# Electromyography analysis for assessment of lower extremity muscles during squat and stoop movement

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ABSTRACT

*There are diverse styles of lifting an object from the ground and each style employs different types of muscles with varying degrees of usage. The objective of this study was to explore the muscle activities between squat and stoop movement while lifting the load in to understand risk of low back pain and muscles fatigue. The muscles involved in this study are medial head of gastrocnemius, quadriceps femoris and erector spinae. Electromyography (EMG) analysis comparing the stoop and squat technique were systematically reviewed. The selected subjects were two healthy males and two healthy females with same body mass index (BMI) range (18.5 – 24.9). ProEMG stand-alone V2.1.2.5 software was used to analyse the activities of the muscles. The subjects performed 15 repetition of stooping and squatting as recommendation by SENIAM. We found that squat load lifting is safer and cause less muscle fatigue compared to stoop load lifting.*

**Keywords:** *Electromyography; musculoskeletal disorders; squat; stoop; load lifting; lower extremity muscles.*

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## Introduction

Work-related musculoskeletal disorders (WMSD) is common among manual worker. WMSD is pain of musculoskeletal system such as tendons, joints, bones and muscles [8]. Working in the same position for long periods, stoop or cramped positions and handling an excessive number of load lifting in one day were found to contributed to the development of WMSDs [9]. It effects workers' quality of life, reduce labour productivity and among the most expensive form of work related disability [1]. This is supported by Motamedzade M. et al., which stated that load lifting is the most stressful activity that able to trigger the WMSD [2]. WMSD are common in industrial workplaces and has been acknowledged to contribute a significant financial burden to companies, society and the health care system [3]. One of the common WMSD is low back pain (LBP) [4]. Many workers that involve with manual material handling in the industry have LBP. They do not perform the squat lifting technique as they do not realise the importance of the correct lifting technique. Study on lifting by Hwang et al. and Van Dieën et al. [5,6], suggested squat lifting technique to avoid LBP when load lifting. In the squat lifting, the leg muscles will be utilized while the back muscle remains erect [10]. However, squat technique gains less popularity among the worker due to its high energy use [7]. The technique that preferred and commonly used by the general population is the stoop technique, where the lower back muscle is bent more compared to the squat.

The studies on squat and stoop movement have been conducted before, however it was very less in comparing muscle activities between the two movements, especially by using SEMG (Myon EMG). Thus, there is a need to fill this gap in the literature. To achieve this, electromyography analysis, especially in the lower limb muscles, is recorded to detect the muscles that are being worked. Thus, the deliberate study of EMG signal means to increase further understanding about the muscles of the lower limb and to examine the associated muscles use during the squat and stooping for load lifting in order to lessen the low back pain and the muscles fatigue. Therefore, this study was to investigate the muscle activities between stooping and squatting in order to avoid low back pain and the muscle activities differ from a correct technique of squatting and an incorrect one.

## Methods

### Participants

To analyse the difference of muscle activities between stooping and squatting, four subjects which consist of two males and two females with the same normal body mass index (BMI) range (18.5 – 24.9) were recruited for the study to perform both stoop and squat movement. In order to reduce the different

strength capability when lifting a weight, the subjects nearly have similar figures for the same gender. All participants were 24 years old, had similar height on the same gender but different stature and were non-athlete. No subject had a history of lower limb and back injuries in the previous six months to the experiment and they were informed to not undertake vigorous physical activity within 48 hours preceding the test because muscle fatigue may yield to mislead outcome results.

## Experimental set-up

The experimental set-up is shown in Figure 1. Prior in starting the experiment, the transmitter and the receiver has to be fully charged first. The charging duration is around two to three hours for the transmitter to be fully charged.

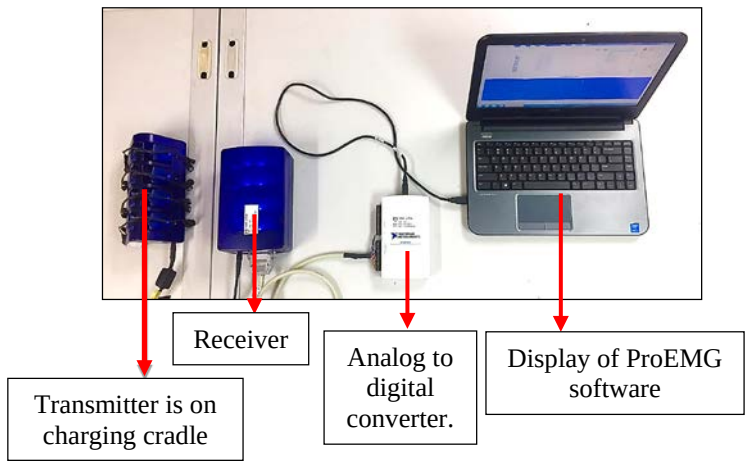
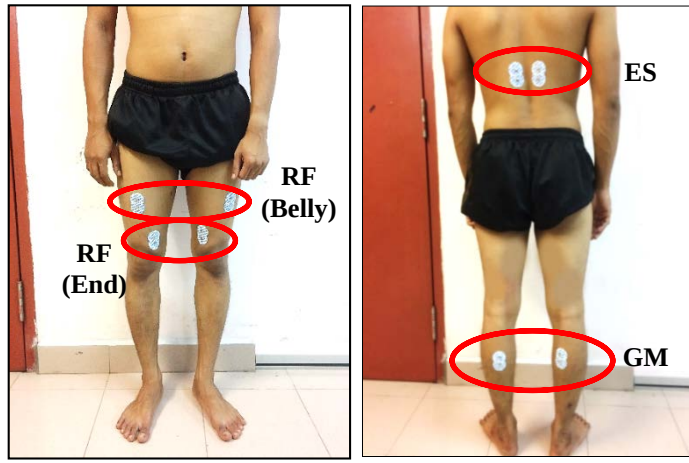



Figure 1: The experiment setup layout.

Participants changed to proper attire to prepare themselves for shaving and electrode placements. Before placing the electrodes, the skin was cleaned and wiped with alcohol swab. After preparation, conductive adhesive hydrogel disposable foam electrode (Kendall Product) with 1 and ½ inch diameter and an inter-electrode distance of 2 cm were attached in parallel to the muscle fibres as shown in Figure 2, of the medial head of *g*astrocnemius (GM), rectus femoris (RF) as the lower limb muscles and erector spinae (ES) as the back muscle according to the recommendation of SENIAM.




(a) (b)

Figure 2: Electrode positions for transmitter placement at Rectus Femoris (RF) (belly & end muscles), Erector Spinae (ES) and Medial head of Gastrocnemius (GM) muscles based on SENIAM recommendation [8].

## Experimental procedure

The experiment was started with stooping then squatting without warming up and no precise angle of body flexion, to mimic real-life event in the industry when workers do the lifting. The experiment started out with stooping followed by squatting. For both stooping and squatting, the experimental set up was similar, where the participant stood straight in front of the weight (1.5kg) with a distance of 20 cm. Then the participants initiated the first movement (stooping), repetitively for 15 repetitions. A rest period of 15 minutes was given to the participant to allow full recovery, and then performed the second movement (squatting) directly after. The procedure was also conducted similarly for every subject.


(a) (b)

Figure 3: Subject performing (a) stoop, (b) squat.

## Measurements

Surface electromyographic (SEMG) signals were recorded from the muscles using Kendall™ 200 Series Foam Electrodes. Bipolar electrodes were used and placed on the muscle, with a distance of two centimetres between centres. Before placing the electrodes, alcohol swabs were used to clean the skin surfaces. Any hair skin was shaved before applying alcohol to increase the accuracy of the data output. The transmitters that were attached to the electrodes are held by using disposable adhesive tapes. The transmitter is transmitting the signal to the receiver then convert it from analogue to digital through National Instruments (NI) data acquisition system then imported to processing computer. All signals were full-wave rectified. The EMG amplitude was normalised and smoothen before the measurement of the RMS and mean frequency (MF) values through ProEMG software. Smoothing operations are designed to make noisy signal smooth. The smoothing operations that were used were referred by L. R. Released et al. (2013) [12]:

- Moving average smoothing (filtering technique to remove noise):

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

Where, N= number of samples and S= sample

- Root mean square smoothing (minimise artefacts left)
  Recommended by Basmajian and DeLuca [13]:

$$RMS_n = \sqrt{\frac{1}{N}} \sqrt{\sum_{n-N/2}^{n+N/2} S_i}$$

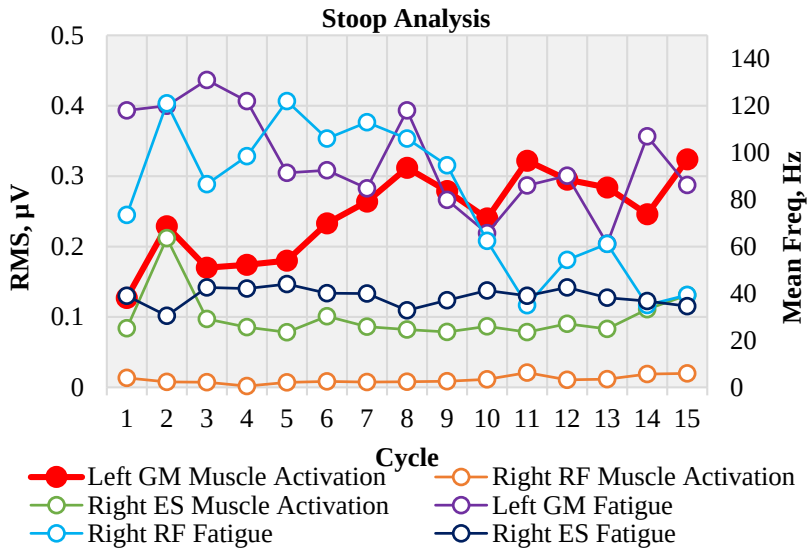
Where, N= number of samples and S= sample

Both RMS and MF were used in this study. Median Frequency and Integrated EMG were not used because the primary objective of this study is to investigate the muscle activity between stooping and squatting. Thus, RMS and MF are sufficient for this study as RMS will give info about muscle activation strength and MF to identify muscle fatigue.

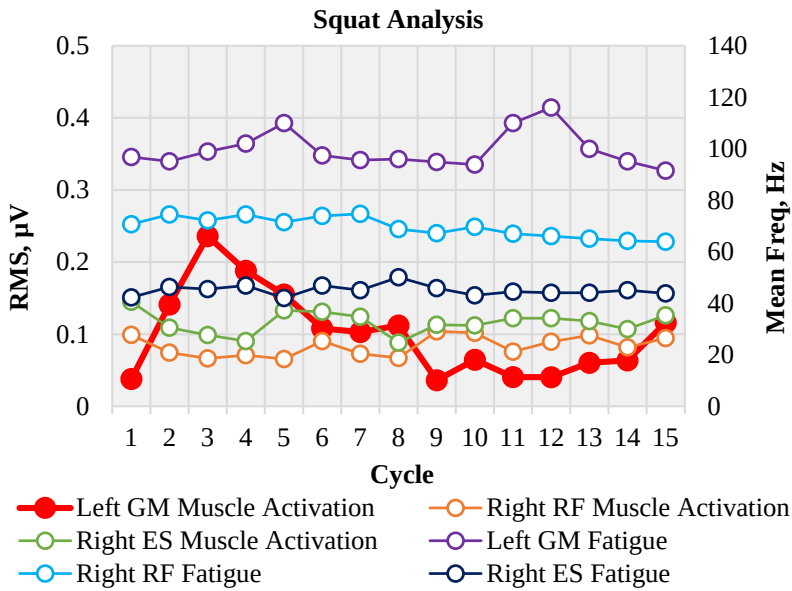
## Result and Discussion

The objective of this study is to identify the muscle patterns during squat and stoop between different subjects' ability. The muscle pattern can be described through the root mean square (RMS) and the muscle fatigue was described through the mean frequency (MF) of the muscle activities for both squat and stoop for every subject. The results are shown in figures below. The results were recorded and analysed for 15 repetitions with the same load of 1.5kg being put 20cm in front of participants. The same selected session analysed for RMS is used for mean frequency analysis for better references. This section will discuss on the significant result of stooping and squatting for four subjects which are:

- Subject 1 (Male – BMI 23.1)
- Subject 2 (Male – BMI 22.8)
- Subject 3 (Female – BMI 20.3)
- Subject 4 (Female – BMI 21.4)



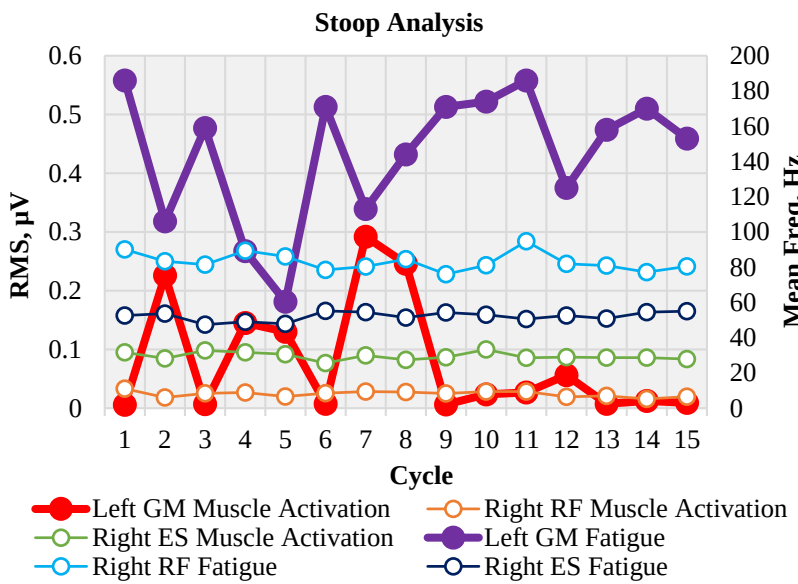

(a)



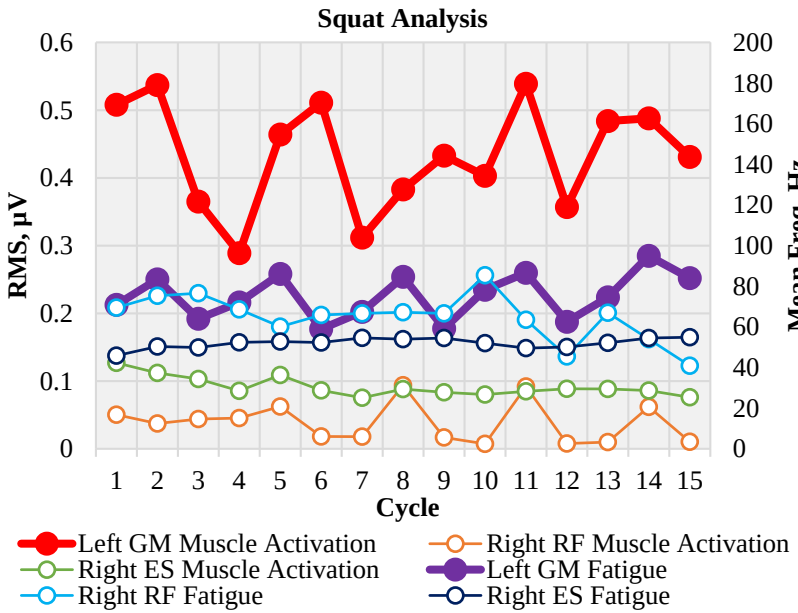

(b)

Figure 4: The RMS average and Mean Frequency analysis for (a) Stoop and (b) Squat of Male subject 1.

Above figures show the data of the average RMS and Mean Frequency (MF) for both lifting techniques of male subject 1. From stoop analysis, it shows that there is muscle spike during stooping at the left medial head of gastrocnemius (GM) muscle. From cycle 3 to 8, left GM shows the increment which indicates the increases in the muscle activities until the end of the cycles. This shows that the particular muscle requires more effort to do the stooping activity. However, comparing the data to squat RMS, left GM muscle shows little increment from cycle 1 to 3. This is due to higher muscle activation needed to start squatting. The muscle activation for GM in the squat is lower than stoop. Mean Frequency indicated the power consumption of a particular muscle to do the movements. So, MF is used to analyse the muscle fatigue. In stoop analysis, we can clearly see higher power needed to do stoop movement when lifting the load. In the squat analysis, the muscles reducing in power by time, however, it consumes lower power while squatting when picking up the load from the ground and from the trend, it shows that squatting also has nearly constant reading for every muscle fatigue compared to stoop.



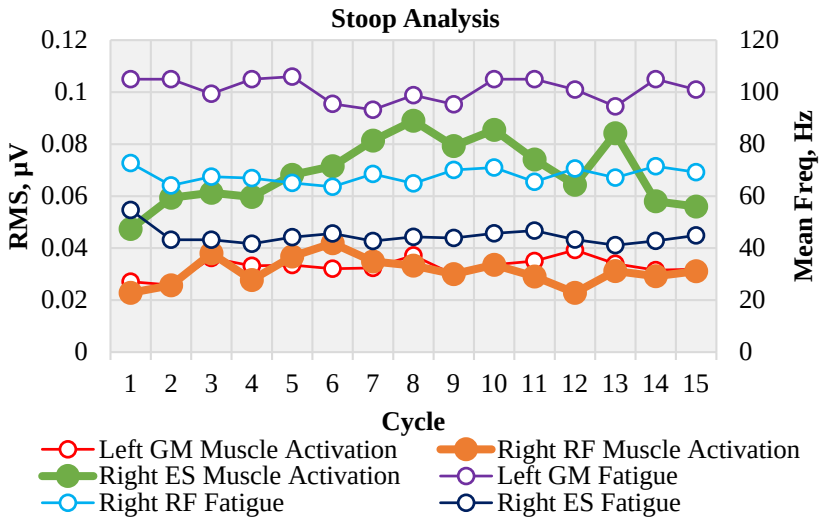

(a)



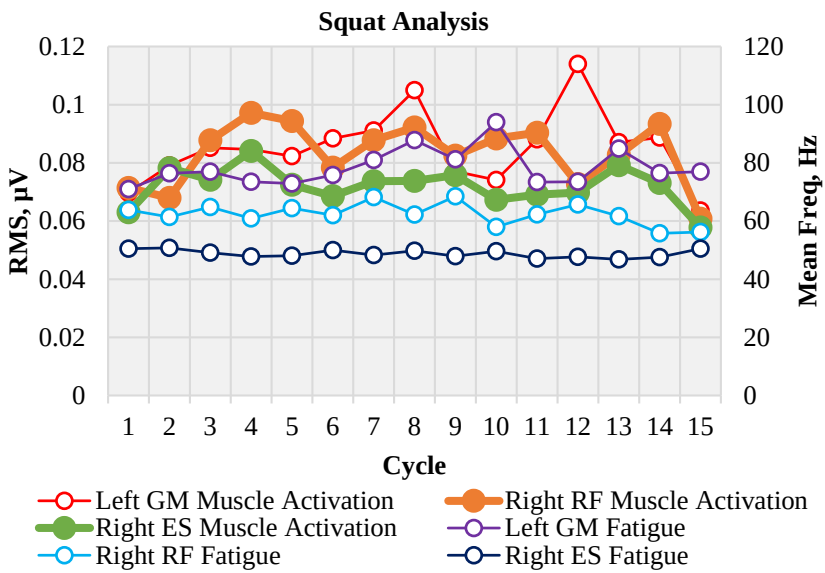

(b)

Figure 5: The RMS average and Mean Frequency analysis for (a) Stoop and (b) Squat of Male subject 2.

Figure 5 displays the analysis for male subject 2. As we can see, the trends are completely different from the male subject 1. For this subject, while stooping his left GM experienced lower muscle activation compared to squat. This may due to high usage of lower limb muscles during squatting. However, it gives out high muscle fatigue when stooping compared to squat. The left GM muscle fatigues during squat gives out approximately constant and lower data reading. Thus, this show that squatting produces high muscle activation but low muscle fatigue when load lifting. From both graph it can be said that, it is better to have more muscle activations than to have higher muscle fatigue.



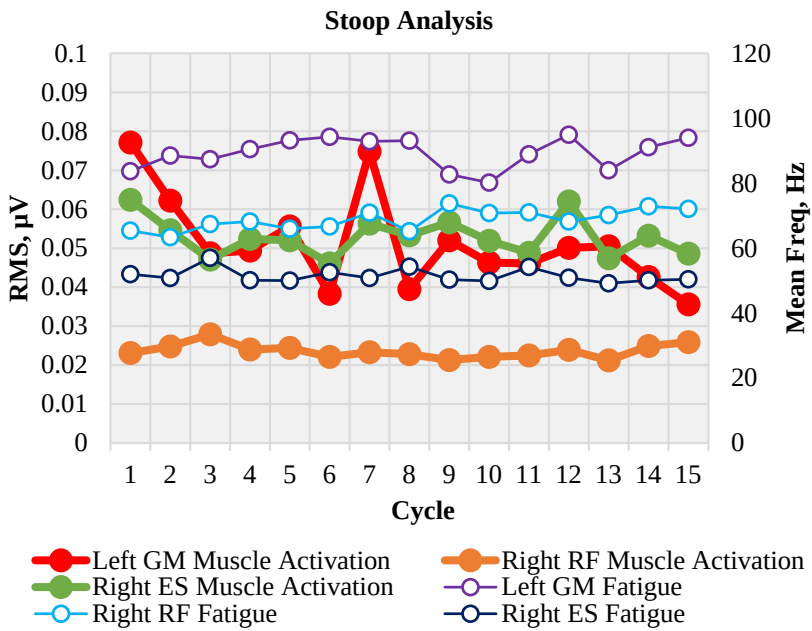

(a)



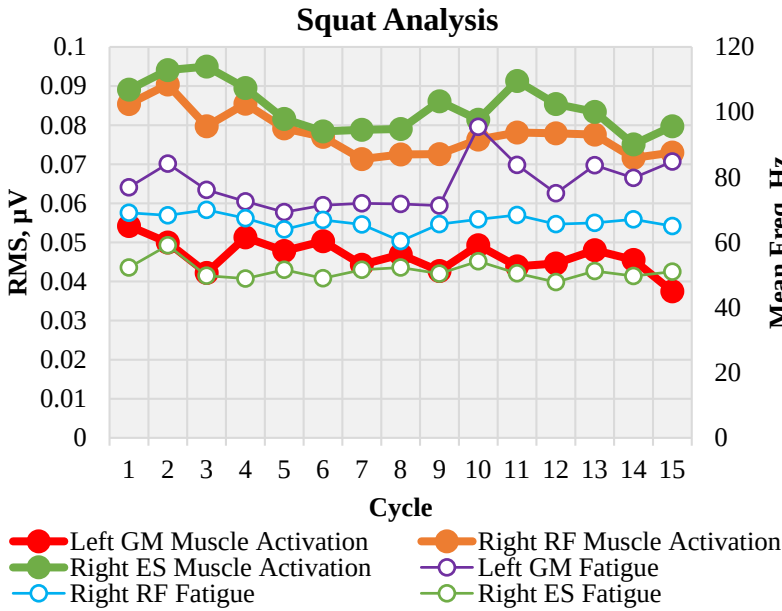

(b)

Figure 6: The RMS average and Mean Frequency analysis for (a) Stoop and (b) Squat of Female subject 3.

Figure 6 shows the analysis for female subject 3. Subject 3 is presenting slightly different data comparing to the male subject. For this subject, during stooping, she tends to use a higher amount of muscle activation for right ES muscle than left GM muscle. Which mean, she uses her lower back muscle a lot during stooping. Higher usage of lower back muscle may result in lower back pain. In contrast, her muscle activation for lower limb muscle (right RF) is higher than back muscle (right ES) muscle while squatting. This would reduce the usage of lower back muscle in hope to lessen the risk of getting the low back pain to lift the load.




(a)




(b)

Figure 7: The RMS average and Mean Frequency analysis for (a) Stoop and (b) Squat of Female subject 4.

Figure 7 illustrate the study of RMS average and Mean Frequency (MF) for stoop and squat of female subject 4. When stooping while load lifting, the usage of her back muscle (right ES) is higher than the lower limb muscle (right RF). This may increase the chances of getting lower back pain (LBP). In squatting, she uses high amount of muscle activation for right ES than her lower limb muscles (left GM and right RF). However, in squat she used nearly the same amount of muscle activation. This shows that during squat the body posture is more stable compare to stoop when picking up the load.

## Conclusion and Recommendation

For this study, the muscle activities of the lower extremity were investigated through performing stoop and squat movements by using electromyography (EMG). The EMG data for all muscles involved in the study for both squat and stoop had been accumulated for comparison. From the analysis of the usage of muscle, it can be seen that the squatting technique is better as it promotes the better and stable reading of muscle data while lifting the load. This can be proved by the result of all four of the subject. The RMS and MF graphs for every subject almost show stable or constant reading of left GM, right ES and right RF muscles during squatting compared to stooping. For every subject, the data shows that erector spinae (ES) muscle experienced lowest muscle fatigue either in squat or stoop. Though, squatting data shows lower fatigue than stooping. The minimum usage of back muscle (ES) hopefully may reduce the chances of getting low back pain while load lifting. As proclaimed by National Institute of Neurological Disorders and Stroke (NIH), having a daily job that requires heavy lifting, pushing or pulling especially when it involves the twisting or vibrating the spine was one of the risk factors for developing low back pain (LBP) is which can lead to injury and low back pain [14].

However, several past studies stated that there appears to be no single best lifting technique and there is still no study able to prove and state that the squat technique is better than stoop for lifting the load. Thus, this study is to prove that the squat technique is better than to stoop while picking up the load in order to lessen the low back pain. From this conducted study, we manage to provide that squatting promotes stable and constant data reading either for muscle activation or muscle fatigue compared to stooping when picking up the weight. Constant reading of muscle activation means the power of the muscle is spreading evenly for all muscles involved when lifting the load. This would reduce muscle fatigue. The results also show the muscle experienced lower fatigue in squat than during stoop. This hopefully to be the pioneer study to investigate the relation between the correct muscle usage during load lifting in order to reduce the lower back pain (LBP).

For the recommendation, it is suggested that the next experiment would involve as many subjects as possible to have more data especially for people that applied the stoop and squat movement as their daily working routine in the industry, in order to prove the correct technique of load lifting. Even though there are still lack in the study to prove that squat is the best lifting technique, from my point of view, I would like to propose squat as preferable lifting technique as it is not only creating a stable body posture to lift the load but also spread the muscle usage evenly throughout the body. Thus, is hope to lessen the risk of getting low back pain. This hopefully to be the pioneer study to investigate the relation between the correct muscle usage during load lifting in order to reduce the lower back pain (LBP) hence, able to create awareness

for general working population that applied the manual lifting in their daily work routine.

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