Electromyography (EMG) for Assessment in Low Back Pain; Erector Spinae Muscle

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Abstract. The purpose of electromyography (EMG) study is to identify which position of surface EMG sensor attached to erector spinae muscle related with lower back pain by squat and stoop lifting technique. This is to avoid lower back pain (LBP) occur during Manual Materials Handling (MMH). There are only one types of upper extremity muscle were chosen to be monitored in this study which is erector spinae (ES) muscle with different electrodes placement on the surface electromyography (sEMG) sensor. However, each of the lifting styles come out with the different reading of root mean square (RMS) frequency for each muscle chosen. In this study, the two subjects consist of two females with normal body mass index (BMI) range from 18.5 to 24.9 with same physical measurement, was selected in order to perform both styles of lifting which are squatting and stooping. For every session the subject will undertake 15 repetitions with 15 minutes rest in between for each movement. In furtherance of to get the analysis muscle activity, proEMG software is used. The results of study for subject female 1 showed that the squat technique had higher levels of muscle activation compared to stoop technique on left erector spinae (LES) muscle. However, the LES muscle activation for subject 2 is greater at stoop activity. On the contrary, squat technique had lower fatigue analysis compared to stoop technique for both subjects on LES muscle. Conclusion, squat technique is better than stoop technique but stoop lift is more natural and spontaneously used for MMH.

1. Introduction

The widely recognized activity of manual material handling (MMH) in the workplace is the load lifting object [1]. Work associated musculoskeletal injuries are often associated with excessive work of the body at the workplace [2]. The musculoskeletal and LBP issue are usually related with overexertion of the body when the human operator attempts to fulfil the need of MMH activity [2]. The MMH activity is a main cause of musculoskeletal disorders (MSD). Low back pain (LBP) is the most common health disorder problem among all ages [3]. Most people who affected with LBP, they do not taking this disease as a serious problem and continue their life journey as a normal human being without taking any treatment or receive the advice from a doctor. Due to a common group of lack awareness about LBP, may lead to long-term back pain. Incorrect MMH method may result in LBP disease especially when lifting the object through squatting and stooping technique.

Exploration for a safer lifting technique has attracted great attention due to the high risk of injury and LBP related to frequent lifting in the workplace [4]**.** Regardless of the well-recognized contribution of lifting in low back injuries [4]**,** the literature on safer lifting techniques between squat versus stoop lifting remains controversial [5, 6]**.** However, the significance of the squat versus stoop lifting technique has been downplayed due to the lack of a clear biomechanical rationale for the preferment of either style may reduce the LBP [5, 6, 7]. According to [4], it is stated that ideal lifting methods, squat lifting technique is generally considered to be safer than the stoop lifting technique in bringing the load closer to the body and, also reducing the extra demand on back muscles. In spite of that, many workers prefer the stoop lift due to its easier operation and lower energy consumption in repetitive lifting tasks [4].

The purpose of this study is to identify the best technique of lifting an object as well as the best position of surface EMG sensor attached to erector spinae muscle by an invention of squatting rather than stooping technique. Therefore, In order to determine the ideal techniques, the sEMG will be used to support based on upper extremity muscle study which is erector spinae. From the data collection of sEMG, the conclusion or assumption can be made to respond the question of which exact position of sEMG sensor that should be working when doing proper squatting in order to avoid back pain as well as for stooping technique.

2. **Methods**

2.1 Participants

Two students volunteered for the present study has been selected, consist of two females with the same physical body measurement and normal body mass index(BMI) range between (18.5 – 24.9) were recruited in order to perform both stoop and squat movement techniques for this particular experiment and muscle. All subjects had no complaints of spine, or pathological since a decade ago for knee conditions which is they are in healthy condition throughout this experiment.

2.2 Experiment set-up

From Figure 1 show, the setup tools for placement of electrodes. Before starting the experiment, it is essential to charge the transmitter and the receiver first. The transmitter and receiver can be used up to two hours long after fully charged. Next, the erector spinae muscle palpation study based on SENIAM standard [15]. Then, the electrodes are attached along the erector spinae muscle for both subjects as illustrated in Figure 2.
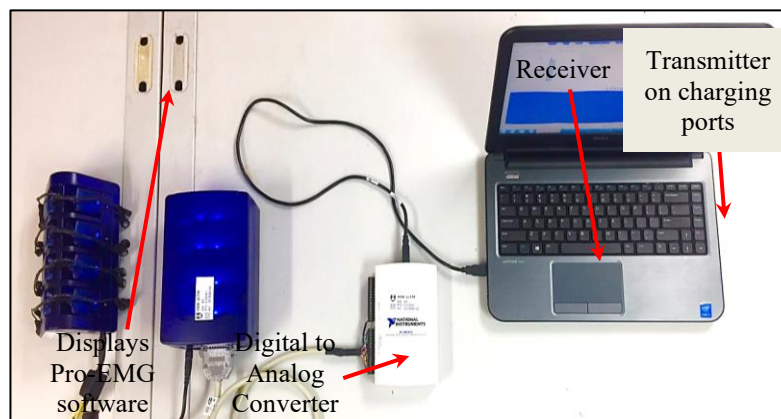
Figure 1. The experimental setup layout for EMG apparatus.
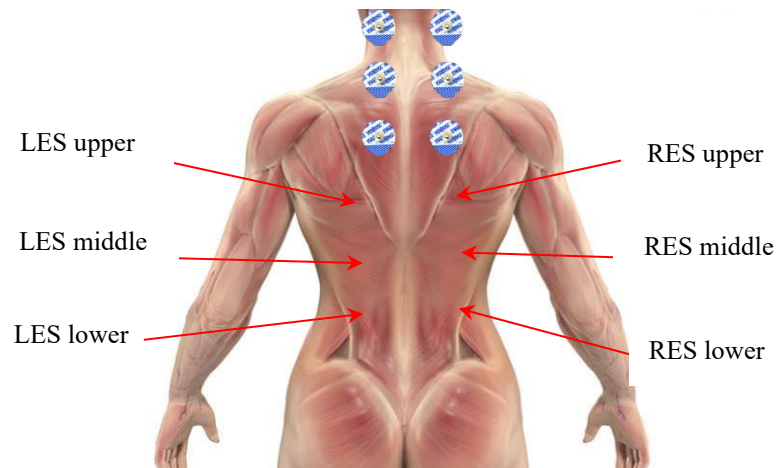
Figure 2. Illustration diagram for the position of electrodes attached to the Left Erector Spinae (LES) and Right Erector Spinae (RES) muscle.

2.3 Experimental procedure

The experiment session was conducted in a day. The subject will be performing the stooping and squatting techniques with 15 repetitions consecutively for every movement while carried the weight of 1.5kg which is acceptable weight from floor to knuckle height for female subjects. To avoid the possible biases resulting from the serious fatigue effect, a 15-min break was given among both movements [8]. From Figure 3 and Figure 4, that is how the stooping and squatting was performed during recording data. The stoop technique typically start with slanted trunk and almost broadened knees (knee flexion edge would be more than 135-degree with trunk flexion around 90-degree) [8]. The knee is kept straight, while the back and arms are forward to hold the object when lifting from floor level; this technique is known as lifting with back (back lift) as shown in Figure 3 [8]. A squat technique can be done with the initial position of deep knee flexion with the trunk near erect, as shown in Figure 4. Particularly the subjects when lifting from floor level this quantitative can be described as a knee flexion around 45-degree and trunk flexion not more than 30-degree [8].

Figure 3. The stooping technique.

Figure 4. The squatting technique.

2.4 Data Collection

The data collected and will be compared from both sessions of stooping and squatting techniques for three positions of erector spinae muscle which is upper, middle and lower. The purpose of data analysis procedure is to compared muscle activities and fatigue analysis related for stooping and squatting technique. The root mean square (RMS) values consider as muscle activation and Mean Frequency (MF) values as fatigue analysis. Therefore, these can be accomplished by normalizing the raw EMG signal data analysis gathered and filtered by using peak and mean dynamic method.

The analysis data is done by using equation root mean square (RMS) smoothing (minimize artefacts left) recommended quantification method by Basmajian and DeLuca [9, 10] to filter the EMG signal data.

$$RMS_n = \sqrt{\frac{1}{N}\sqrt{\sum_{n-N/2}^{n+N/2} S_{i^2}}} \qquad (1)$$

The two most important parameters for fatigue analysis are the median and mean frequency (MF). However, in our case study we only used MF to calculate fatigue analysis [6]. Analysis data by using equation Moving Average smoothing for fatigue analysis.

$$MAV_n = \frac{1}{N}\sum_{n-N/2}^{n+N/2} S_i \qquad (2)$$

3. Result and Discussion

The measurement data for the activation stage of each electrodes placement on erector spinae muscle target for subject 1 and subject 2 females has been normalized against the root mean square (RMS) and Median frequency (MF). The measurement results for 1.5 kg lift load being put 20cm in front of the subject. Then, the result were analysed for 15 cycles consecutively for both technique stoop and squat are presented in table below. Based on the table, the EMG signal coming from the muscles of both subjects performing squat and stoop techniques. The signals represent the graph in volt versus cycle.

Table 1. Data on the rate of muscle activation for subject 1.

CYCLE	Subject 1 Stoop Technique, (RMS Average)						Subject 1 Squat Technique, (RMS Average)					
	LES Upper	RES Upper	LES Middle	RES Middle	LES Lower	RES Lower	LES Upper	RES Upper	LES Middle	RES Middle	LES Lower	RES Lower
1	0.0750	0.0893	0.0847	0.0853	0.1230	0.1160	0.0870	0.0684	0.0803	0.0786	0.120	0.114
2	0.0747	0.0749	0.0813	0.0822	0.1220	0.1160	0.0790	0.0827	0.0773	0.0760	0.138	0.143
3	0.0848	0.0944	0.0980	0.0978	0.1460	0.1280	0.0789	0.0776	0.0802	0.0764	0.124	0.125
4	0.1050	0.0966	0.0992	0.0994	0.1230	0.1140	0.069	0.0766	0.0775	0.0757	0.127	0.130
5	0.0795	0.0861	0.0884	0.0952	0.1310	0.1310	0.0933	0.0732	0.0866	0.0864	0.136	0.132
6	0.0977	0.0852	0.0933	0.0926	0.1350	0.1200	0.0781	0.0767	0.0788	0.0799	0.131	0.118
7	0.0894	0.0950	0.0851	0.0953	0.1290	0.1230	0.0931	0.0788	0.0858	0.0837	0.144	0.127
8	0.1100	0.1070	0.1030	0.1020	0.1310	0.1270	0.0818	0.0711	0.0736	0.0841	0.136	0.142
9	0.1120	0.1080	0.0955	0.1010	0.1220	0.1110	0.0770	0.0623	0.0776	0.0736	0.139	0.130
10	0.0878	0.0775	0.0806	0.0840	0.1070	0.0999	0.0837	0.0674	0.0692	0.0721	0.119	0.119
11	0.0937	0.1020	0.0844	0.0963	0.1150	0.0965	0.0743	0.0659	0.0752	0.0895	0.142	0.139
12	0.0932	0.1000	0.0864	0.0886	0.1120	0.1050	0.0757	0.0650	0.0799	0.0864	0.149	0.130
13	0.0819	0.0873	0.0671	0.0755	0.0865	0.0834	0.0666	0.0578	0.0774	0.0773	0.129	0.121
14	0.0761	0.0868	0.0704	0.0827	0.1080	0.0895	0.0843	0.0661	0.0808	0.0932	0.148	0.137
15	0.0896	0.0859	0.0799	0.0875	0.1060	0.1110	0.0577	0.0474	0.0671	0.0772	0.127	0.126

Table 2. Data on the fatigue analysis for subject 1.

CYCLE	Subject 1 Stoop Technique, (Median Average)						Subject 1 Squat Technique, (Median Average)					
	LES Upper	RES Upper	LES Middle	RES Middle	LES Lower	RES Lower	LES Upper	RES Upper	LES Middle	RES Middle	LES Lower	RES Lower
1	39.0	39.1	42.6	38.5	43.3	47.4	40.1	45.9	49.4	49.8	45.5	49.7
2	38.4	37.7	43.3	42.4	44.5	47.8	43.4	45.9	48.2	47.4	44.4	52.0
3	41.4	40.8	43.7	41.9	43.8	47.2	42.3	48.6	45.4	48.4	45.6	52.0
4	36.2	40.6	42.9	43.7	46.0	45.3	40.9	45.1	47.1	50.6	47.5	49.8
5	32.8	34.9	40.5	40.1	44.6	47.1	45.3	47.1	47.8	50.4	46.6	52.9
6	36.4	39.1	43.7	41.6	48.1	49.0	40.8	47.8	48.0	47.1	45.1	50.3
7	38.5	37.0	41.9	40.3	47.4	49.3	43.5	44.2	42.0	44.4	45.4	49.6
8	32.9	42.4	41.7	42.5	47.0	48.0	39.3	43.5	44.9	46.6	45.5	47.9
9	36.0	38.1	39.5	41.0	45.9	46.1	40.5	45.3	43.4	45.5	42.5	48.8
10	33.7	38.2	42.9	44.2	45.5	48.1	42.4	46.5	37.3	41.8	48.1	51.1

11	34.1	38.2	37.0	39.0	48.4	49.1	40.8	46.7	38.3	42.2	43.1	46.3
12	36.6	39.3	40.8	39.9	44.8	46.5	37.8	41.8	42.2	42.0	42.9	45.1
13	37.7	44.3	41.3	44.2	47.5	47.9	40.5	38.9	45.2	41.7	46.2	49.3
14	36.8	37.2	38.0	41.3	46.9	51.3	35.9	42.1	44.8	41.5	44.4	47.5
15	35.2	36.2	39.9	38.5	44.7	50.9	37.9	41.3	42.4	43.3	43.5	44.4

Table 3. Data on the rate of muscle activation for subject 2.

| | Subject 2 Stoop Technique, (RMS Average) | | | | | | Subject 2 Squat Technique, (RMS Average) | | | | | |
CYCLE	LES Upper	RES Upper	LES Middle	RES Middle	LES Lower	RES Lower	LES Upper	RES Upper	LES Middle	RES Middle	LES Lower	RES Lower
1	0.0503	0.0885	0.0548	0.0521	0.557	0.0642	0.0419	0.0766	0.0563	0.067	0.912	0.0677
2	0.0503	0.1050	0.0538	0.0468	0.755	0.0537	0.0410	0.0832	0.0584	0.0598	0.818	0.0627
3	0.0427	0.0897	0.0496	0.0449	0.861	0.0527	0.0395	0.0772	0.0573	0.0672	0.911	0.0662
4	0.0410	0.0867	0.0470	0.0412	0.672	0.0525	0.0376	0.0606	0.0585	0.0596	0.835	0.0734
5	0.0517	0.1080	0.0500	0.0436	0.684	0.0476	0.0241	0.0476	0.0638	0.0482	1.010	0.0478
6	0.0392	0.0901	0.0436	0.0390	0.725	0.0456	0.0387	0.0694	0.0702	0.0626	0.603	0.0639
7	0.0504	0.0973	0.0346	0.0355	0.811	0.0395	0.0347	0.0648	0.0674	0.0594	0.623	0.0633
8	0.0474	0.1090	0.0415	0.0359	0.740	0.0399	0.0442	0.0854	0.0858	0.0670	0.608	0.0687
9	0.0484	0.1050	0.0435	0.0359	0.808	0.0432	0.0310	0.0587	0.0693	0.0575	0.730	0.0660
10	0.0504	0.1170	0.0408	0.0408	0.748	0.0465	0.0375	0.0585	0.0773	0.0620	0.878	0.0681
11	0.0383	0.0790	0.0466	0.0409	0.779	0.0504	0.0287	0.0570	0.0559	0.0567	1.040	0.0615
12	0.0528	0.1210	0.0381	0.0327	0.727	0.0420	0.0347	0.0686	0.0698	0.0514	0.940	0.0652
13	0.0439	0.0976	0.0443	0.0433	0.836	0.0497	0.0382	0.0799	0.0802	0.0509	0.857	0.0609
14	0.0470	0.1110	0.0415	0.0385	0.726	0.0430	0.0274	0.0510	0.0781	0.0518	1.070	0.0586
15	0.0472	0.0812	0.0472	0.0405	0.911	0.0451	0.0279	0.0505	0.0793	0.0475	0.855	0.0544

Table 4. Data on the rate fatigue analysis for subject 2 (female)

| | Subject 2 Stoop Technique, (Median Average) | | | | | | Subject 2 Squat Technique, (Median Average) | | | | | |
CYCLE	LES Upper	RES Upper	LES Middle	RES Middle	LES Lower	RES Lower	LES Upper	RES Upper	LES Middle	RES Middle	LES Lower	RES Lower
1	44.5	44.6	40.8	44.7	39.7	40.7	35.9	42.2	43.8	50.4	37.0	41.0
2	49.8	46.8	39.9	44.2	41.2	40.7	47.4	46.0	38.2	41.0	50.9	40.8
3	40.7	40.4	42.2	41.2	39.5	40.6	44.3	46.4	41.8	41.9	32.6	42.2
4	45.7	47.3	40.0	43.6	47.4	43.4	26.5	42.7	39.5	37.9	30.9	38.4
5	39.6	39.4	39.4	39.2	47.5	39.9	44.8	46.0	38.3	43.6	37.6	36.8
6	50.8	51.9	39.2	37.8	49.9	37.6	40.0	35.0	40.5	37.7	41.0	36.6
7	50.7	43.2	34.1	35.4	42.0	36.0	42.6	41.2	39.1	38.1	36.7	35.9
8	41.1	42.7	36.9	38.9	49.0	38.7	38.6	39.3	40.0	41.5	43.2	34.0
9	47.3	48.7	32.7	37.4	54.2	38.0	39.5	43.4	42.9	45.9	35.3	37.1
10	45.3	47.3	39.7	37.5	41.6	35.4	40.4	37.4	41.0	38.1	42.5	41.3
11	44.3	42.7	39.9	39.9	45.1	40.3	47.9	46.3	41.9	45.7	38.5	43.1
12	47.6	51.1	34.3	35.3	54.7	38.8	43.9	40.4	39.2	41.8	39.8	38.5
13	41.9	40.8	38.0	40.3	39.7	39.3	51.3	49.4	43.4	39.9	41.2	37.4
14	42.0	45.2	34.7	34.2	48.7	33.2	49.1	47.8	42.2	47.6	44.2	42.2
15	48.2	48.5	39.0	37.1	60.2	38.6	44.2	37.6	40.1	41.0	47.6	42.7
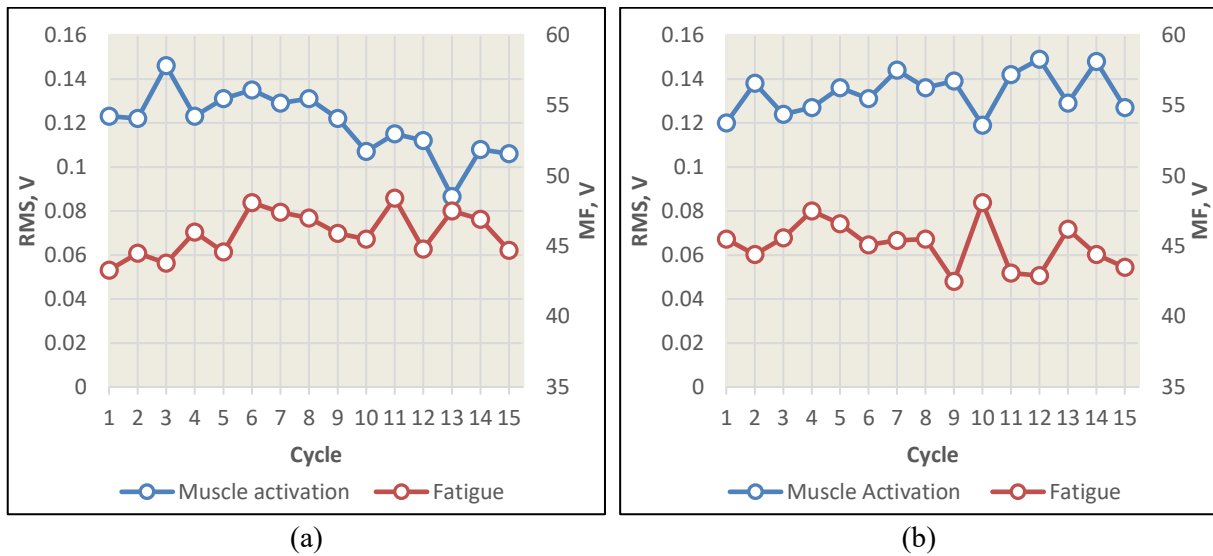
Figure 5. The RMS average and MF analysis (a) stoop, (b) squat at LES lower muscle of subject 1.
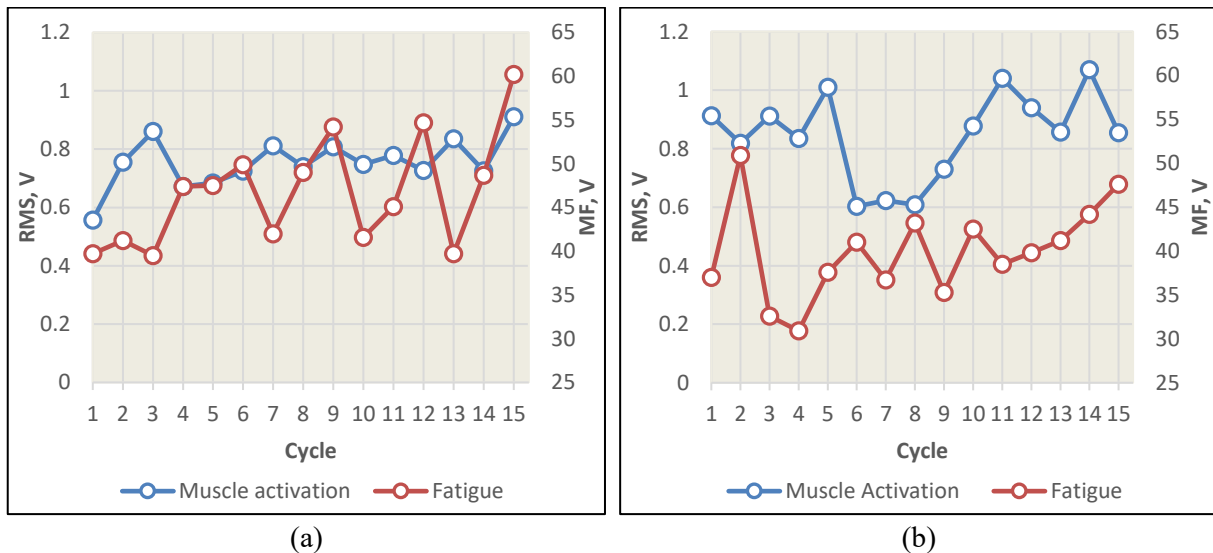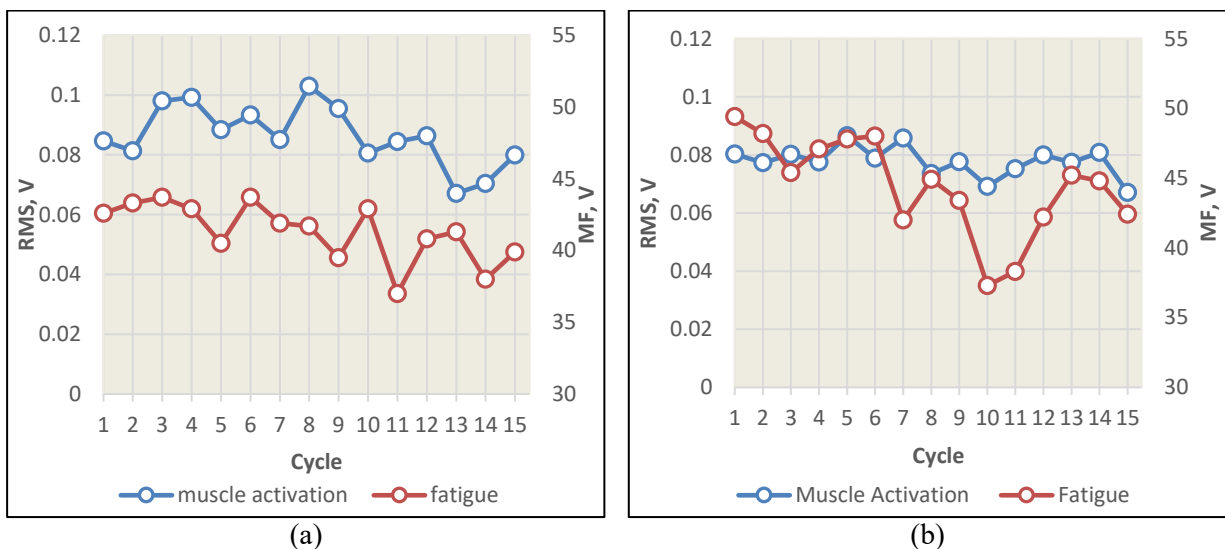

Figure 6. The RMS average and MF analysis stoop (a) and squat (b) at LES lower muscle of subject 2.

The figure above shows the data of the average RMS and MF for both lifting techniques on electrodes placement at LES lower muscle for subject 1 and subject 2 female. RMS signal is used to look into muscle activation while MF is for fatigue analysis. From Figure 5(a) shows the muscle for subject 1 start to decrement from cycle 1 until 15 which indicates the decreases in the muscle activations. This shows that LES lower muscle which is representing the belly muscle of the ES requires more effort during stoop activity. However, from Figure 5(b) it shows different trends for squat activity. The muscle starts to spike from cycle 1 to 15 during squatting. This shows that LES lower muscle required less effort to lift weight during squat activity. Comparing both techniques the most significant finding in the study was the stoop technique understood to be wrong technique as the activation muscle at the belly muscle of ES can lead to low back pain. Nevertheless, the RMS value for subject 2 shows a different trend than subject 1 for both techniques. Based on Figure 6(a), from cycle 4 to 15 the LES lower muscle activation starts to ascend. However, the Figure 6(b) shows from cycle 1 to 6 the muscle activation start to show decrement before entering the stable phase along cycle 6 to 8 while squatting activity. Then, from cycle 8 to 15 the RMS value starts to show increment phase. Unfortunately, the RMS value for subject 2 is greater at stoop activity. Subject 1 showing stable data than subject 2. This is due to differ

in lifting technique produce for each subject. Since, the significant studies have acknowledged that the stoop lift is widely and spontaneously used for "Bent-Over work" [11].

MF value is for fatigue analysis. From Figure 5(a) it shows that the LES lower muscle spike during stooping for subject 1. From cycle 1 to 15, the LES lower muscle shows the increment which represents muscle fatigue until the end of the cycle. When the muscle fatigue is increase, that means is not appropriate to lift weight especially during stooping technique. Nevertheless, it shows different trends for squat activity in Figure 5(b) the muscle starts to descend from cycle 1 to 15 during squatting. This shows muscle fatigue is reduced at the end of the cycle. Based on Figure 6(a) the subject 2 shows the LES lower muscle of data fatigue analysis starts to ascend from cycle 3 to 15 for stoop activity. Then, for squatting the subject 2 also have experience muscle fatigue since the trend increases from cycle 5 to 15. The MF value of subject 2 at 15 cycles for stooping (60.2V) is higher than squatting (47.6V). This indicates that subject 2 using a lot of muscle usage on LES lower while performing stooping activity and the effect by that can cause of muscle fatigue. Based on the previous study, squat is acknowledged as 'correct technique' for lifting low-lying objects. Thus, the decrement trend shows for squat activity proof that the squatting technique a little bit can reduce lower back pain [11].
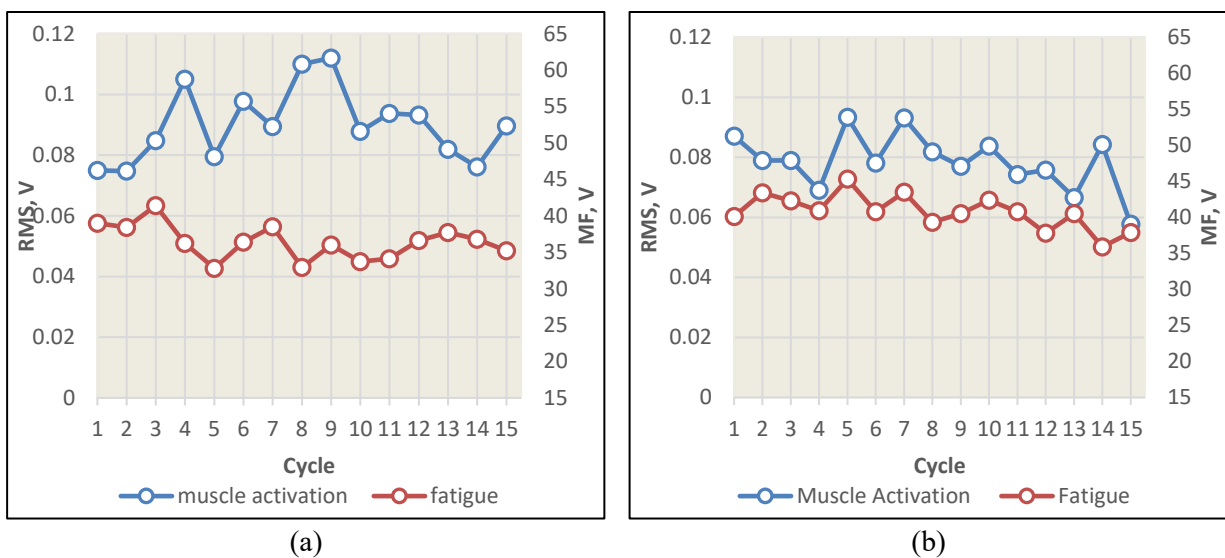

(a)   (b)

Figure 7. The RMS average and MF analysis stoop (a) and squat (b) at LES middle muscle of subject 1.


(a)   (b)
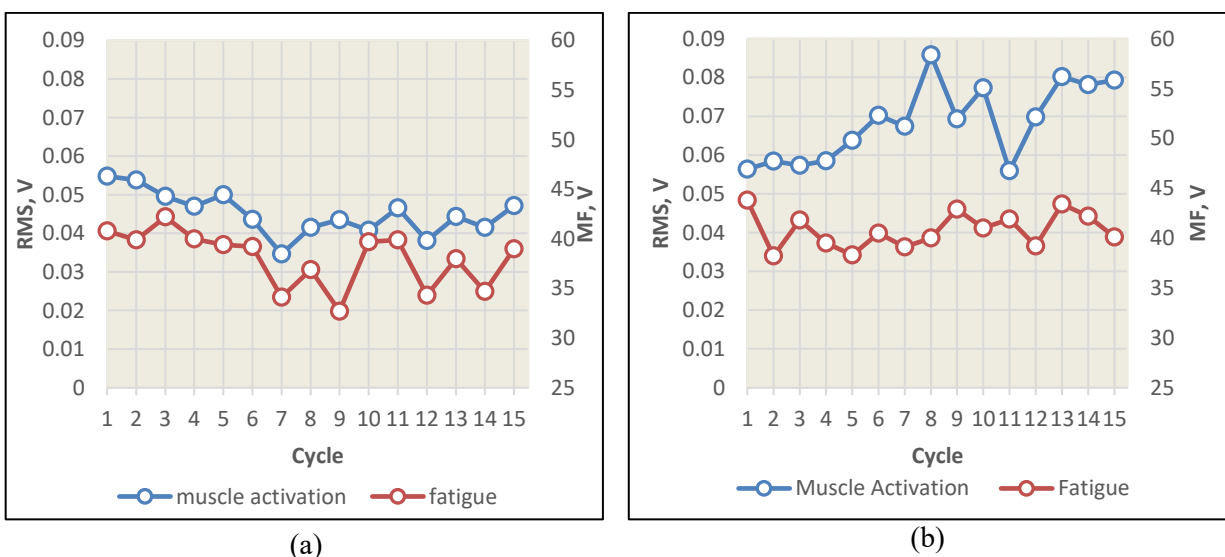
Figure 8. The RMS average and MF analysis stoop (a) and squat (b) at LES middle muscle of subject 2.

From the Figure 7(a), 7(b) shows decrement MF value of electrode placement on LES middle muscle value of subject 1 start from cycle 1 to 15 for both techniques of stoop and squat activity. The significant value indicates subject 1 is using the same capacity of energy during both lifting techniques. As we can see that the muscle activation and fatigue analysis have the significant value between both techniques. Comparing to electrode placement on LES lower muscle the value is quite different. Since the value of MF for LES lower is much higher (0.120V) as compared to LES middle (0.0803V) for squat activity. Same as well as stoop activity where the MF value for LES lower (0.123V) and for LES middle (0.0847). So, the placement of electrodes at the LES lower is more effective than LES middle since it come out with more stable fatigue analysis.

Based on Figure 8(a), the subject 2 shows decrease in LES muscle activation through stoop technique from first to the end of cycle. However in Figure 8(b), RMS value increase through squat technique from cycle 1 to 15. Differ from the value of fatigue analysis, whereby for both technique shows decrement trends.

Figure 9. The RMS average and MF analysis stoop (a) and squat (b) at LES upper muscle of subject 1.
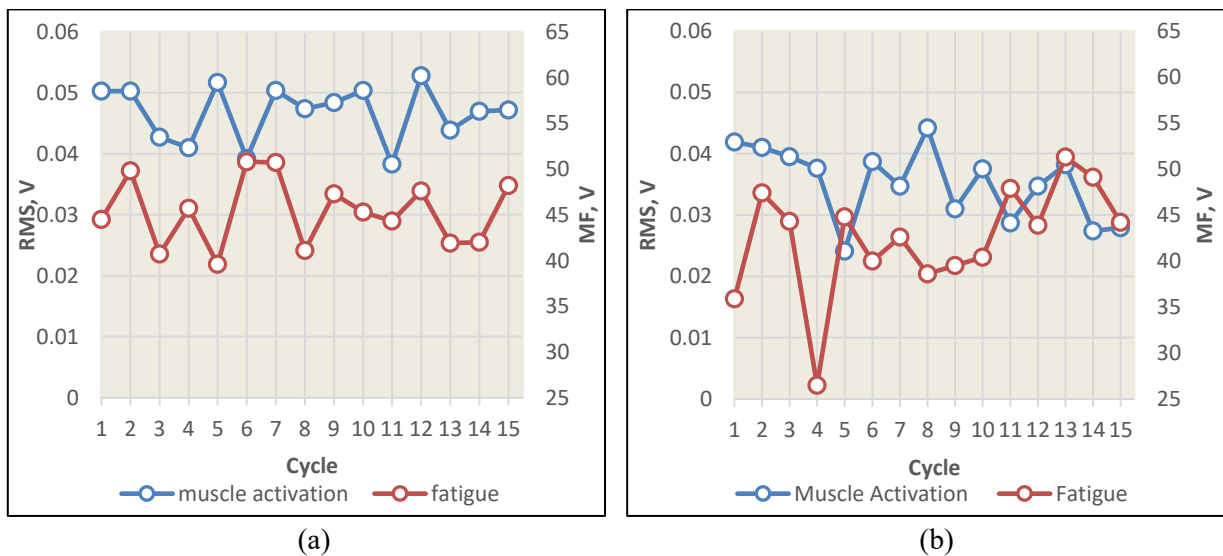
Figure 10. The RMS average and MF analysis stoop (a) and squat (b) at LES upper muscle of subject 2.

From Figure 9(a), 9(b) shows the MF for both lifting techniques on electrodes placement at LES upper muscle for Subject 1 and Subject 2 female. The Figure 9(a) shows the muscle activation for

subject 1start to decrease from cycle 1 to 15 for stooping technique. However, the RMS value at cycle 1 is slightly differing than cycle 15 which is 0.075V to 0.0896V. Whereas for stooping technique Subject 2 as shown in Figure 10(a), the RMS value is stable but slightly increased from cycle 1 (0.0503V) to cycle 15 (0.0472V). This indicates that the placement electrode at the upper muscle of ES does not give any different in RMS value for stoop activity. But, for squat activity towards Subject 1, the muscle activation still can be seen. Since, the trend starts to show decrement from cycle 1 until 15. Similar with Subject 2 in Figure 10(b), the squat activity also shows decrement trends. The significant study acknowledge that, the electrodes placement at the LES upper muscle does not gives any different in RMS value for stooping technique. Although, for squatting technique still can be used.

4. Conclusion and Recommendation

From this study, we found the muscle activation activities of upper extremity were investigated through performing squat and stoop movements by using electromyography (EMG) to avoid LBP. The EMG data for different electrodes position of the ES muscle through stoop and squat technique had been accumulated for comparison. Both technique had been accumulated and normalized to root mean square (RMS) and Median Frequency (MF), where RMS represent muscle activation and MF indicate muscle fatigue. From Figure 5,6 the analysis of the muscle usage for subject 1, it can be seen that squatting movement is an ideal lifting technique as it promotes better and stable reading of LES lower muscle data as compared to stoop movement. However, for subject 2 the RMS value is greater at stoop activity. As stated in [12], the squat lifting technique appears to have lower lumbar shear pressure and less stressed places on the spinal passive tissue, while stoop lifting looks more natural and less fatigue as it is spontaneously used. For fatigue analysis for subject 1, based on Figure 5 it shows that the LES lower muscle spike during stooping. However, through squatting the muscle fatigue start to show decrement. Muscle fatigue during stoop lifting techniques can increase the risk of musculoskeletal injury during rapid disruption [13]. This indicates that, squat lifting technique is proper lifting technique to reduce LBP.

Although, some previous studies state that there is no single lifting technique that is best. There is still no significant study able to prove and state that squat technique is better than stoop for lifting weight to avoid LBP [11]. Besides that, from my point of view, I would suggest that squat technique is more ideal and proper lifting technique as it is more stable than stoop technique. For the recommendation, it is suggested that for the next experiment would involve at least 10 subjects as possible to have more data collection. The recommended subject consist of people who conduct stoop and squat movement as their daily basis working routine in order to prove the proper lifting technique. The other suggestion is from [14], it is recommended that to precisely designed and precise program aimed at the development of safe lifting techniques for employees involved in manual handling and lifting of work as a way to reduce the risk of injury in the back. Lastly, set up a variety of motion exercises that permit the lifters to use the correct biomechanics when lifting, preventing postural abnormalities and enhancing their movement network at the connection required performing regular manual handling tasks [14].

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