapezius Transversalis (middle) (f) Trapezius Descendens (upper) (g) Deltoideus Anterior (h) Deltoideus Medius (i) Deltoideus Posterior

Table 3: Active arm/ hand muscle during normal upper limb routine (with additional load)

Activity	Arm/hand		
	Biceps Brachii	Triceps Brachii (Long Head)	Triceps Brachii (Lateral Head)
Flexion	/	x	/
Extension	x	/	/
Pronation	x	x	/
Supination	/	x	/

Table 4: Active arm/ hand muscle during normal upper limb routine (with additional load)

Activity	Shoulder					
	Trapizius Transversalis	Trapezius Descendens	Trapezius Ascendens	Deltoideus Medius	Deltodius Anterior	Deltodeus Posterior
Flexion	/	/	/	/	/	/
Extension	/	x	/	x	x	x
Pronation	/	/	/	/	/	/
Supination	/	/	/	/	/	/

4.0 CONCLUSION

Arm flexion, extension, supination, and pronation are some of the normal routines done by the human upper limb. In this work, the muscles that are involved during these movements were investigated and studied using BITalino (R)evolution kit. Data for different upper limb movements were recorded and investigated for both with and without the additional load. Active muscles during these movements have also been identified. In this study, it is seen that 4 types of muscles are involved during arm flexion, extension, pronation, and supination which are Biceps Brachii, Triceps Brachii, Trapezius and Deltoideus. Among these muscles, it is observed that an average of 2 muscles are active for each upper limb movement. Also, it is seen that an increase in electrical activity was observed with the additional load. Results from this experiment can be used for future work involving the classification of muscle intention as the identified muscle can be used for optimal sensors locations.

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