Evaluation of muscle activities during locking–unlocking movements

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ABSTRACT

Objective: To investigate muscle activities during locking-unlocking movements.

Methods: Thirty right-handed healthy volunteers, aged between 18-23 years, without any orthopedic or neurological disorders participated in the study. We choose the clavicular part of the deltoid muscle, biceps brachii, pronator teres, extensor digitorum, pronator quadratus, first dorsal interosseous muscles and muscles of the thenar eminence for the study. We adjusted the height of the lock at 80 cm, 100 cm and 120 cm from the ground surface. We recorded the activities of the chosen muscles electromyographically using surface electrodes. We obtained the electromyography recordings between September 2000-January 2001 in the Electrophysiology Laboratory of Gazi University School of Medicine, Department of Physical Medicine and Rehabilitation.

Results: There was a statistically significant increase in area (mVms) and amplitude (μV) values obtained from the EMG recordings of the clavicular part of the deltoid muscle and biceps brachii during locking and unlocking movements as the height of the lock increased ($p<0.05$). There was no statistically significant difference in the activities of the other muscles chosen for the study during locking and unlocking movements with the increase in height of the lock ($p>0.05$). When we considered the total activity recorded from the muscles chosen for this study, there was a statistically significant difference in the area values with the increase in height of the lock during locking and unlocking movements ($p<0.05$). This means that the activity recorded from the entire upper limb increased with the increase of the height.

Conclusion: The recorded muscle activity obtained with the lock at 80 cm from the ground surface was lower compared with the activities recorded at 100 cm and 120 cm. For this reason, we suggest that it could be better to locate the lock at 80 cm from the ground surface.

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Movement, which is a prime sign of human life, has attracted attention and has been researched through the ages. The skeletal system provides levers to which the muscles apply force and provides joints around which the movement occurs, whereas the nervous system provides nerve impulses that control contraction.[1] Various methods, including topographical studies of cadaver muscles with mechanical calculation of what they "ought to do", direct electrical stimulation of muscle, visual observation and palpation through the skin of the muscles during movement and study of paralyzed patients, and the evaluation of deficits have been used to investigate and evaluate muscle function.[2-5] However, these classical methods may lead to inadequate and incorrect information,[2,4] and it is not enough to estimate what muscles can do or might do. Electromyography (EMG), which is a method that depends on the detection of electrical signals produced by muscles, is unique to determine and evaluate the activity of a muscle at any time during various movements and postures.[2] Detection of muscle activities during daily

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or vocational activities and sports movements allows researchers to design systems and tools suitable for the human body, and optimize sports movements, training possibilities, and prevent injuries.[6] Therefore, this study was designed to detect and evaluate muscle activities during locking-unlocking movements that are performed many times during daily life. Within the locking-unlocking movements, supination and pronation of the forearm occur. Supination and pronation are the movements that are commonly used while screwing or locking or unlocking a cap, and so forth, during daily activities. Supination and pronation of the forearm adjusts the position of the hand on the horizontal plane.[7] The clavicular part of the deltoid muscle, biceps brachii, pronator teres, extensor digitorum, pronator quadratus, first dorsal interosseous (FDI) muscles, and the muscles of the thenar eminence were chosen for the study. The lock is placed at 100 cm from the ground surface as stated by the Turkish Standards Institution.[8,9] This study is designed to evaluate and compare the activities of the muscles mentioned above, when the height of the lock is adjusted at 80 cm, 100 cm, and 120 cm from the ground surface, and to determine which height could be more suitable for the human body ergonomically.

Methods. The locking-unlocking movements were investigated in 30 right-handed healthy volunteers, without any orthopedic or neurological disorders. The volunteers were university students. Informed consent from all participants was obtained, and the Ethics Committee of Gazi University endorsed its approval for the study. The electromyography recordings were obtained between September 2000-January 2001 in the Electrophysiology Laboratory of Gazi University School of Medicine, Department of Physical Medicine and Rehabilitation. In order to obtain appropriate EMG recordings, a door model with a weight of one kg attached to the lock was designed. This model allowed the lock to be adjusted at different heights of 120 cm, 100 cm and 80 cm from the ground surface. The EMG recordings from the selected muscles were obtained at those heights during locking and unlocking movements. The clavicular part of the deltoid muscle, biceps brachii, pronator teres, extensor digitorum, pronator quadratus, FDI muscles and the muscles of the thenar eminence (abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis) were chosen for the study. As the 3 muscles that form the thenar eminence are small and placed close to each other, it would be difficult to obtain EMG recordings using surface electrodes for each of them separately. For this reason, the EMG recordings from these muscles were recorded as a group. Standard surface electrodes were placed on the chosen muscles. The electrode placements are shown in **Table 1**.[10,11] In order to obtain adequate electrical contact between the muscle and the electrode, a gel was applied and then the electrodes were fixed with adhesive bands.[2,12-14] The electrode positions were approved by the test maneuvers.[15] In addition to these, a ground electrode was placed on the right forearm without hindering the movements and effecting the electrode placements. In this way, artifacts that could effect the EMG signals were

Table 1 - Electrode positions.

Muscle	Active electrode	Reference electrode	Test maneuver
Clavicular part of the deltoid muscle	Three fingerbreadths below the anterior margin of the acromion	Acromion	Flexion of the arm
Biceps brachii	Belly of the muscle in mid-arm	Medial epicondyle of humerus	Flexion or supination of the forearm
Pronator teres	Two fingerbreadths distal to the midpoint of a line connecting the medial epicondyle and biceps tendon	Olecranon	Pronation of the forearm
Extensor digitorum	Middle point of a line connecting the upper and middle thirds of radius and ulna	Lateral epicondyle of humerus	Extension of metacarpophalangeal joints
Pronator quadratus	Three fingerbreadths proximal to midpoint of a line connecting the radial and ulnar styloids	Ulnar styloid process	Pronation of the forearm
First dorsal interosseous	Just radial to the second metacarpal	Proximal phalanx of index finger	Abduction of index finger
Thenar eminence	The most prominent point of the muscle group	Proximal phalanx of thumb	Abduction and flexion of thumb

avoided.[11,13,14,16] The EMG recordings were obtained using an 8 channeled EMG system (Nihon Kohden MEB 5508K). After the placement of the electrodes on the right upper limb, the volunteers were informed about muscle contraction and relaxation by the help of the EMG monitor. The necessity of muscle relaxation after contraction was taught, and with several trials, the volunteers learned to relax by watching the monitor. Before obtaining the EMG recordings, the volunteer was informed about the movements he/she was supposed to perform. The volunteer was supposed to behave as in daily life. They were told to behave as if the lock placed on the door model was the lock of their house door. The volunteer stood 25 cm from the door model with his right shoulder in line with the lock. At the beginning, the volunteer stood straight with the upper limbs at the sides. With an order, the volunteer moved his/her right upper limb towards the lock, and gripped the key, then took his/her beginning position after locking/unlocking the key. After observing the exact relaxation on the monitor and passage of adequate time (15–20 sec), the order was repeated until appropriate numbers of EMG recordings were obtained. Meanwhile, the lock was replaced in its original beginning position by the researcher between each movement. The volunteers performed this movement with the lock adjusted at 120 cm, 100 cm, and 80 cm from the ground surface. At each height, EMG recordings were obtained for locking and unlocking separately. The volunteers had a rest interval of 5 minutes between each height and movement. Sixteen EMG recordings were obtained from the selected muscles during each of the locking and unlocking movements for each height. The movements changed depending on the side of the door that the volunteer stood at during the locking and unlocking movements. Considering this fact, this study was conducted with locking movement as supination and the unlocking movement as pronation. During EMG recordings, trigger and delay functions were used. By this method, one of the muscles' recorded activity was detected by the EMG system. When the EMG system has detected the activity of the muscle chosen as the trigger, the activities from all the other muscles were recorded. In this study, the biceps brachii muscle was chosen as the trigger. Ten of the 16 EMG recordings obtained from the chosen muscles were selected for evaluation of supination and pronation of the forearm separately. The raw EMG traces were full wave rectified,[6,13,14,17] area (mVms) and amplitude (μV) values were obtained to compare the activities.[14,17,18] Mean ± SD values were calculated and used for evaluation. During evaluation of full wave rectified EMG traces, the first deviation from the isoelectric line was considered as the starting point of the activity and the point the activity returned to at the isoelectric line was the end of the activity. These 2 points were checked, and the EMG system calculated the area (mVms) and amplitude (μV) values.

For statistical analyses, SPSS 8.0 for Windows software was used. One way ANOVA test was used to compare the activities obtained with the lock adjusted at different heights.

Results. The study comprised 30 right-handed healthy volunteers, aged between 18-23 years (mean 19.73±1.05), 14 of the volunteers were males (46.7%) whereas 16 of them were females (53.3%). Descriptive data of the volunteers are shown in **Table 2**. Area (mVms) and amplitude (μV) values calculated from the full wave rectified EMG recordings were chosen as the parameters to compare muscle activities. The differences in the activities of the chosen muscles with the lock adjusted at different heights are shown in **Tables 3-6**. There was a statistically significant increase in area (mVms) values obtained from the EMG recordings of the clavicular part of the deltoid muscle and biceps brachii during locking movements as the height of the lock increased ($p<0.05$). There was no statistically significant difference in area (mVms) values obtained from the EMG recordings of pronator teres, extensor digitorum, pronator quadratus, FDI muscles and the muscles of the thenar eminence during locking movements with the increase in height of the lock ($p>0.05$) (**Table 3**). There was a statistically significant increase in area (mVms) values obtained from the EMG recordings of the clavicular part of the deltoid muscle and biceps brachii during unlocking movements as the height of the lock increased ($p<0.05$). There was no statistically significant difference in area (mVms) values obtained from the EMG recordings of pronator teres, extensor digitorum, pronator quadratus, FDI muscles and the muscles of the thenar eminence during unlocking movements with the increase in height of the lock ($p>0.05$) (**Table 4**). When the total activity recorded from the muscles chosen for this study was considered, there was a statistically significant difference in the

Table 2 - Descriptive data of the study participants.

Gender	Number (n)	Age (year) Mean±SD	Height (cm) Mean±SD	Weight (kg) Mean±SD
Male	14	19.86±0.95	181.64±7.00	79.18±16.82
Female	16	19.63±1.15	167.56±5.53	59.23± 7.65
Total	**30**	**19.73±1.05**	**174.13±9.42**	**68.54±16.11**

area values with the increase in height of the lock during locking and unlocking movements ($p<0.05$) (**Tables 3 & 4**). There was a statistically significant increase in amplitude (μV) values obtained from the EMG recordings of the clavicular part of the deltoid muscle and biceps brachii during locking movements as the height of the lock increased ($p<0.05$). There was no statistically significant difference in amplitude (μV) values obtained from the EMG recordings of pronator teres, extensor digitorum, pronator quadratus, FDI muscles and the muscles of the thenar eminence during locking movements with the increase in height of the lock ($p>0.05$) (**Table 5**). There was a statistically significant increase in amplitude (μV) values obtained from the EMG recordings of the clavicular part of the deltoid muscle and biceps brachii during unlocking movements as the height of the lock increased ($p<0.05$). There was no statistically significant difference in amplitude (μV) values obtained from the EMG recordings of pronator teres, extensor digitorum, pronator quadratus, FDI muscles and the muscles of the thenar eminence during unlocking movements with the increase in height of the lock ($p>0.05$) (**Table 6**). When the total activity recorded from the muscles chosen for this study was considered, there was a decrease in the amplitude values with the increase in height of the lock from 80 cm to 100 cm during locking and unlocking movements. Also, there was an increase in the amplitude values with the lock located at 100 cm from the ground surface. The differences within these values were not statistically significant ($p>0.05$) (**Tables 5 & 6**).

Discussion. Studies on kinesiology of the human body have increased and are widespread with the development of EMG apparatus and multi-channeled

Table 3 - Area values (mVms) obtained from the EMG recordings of the chosen muscles during locking movement with the lock adjusted at different heights (n=30).

Muscle	80 cm Mean ± SD	100 cm Mean ± SD	120 cm Mean ± SD
Clavicular part of the deltoid muscle*	163.63±75.60	220.54±131.17	304.53±130.80
Biceps brachii*	97.00±42.01	115.52±48.26	160.11±46.11
Pronator teres	109.15±59.21	98.45±37.90	117.86±45.70
Extensor digitorum	189.70±66.82	208.96±176.15	232.61±189.40
Pronator quadratus	107.67±56.03	98.03±47.98	104.29±46.31
First dorsal interosseous	120.79±35.74	108.26±37.68	121.80±39.83
Thenar eminence	202.15±83.33	171.05±55.54	195.35±92.21
Total*	**990.08±184.46**	**1020.81±295.49**	**1236.55±352.67**

*Changes in the muscle activity with the lock adjusted at different heights is statistically significant ($p<0.05$).

Table 4 - Area values (mVms) obtained from the EMG recordings of the chosen muscles during unlocking movement with the lock adjusted at different heights (n=30).

Muscle	80 cm Mean ± SD	100 cm Mean ± SD	120 cm Mean ± SD
Clavicular part of the deltoid muscle*	186.01±65.38	238.55±85.72	340.09±117.33
Biceps brachii*	111.37±40.63	141.60±50.66	184.25±57.01
Pronator teres	135.55±62.66	119.36±41.03	138.92±50.99
Extensor digitorum	193.84±94.89	185.76±105.82	206.96±116.57
Pronator quadratus	117.43±40.18	111.28±44.30	120.19±44.40
First dorsal interosseous	182.89±101.95	155.67±63.62	162.88±81.31
Thenar eminence	260.23±141.14	250.68±98.79	274.99±116.19
Total*	**1187.31±251.91**	**1202.90±247.98**	**1428.27±351.60**

*Changes in the muscle activity with the lock adjusted at different heights is statistically significant ($p<0.05$).

Table 5 - Amplitude values (μV) obtained from the EMG recordings of the chosen muscles during locking movement with the lock adjusted at different heights (n=30).

Muscle	80 cm Mean ± SD	100 cm Mean ± SD	120 cm Mean ± SD
Clavicular part of the deltoid muscle*	433.53±184.47	521.00±187.56	712.31±285.85
Biceps brachii*	294.19±137.62	348.87±147.02	398.28±132.48
Pronator teres	425.92±298.47	363.64±186.87	418.74±444.41
Extensor digitorum	587.42±187.29	626.02±443.77	643.54±439.95
Pronator quadratus	437.31±442.69	374.58±251.09	336.36±153.03
First dorsal interosseous	650.86±276.65	610.90±274.59	603.10±220.62
Thenar eminence	814.99±238.37	765.74±240.16	793.51±272.29
Total	**3644.22±884.57**	**3610.75±902.35**	**3905.58±1075.34**

*Changes in the muscle activity with the lock adjusted at different heights is statistically significant ($p<0.05$).

Table 6 - Amplitude values (μV) obtained from the EMG recordings of the chosen muscles during unlocking movement with the lock adjusted at different heights (n=30).

Muscle	80 cm Mean ± SD	100 cm Mean ± SD	120 cm Mean ± SD
Clavicular part of the deltoid muscle*	485.92±233.11	605.91±181.92	917.80±456.24
Biceps brachii*	386.92±162.02	465.60±268.92	570.93±250.73
Pronator teres	528.13±306.07	457.76±217.04	487.00±218.34
Extensor digitorum	661.31±348.45	578.30±393.66	577.71±441.97
Pronator quadratus	518.50±273.30	458.36±191.49	505.31±236.06
First dorsal interosseous	864.88±378.75	794.92±386.70	817.28±415.21
Thenar eminence	1197.32±703.15	1078.42±506.16	1273.43±512.53
Total	**4642.97±1155.73**	**4439.27±1088.14**	**5149.46±2359.77**

*Changes in the muscle activity with the lock adjusted at different heights is statistically significant ($p<0.05$).

recorders since the 1950s. The first study that gained wide acceptance was an article by Inman et al,[19] published in 1940 on movements of the shoulder region.[2,19] Electromyographic studies on elbow flexors, forearm supinators and pronators were published by Basmajian et al.[2,20] In the beginning, studies concerning analyses of simple movements were performed, and with the improvements in electronics, analyses of more complicated movements are possible.[21-26] In this study, the activities of the clavicular part of the deltoid muscle, biceps brachii, pronator teres, extensor digitorum, pronator quadratus, FDI muscles and the muscles of the thenar eminence were evaluated during locking-unlocking movements. Area (mVms) and amplitude (μV) values obtained from the clavicular part of the deltoid muscle increased with the elevation of the height of the lock during both locking and unlocking movements, and this measurement was statistically significant (**Tables 3-6**). In the study of Grant and Habes,[27] the upper extremity muscle activities were evaluated during meat cutting tasks. In their study, they stated that for vertical exertions, the ratio of deltoid activity to force produced increased significantly as handle height decreased and also for horizontal exertions, muscle activity increased relative to force production as the handle was raised. In the same study, EMG amplitude values were chosen for the comparison of the muscle activities. Although they compared the ratio of the muscle activity to force produced, the changes in this ratio reflect the changes in the muscle activity. Taking into account that locking-unlocking is a movement performed in horizontal exertion, the increase in the area (mVms) and amplitude (μV) values obtained from the clavicular part of the deltoid muscle with the increase of the height of the lock is confirmed with the results of Grant and Habes.[27] In this study, during locking-unlocking movements the volunteer flexed his/her arm and forearm in order to reach the key. During this movement, the activities recorded from the biceps brachii is an expected finding and is similar to the published data.[2,28,29]

During the locking movement, the forearm performed supination. The data obtained from EMG activity of the biceps brachii muscle during supination is similar to the published data.[2,20] During unlocking movement, the forearm performed pronation. During pronation, EMG activity from the biceps brachii muscle was also obtained. In the study of Basmajian and Latif it was stated that the biceps brachii muscle did not show any activity during elbow flexion with the forearm in the prone position and keeping the elbow in flexion, extension of the elbow with the forearm in the prone position and performing this movement against a resistance.[20] In this study, the activity recorded from the biceps brachii during pronation of the forearm may depend on this muscle's carrying function of the forearm throughout the movement and maintenance of flexion throughout the movement.

Area (mVms) and amplitude (μV) values obtained from the biceps brachii muscle increased with the increase of the height of the lock during both locking and unlocking movements, and this increase was statistically significant (**Tables 3-6**). In the study of Grant and Habes,[27] it was stated that the ratio of muscle activity to force produced increased significantly with the increase of the height of the handle. The changes in this ratio reflect the changes in the muscle activity. In this study, the increase in the area (mVms) and amplitude (μV) values obtained from the biceps brachii with the increase of the height of the lock was compatible with the results of Grant and Habes. Habes et al[30] reported that the amplitude of EMG recordings increased with the increase in height. In this study, there was a statistically significant increase in the amplitude values obtained from the biceps brachii during both locking and unlocking movements. (**Tables 5 & 6**), in agreement with Habes et al.

In the studies of Long et al,[31,32] in which they investigated the kinesiology of the hand using EMG, they stated that the extensor digitorum muscle extended the metacarpophalangeal joint or kept this joint in the extension position, and furthermore limited the movement during flexion of the metacarpophalangeal joint. In the study of McFarland et al,[33] they reported that during simple extension of the wrist, electrical activity was obtained from the extensor digitorum muscle. In the present study, taking into account that during the investigated movement the wrist was held in extension, and the metacarpophalangeal joint was in flexion, the EMG activity obtained from this muscle was similar to the findings stated in the literature. In the study of Grant and Habes,[27] it was stated that EMG activities obtained from the extensor digitorum muscle were not influenced by the height, which was one of the variables they have evaluated. In the present study, area (mVms) and amplitude (μV) values obtained from the extensor digitorum muscle during the locking movement increased step by step with the increase of the height of the lock, but this increase was not statistically significant (**Tables 3 & 5**). Also, the changes of the area (mVms) and amplitude (μV) values obtained from this muscle during the unlocking movement with the increase of the height of the lock were not statistically significant (**Tables 4 & 6**).

In this study, the EMG activity from the pronator teres and pronator quadratus muscles was recorded during both locking and unlocking movements. Basmajian[2] stated that pronator teres and quadratus muscles were active during slow pronation from comfortable supine position to the fully prone position, and during fast pronation and during holding the forearm in the prone position. The EMG activity recorded from these muscles during the unlocking movement is a finding that is similar with those stated in classical textbooks,[28,29] and Basmajian's findings.[2] Basmajian also stated that during slow supination there was no activity, and during fast supination there was negligible activity obtained from these muscles.[2] In our study the activity recorded from these muscles during the locking movement was a finding in contrast to those stated by Basmajian. In the present study, during the movement that was investigated, the forearm was performing flexion. Basmajian[2] stated that pronator teres muscle was active during flexion of the elbow joint against a resistance. Taking into account that gravity could be a resistance against the muscles' activity, the EMG activity obtained from pronator teres muscle during locking movement could be explained. Furthermore, it should be held in mind that this study was performed using surface electrodes, and in such studies cross-talk from other muscles could be possible.[14] Also, the pronator quadratus muscle is a deeply placed muscle, and using surface electrodes could lead cross-talk from other superficial muscles.[14]

The FDI is a muscle with a rather distinct belly, which is readily accessible for investigation using surface EMG recording.[34] The main function of the FDI muscle is to stabilize the metacarpophalangeal joint of the index in all planes, thereby allowing the opposition of thumb and index.[35] In the study of Boivin et al,[36] it was stated that the FDI muscle participated in the flexion of the metacarpophalangeal joint and did not participate, or participated less in the extension of the interphalangeal joint. In the studies of Close and Kidd[37] and Eyler and Markee,[38] they also reported that the FDI muscle was active during flexion of the metacarpophalangeal joint and was not active during extension of the interphalangeal joint. In the present study, during the investigated movement the volunteer gripped the key and this was an example of lateral pinch grip. During gripping, all the other fingers were in semiflexion in order to support the thumb. The thumb was in opposition and in flexion and in contact with the side of the index.[39] The index was against the resistance of thumb and this was possible with the contraction of the FDI muscle.[34] For this reason, the EMG activity recorded from this muscle was an expected finding. Area (mVms) and amplitude (μV) values obtained from the FDI muscle during both locking and unlocking movements, with the increase of the height of the lock were not statistically significant (**Tables 3-6**). Kilbreath and Gandevia[40] stated that during grasping heavy weights, and lifting them with the increase of the weight, EMG activity recorded from the thumb and index fingers' muscles increased.[40] However, there were no findings in the literature regarding the activity changes of the FDI with height changes. In this study, the EMG activities recorded from the FDI did not show any statistically significant changes with the increase of the lock. This suggested that change of height was not a variable that affected the activities of the FDI muscle.

The abductor pollicis brevis, flexor pollicis brevis, and the opponens pollicis muscles that constitute the thenar eminence are mainly responsible for the opposition of the thumb.[28,29] As these muscles were small and placed close to each other, the EMG recordings obtained from the thenar eminence using surface electrodes would reflect the activities of these 3 muscles. It was stated that each of the 3 muscles of the thenar eminence participated in all movements of the thumb on a large scale.[2] In gripping movements, such as grasping a key, the 3 muscles that constitute the thenar eminence show activity.[2,41] In the present study, the volunteer gripped the key and during this movement, the activities recorded from the thenar eminence were confirmed with the findings in the literature. Area (mVms) and amplitude (μV) values obtained from the muscles of the thenar eminence during both locking and unlocking movements with the increase of the height of the lock were not statistically significant (**Tables 3-6**). There were no findings in the literature regarding the activities of the muscles of the thenar eminence with the change of the height. In this study, the EMG activities recorded from these muscles did not show any statistically significant changes with the increase of the lock height. This suggested that change of height was not a variable that effected the activities of the muscles of the thenar eminence. Although in the study of Kilbreath and Gandevia,[40] it was stated that during grasping heavy weights and lifting them with the increase of the weight, EMG activity recorded from the thumb and index fingers' muscles increased, in the present study the weight of the key did not change, and the weight of the key was not a variable chosen to be investigated.

When the total activity recorded from all the muscles chosen for the study was considered during both locking and unlocking movements with the increase of the height of the lock there was a statistically significant increase in area (mVms) values (**Tables 3 & 4**). When amplitude (μV) values were considered during both locking and unlocking movements with the increase of the height of the lock, the increase was not statistically significant (**Tables 5 & 6**). It should be taken into account that amplitude (μV) value is the highest voltage value at any moment of the movement, so area (mVms) value could be more precise to evaluate the movement. The increase of the total area (mVms) values seemed to depend on the increase of the activities of the clavicular part of the deltoid and biceps brachii muscles. Thus, the total muscle activity obtained from the whole upper limb increased with the increase of the height of the lock. This increase could be explained by these 2 muscles' increased contraction against gravity with the increase of the lock height.

In conclusion, there was a statistically significant increase in area (mVms) and amplitude (μV) values obtained from the clavicular part of the deltoid and biceps brachii muscles during both locking and unlocking movements with the increase of the height of the lock. When the total activity recorded from all the muscles chosen for the study was considered during both locking and unlocking movements with the increase of the height of the lock, there was a statistically significant increase in area (mVms) values. This indicated that the total activity obtained from the whole upper limb increased with the increase of the height of the lock. This increase could be explained by these 2 muscles' increased contraction against gravity with the increase of the lock. When general principles of ergonomics are considered, the tools and equipment used in vocational activities and daily life should be suitable for the human body, and should increase efficiency and reduce problems caused by working conditions. Therefore, less muscle activity for a certain task could be considered as more efficient. In this study, the muscle activity obtained from the muscles when the lock was adjusted at 80 cm from the ground surface was lower than when it was adjusted at 100 cm and 120 cm from the ground surface. For this reason, we suggest that it could be better to locate the lock at 80 cm from the ground surface.

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