IOP Conf. Series: Materials Science and Engineering **834** (2020) 012035 doi:10.1088/1757-899X/834/1/012035

Electromyography Analysis of Lower Extremity Muscles during Squat and Stoop Movement

Noor Azlina Mohd Salleh[1], Muhammad Syukran Al-Baria Noor Sazali[1], Noor Ayuni Che Zakaria[*1], Nadia Mohd Mustafah[2], Aizreena Azaman[3],

[1]Faculty of Mechanical Engineering, Universiti Teknologi MARA Selangor, 40450 Shah Alam, Malaysia
[2]Faculty of Medicine, Universiti Teknologi MARA Sungai Buloh, Jalan Hospital, 47000 Selangor, Malaysia.
[3]School of Biomedical & Health Science, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor.

*ayuni8098@uitm.edu.my

Abstract. There are different styles of lifting objects of the ground, and each style gives out different percentage of contribution of each muscle. The purpose of this study is to investigate the muscle activity between stooping and squatting to avoid low back pain and how the muscle activities differ from a correct technique of squatting, and an incorrect one. The Rectus Abdominis, Erector Spinae, Quadriceps and Hamstrings muscle were chosen to be monitored for differences in this study. Selected subjects were two healthy males, with the same height and age, one subject has no experience in doing squats – define as amateur, and the other subject know the basic method of squat-ting – define as non-amateur. In order to capture and analyze the activity of the muscles, Myon EMG and ProEMG software were used. Participants performed, stooping and squatting movement for 12 repetitions with 5 minutes' rest in between. The muscle activation strength was obtained by calculating the Root Mean Square of the EMG data. Results shows that the non-amateur gave out greater RMS difference in muscle activation for the Erector Spinae and Rectus Abdominis among other muscles compared to amateur for both stooping and squatting. Another finding was that, the results of a non-amateur were more balanced between both left and right muscles activation compared to the amateur subject. These observations raised the need of mind muscle connection and muscle coordination in order to lift efficiently in order to avoid low back injury.

1. Introduction

According to M. Motamedzade, A. Dormohammadi, E. Zarei, and R. Dormohammadi (2016), under the Manual Material Handling, it is stated that load lifting is the most stressful activity and could cause work-related musculoskeletal disorders [1]. Both musculoskeletal disorders (MSD) and low-back pain (LBP) are common in industrial workplaces and has been acknowledge as a significant cost toward companies, society and the health care system [2]. Based on a similar study on lifting done by S. Hwang, Y. Kim, and Y. Kim (2009) [3] and J. H. Van Dieën, M. J. M. Hoozemans, and H. M. Toussaint (1999) [4], in avoiding low-back pain when load lifting, the squat technique is the commonly advised technique to be done. However, squat technique popularity is low among the general population due to its high energetic cost as stated in [5]. The technique that more preferred and commonly used is the stoop technique, where the lower back is bended more compared to the squat. Studies on squat and stoop movement have been conducted before, however very less in comparing muscle activities between the two movements, especially using Myon EMG (myon AG, Schwarzenberg, Switzerland). Therefore, there is a need to fill this gap in the literature.

Squatting is a fundamental human movement pattern that involves nearly every muscle in the body, mainly in the lower extremity [6]. It is considered fundamental because it is required in activities of daily living [6]. For examples, picking stuff up from the ground or even sitting. Sitting is considered to be similar to squatting due to both movements are involve in hip and knee flex-ion. Stoop on the other hand, involves in lumbar flexion or bend at the waist. S. Hwang, Y. Kim, and Y. Kim (2009) did a similar case study but focused on joint angles, moments, power, support moments and including dynamic EMG [3]. From the EMG results, the study found biceps femoris and rectus femoris showed large variances of activation during the squat lifting. While tibialis anterior, medial gastrocnemius and biceps femoris showed large variances of activation during stoop lifting. On top of that, the study also found rectus abdominis and lumbar erector spinae are not significant both during squat and stoop lifting. On the other hand, J. H. Van Dieën, M. J. M. Hoozemans, and H. M. Toussaint (1999) [4] also did a similar case study but with respect to the mechanical load on the back. The parameters used were muscle force, compression, shear and bending moments.

However, despite those studies on comparison between squat and stoop in which technique is superior from one another, there is no similar study found in comparing the correct squat technique and an incorrect one based on the muscle activities using Myon sEMG. Therefore, this study is to investigate the muscle activity between stooping and squatting to avoid low back pain and how the muscle activities differ from a correct technique of squatting and an incorrect one.

2. Methods

2.1 Participants

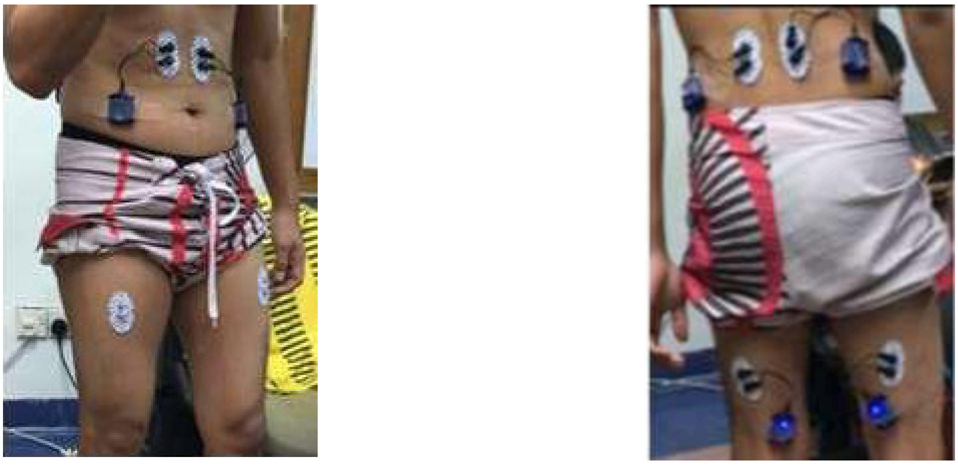
To reduce different strength capability when lifting weight, two young male university students with similar figures were selected for the study. Both participants were 24 years old, had similar height but different stature, and were non-athlete. The subjects were divided into a non-amateur and an amateur. A non-amateur is the person that has experienced in performing both stoop and a correct squat technique, while an amateur is someone that does not have any experience in performing both stoop and a proper squat technique. Both participants had no past injuries mainly in the lower extremity and were in good health.

2.2 Experiment Set-up

The experiment was set-up as shown in Figure 1. 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 of the rectus abdominis (RA), erector spinae (ES), rectus femoris (RF) and bicep femoris (BF) according to the recommendation of a rehabilitation physician.

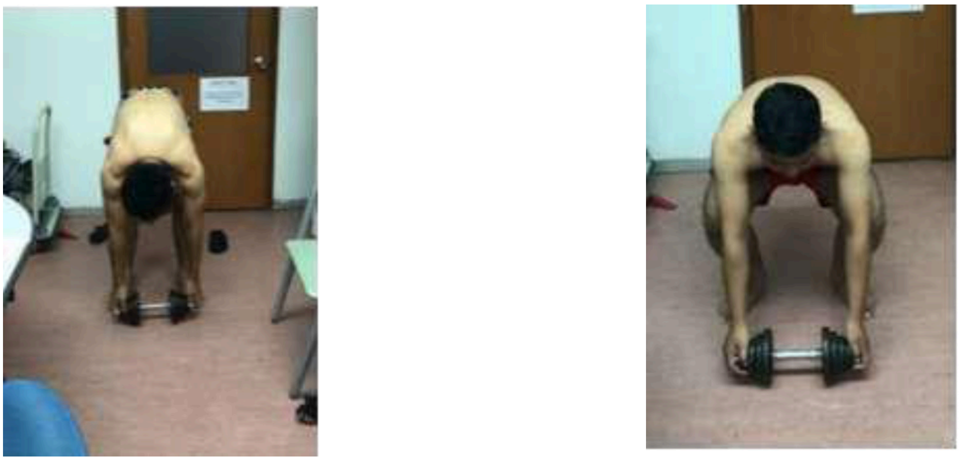
2.3 Experimental Procedure

Subjects were asked not to perform any exercise that may cause muscle leg fatigue or pain prior to the study because muscle fatigue may produce mislead outcome results. The experiment was started with stooping then squatting without warming up, to mimic real life event in the industry where no warming up prior to lifting. The experiment started out with amateur followed by non-amateur. For both stooping and squatting, the set up was similar, where the participant stood straight in front of the weight (dumbbell) with distance of 20 cm. Then the participants initiated the first movement (stooping), repetitively for 12 repetitions. A rest period of 5 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 with non-amateur subject.



(a) (b)

Fig. 1. Picture of electrode positions (a) Rectus Abdominis and Rectus Femoris, (b) Erector Spinae and Bicep Femoris



(a) (b)

Fig. 2. Pictures of non-amateur performing (a) squat, (b) stoop

(a) (b)

Fig. 3. Picture of an amateur performing (a) squat, (b) stoop

IOP Conf. Series: Materials Science and Engineering **834** (2020) 012035 doi:10.1088/1757-899X/834/1/012035

2.4 Measurements
Surface electromyographic (sEMG) signals were recorded from erector spinae (ES), rectus abdominis (RA), rectus femoris (RF) and bicep femoris (BF) using Kendall™ 200 Series Foam Electrodes. Bipolar electrodes were used and placed on the muscle belly of each muscle, with distance of two centimeters between centers. Before placing the electrodes, alcohol swabs were used to cleaned of the skin surfaces. Any hair skin was shaved prior applying alcohol to increase accuracy of the data output. The transmitters that were attached to the electrodes are hold by using disposable adhesive tapes. The transmitter transmits the signal to the receiver then convert it from analog to digital through National Instruments 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 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) [7]:

- Moving Average Smoothing (Mean Frequency)

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

Where, N= number of samples and S= sample

- Root Mean Square

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

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, and RMS and MF are sufficient for this study. As RMS will give info about muscle activation strength and MF to identify muscle fatigue.

3. Results and Discussion
The objective of this study is to identify the muscle pattern during squat and stoop between different subject ability. The muscle pat-tern can be described through the root mean square (RMS) of the muscle activity for both squat and stoop between non-amateur and amateur. The results are shown in figures below. The results were recorded and analysed for one selected session out of 12 repetitions with the same load of 7.5kg dumbbell being put 20cm in front of participants. The same selected session analysed for RMS is used for mean frequency analysis for better references.

Table 1. Pattern of EMG signals of a non-amateur for one cycle (7 seconds)

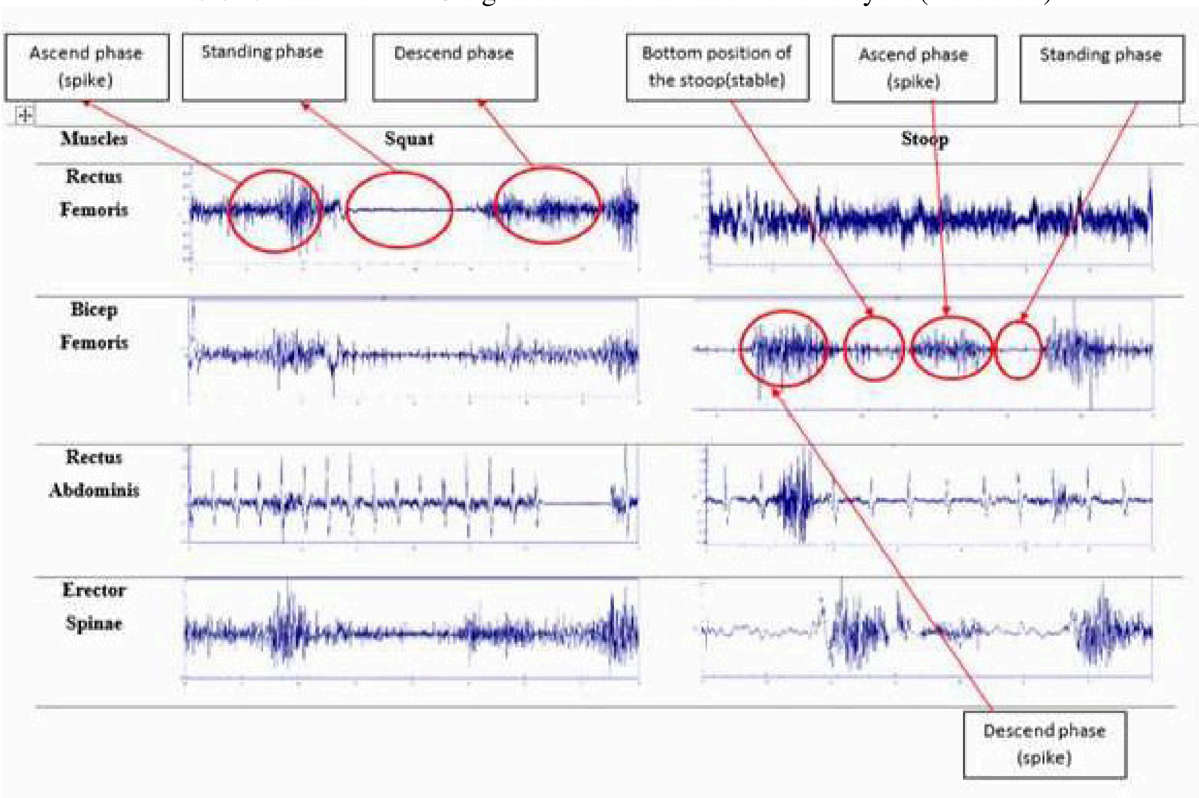


Table 2. Pattern of EMG signals of an amateur for one cycle (7 seconds)

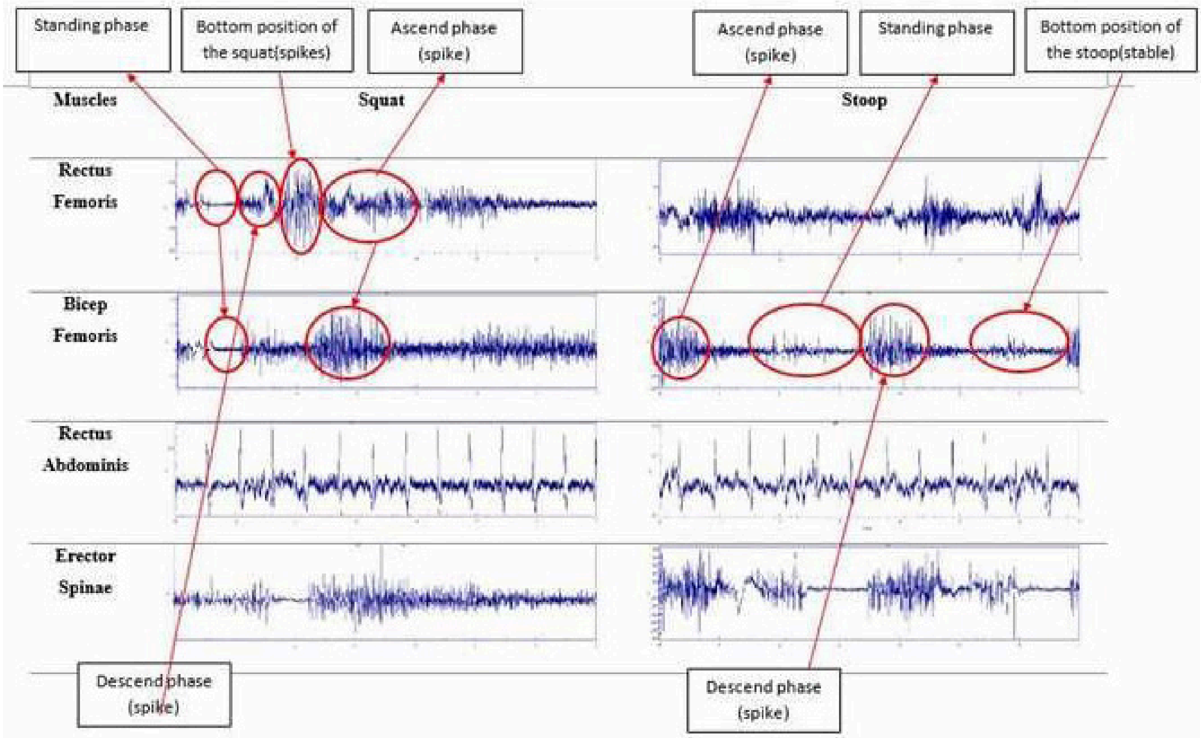
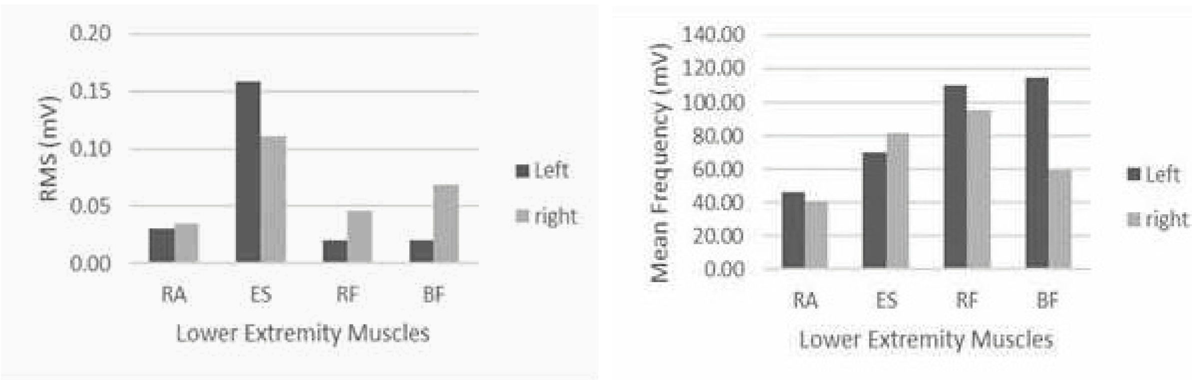


Table 1 and table 2 show the EMG muscle pattern in both subjects during squat and stoop movement. Different muscle signal can be seen during ascending, standing and descending phase. The signals are represented in volt versus time. For squat column, we analyse the movement by looking at the signal coming from rectus femoris. Reading the signal in the table from left to right, the subject began to descend into a squat position where the upper thighs are slightly below parallel from the ground. Once the subject starts to ascend, the EMG signal for rectus femoris spikes, then back to normal (stable) as the subject stands up straight. The signal for bicep femoris and erector spinae can be seen as similar to rectus femoris. It is similar for bicep femoris could be because of being as one of the biarticular muscle same as rectus femoris which is also one of the biarticular muscles. However, as for erector spinae, it is because it functions in keeping an upright torso or a neutral spine to avoid it from curving.

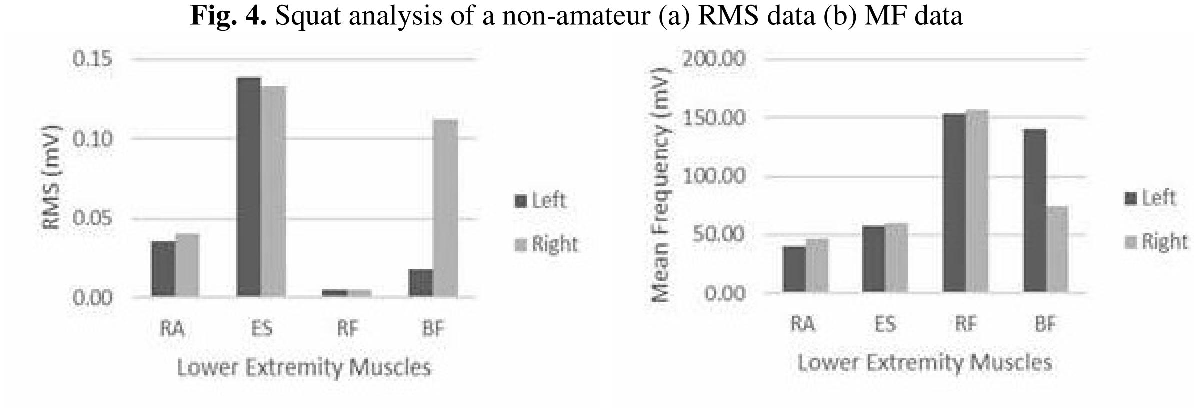
As for stoop column, we analyses the movement by looking at the signal coming from bicep femoris. Reading from left to right, the spikes mean that the subject starts to descend then the signal becomes stable for a while at the bottom position of the stoop. The signal spikes back as the subject starts to ascend back to standing position. Even though stooping means, there is no flexion, or bending occurs at the knees, the subject knows how to engage his muscles so that the leg muscles are being work during lifting in order to avoid straining the lower back.

As expected, overall for both RMS and MF results, the most significant finding in this study was the non-amateur gave out greater EMG activity compared to an amateur for each muscle and for both squat and stoop movements. Based on the data obtained, this may also mean that the non-amateur has better muscle coordi-nation and mind muscle connection due to producing more balanced EMG activity between left and right muscles compared to an amateur. However, this view may not be accurate, as EMG comparison between left and right extremities mostly caused by the dominance side of the individual. For example, left handed person with have higher RMS at left hand. On top of that, as stated in [8], EMG differences in left and right side is also due to gender differences.



(a) (b)

Fig. 4. Squat analysis of a non-amateur (a) RMS data (b) MF data

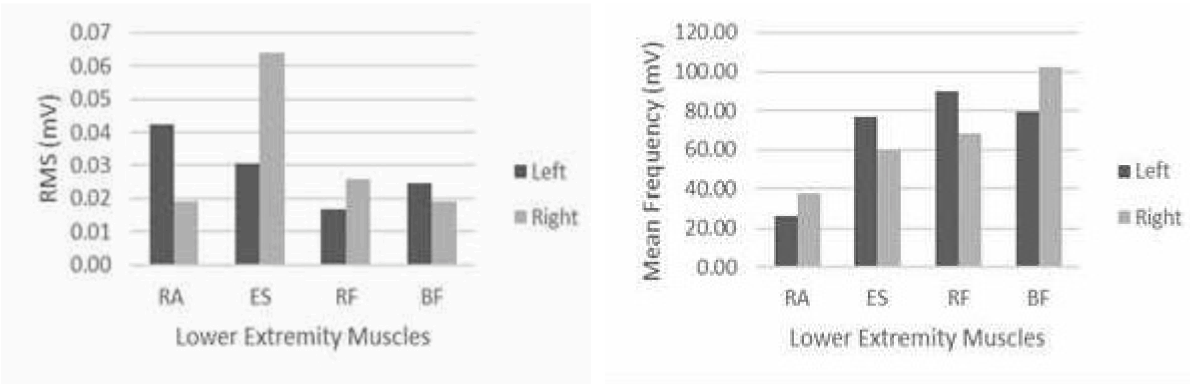


(a) (b)

Fig. 5. Stoop analysis of a non-amateur (a RMS data (b) MF data

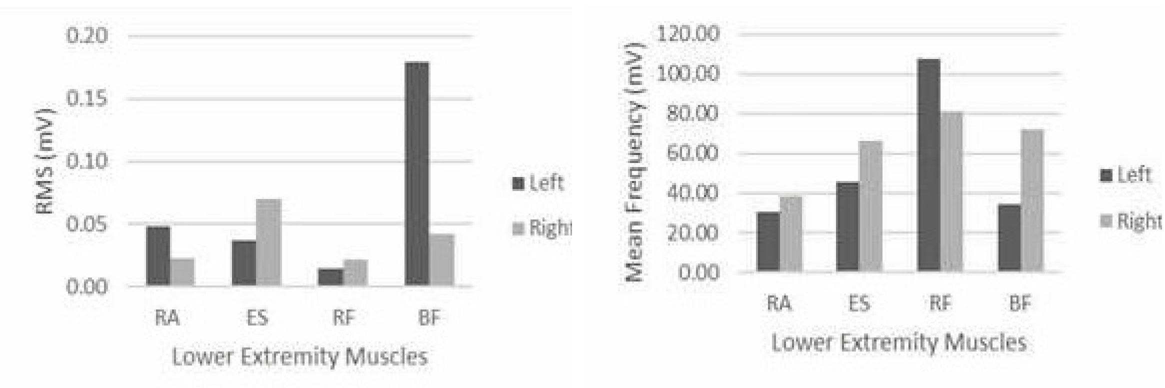
Figure 4 and figure 5 show the squat and stoop analysis for both left and right muscles of a non-amateur respectively. For non-amateur, most of the muscles studied were shown to give balanced electrical (RMS and MF) signals for both right and left sides. However, the BF shows a higher RMS signal coming from the right side compared to the left when performing both squat and stoop. This could probably mean that the non-amateur has muscle imbalances in his rear thigh. However, as for the MF signal it's the opposite, the left side of BF muscle is higher than the right. Rea-son is because the RMS signal is actually used to look into muscle strength, whereas MF used to analyse muscle fatigue, therefore it explains why MF gave reverse data of the RMS. As for this study specifically, we are more focused on the RMS signal because the objective was to determined correct muscle usage i.e. strength, when performing the two movements, rather than to determine which muscles fatigued more. Furthermore, another significant finding would be that the non-amateur also gave out greater

EMG activity for ES during squat (RMS=0.159) than stoop (RMS=0.138) than the RA, hence these findings are in line with S. Hwang, Y. Kim, and Y. Kim, (2009) [3] and G. B. Shane Schwanbeck,Philip D.Chilibeck (2009) [9]. This could be due to the ES was working greater in keeping an upright torso rather than letting the torso bends, specifically at the lumbar region when performing the stoop.



(a) (b)

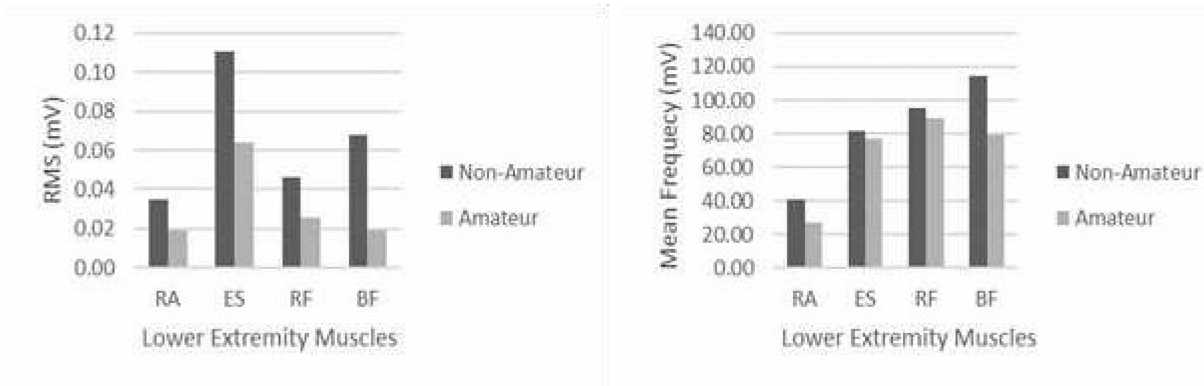
Fig. 6. Squat analysis of an amateur (a) RMS data (b) MF data



(a) (b)

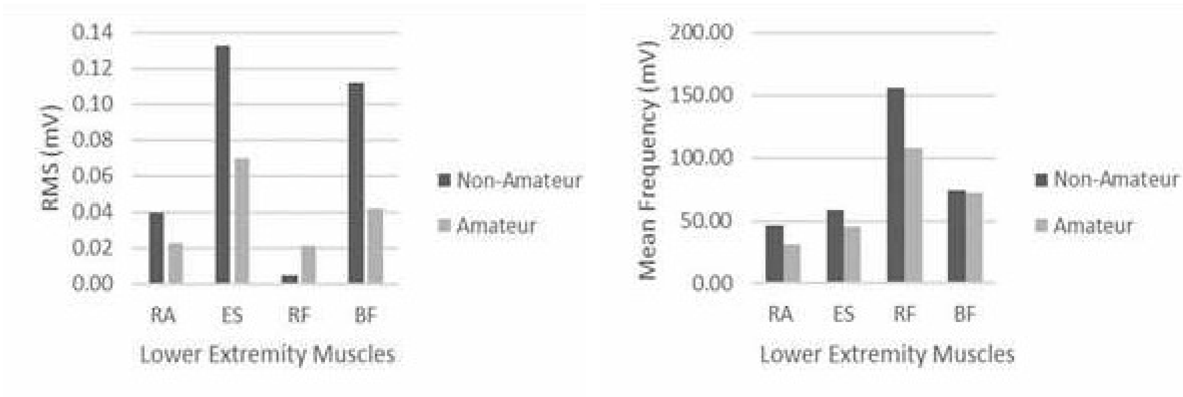
Fig. 7. Stoop analysis of an amateur (a) RMS data (b) MF data

The data obtained from the amateur subject can be referred to figure 6 and 7, where muscle activities of the subject core muscles were significantly unbalanced specifically between left and right ES muscle for both squat and stoop. Another thing to notice is that it can be assumed that the left ES is weaker than the right, due to having lower electrical signal when performed both squat and stoop. This however has been compensated by left RA, which has worked greater than the RA. This is possibly due to the role between agonist and antagonist muscle, where for instance, when the right RA is relatively weak compared to the left, the right ES would work more to stabilize the upper body to avoid from twisting the lower back.



(a) (b)

Fig. 8. Squat analysis between amateur and non-amateur (a) RMS data (b) MF data



(a) (b)

Fig. 9. Stoop analysis between amateur and non-amateur (a) RMS data (b) MF data

Furthermore, from figure 8 and figure 9 we can see and distinguish the difference in muscles activities for squats and stoop between a non-amateur and an amateur. Non-amateur produced higher RMS and MF value for every muscle compared to an amateur. This makes sense because the non-amateur subject is more likely to be able to contracts each muscle proportionately and the whole muscles have to work together simultaneously so that proper technique and good posture can be attained. For example, the electrical signal of RA of a non-amateur would be higher com-pared to the amateur because non-amateur is able to utilized proper bracing technique when perform both squats and even during stooping to reduce the chance of getting low back pain.

Apart from that, there were also unexpected findings where the EMG activity shows a greater muscle electrical activity of BF than RF for squat. Contrary to previous findings, RF activity was usually higher than BF for squats, except for a study conducted by [10]. This may be due to several reasons, but mainly would be due to being inexperience in placing the electrodes accurately. However, it has been stated in a study conducted by Gregory. J. Hoyme. and J. J. J. James W. Youdas, John H. Hollman, James R. Hitchcock (2007) [11] that men are hamstring dominant and better at activating their hamstring more effectively.

4. Conclusion and Recommendation

In this study, the muscle activities of lower extremity were investigated through performing squat and stoop movements by using electromyography (EMG). The EMG data for erector spinae (ES), rectus abdominis (RA), rectus femoris (RF) and bicep femoris (BF) for both squat and stoop had been accumulated and normalized to root mean square (RMS) for ease comparison. The results show greater mean muscle activities for non-amateur than amateur. Apart from that, the non-amateur also gave out more balanced electrical signals in both sides for nearly every muscle except for bicep femoris (BF).

IOP Conf. Series: Materials Science and Engineering **834** (2020) 012035 doi:10.1088/1757-899X/834/1/012035

Even though the root mean square (RMS) value of the bicep femoris (BF) was slightly different from previous research, but the rectus femoris (RF) and core muscles data were in line with previous study.

Several past studies stated that there appears to be no single best lifting technique as stated in [12] and there is still no study able to prove and state that squat technique is superior than stoop for lifting. A correct squat technique is more preferable lifting technique as it requires to utilize the core muscles even more, for proper bracing. Hence, the chances of getting low back pain would be more likely to be reduced as the core muscles surrounding the lumbar area to protect and support it. As stated in L. Del Vecchio, (2017) [12], strengthening the muscles, ligaments and bones would increase the individual's ability to handle heavier loads and resist injuries, thus strengthening the core muscles are crucial in avoiding low back injury. Hence, recommendation to health practitioners and fitness enthusiast would be to create awareness and educate the general public in general lifting guidelines and also give exercise examples for corrective movement patterns from time to time through events such as "Hari Sukan Negara" con-ducted by the Ministry of Youth and Sports Malaysia. A well bal- ance posture and biomechanics are also important to avoid injury and preventing long term complication such as chronic low back pain.

References

[1] M. Motamedzade, A. Dormohammadi, E. Zarei, and R. Dormohammadi, "The role of ergonomic design and application of NIOSH method in improving the safety of load lifting tasks," ARAK Med. Univ. J., vol. 16, no. 6, p. 91, 2013.

[2] A. A. Godwin, J. M. Stevenson, M. J. Agnew, A. L. Twiddy, M. Abdoli-Eramaki, and C. A. Lotz, "Testing the efficacy of an ergonomic lifting aid at diminishing muscular fatigue in women over a prolonged period of lifting," Int. J. Ind. Ergon., vol. 39, no. 1, pp. 121–126, 2009.

[3] S. Hwang, Y. Kim, and Y. Kim, "Lower extremity joint kinetics and lumbar curvature during squat and stoop lifting," BMC Musculoskelet. Disord., vol. 10, no. 1, p. 15, 2009.

[4] J. H. Van Dieën, M. J. M. Hoozemans, and H. M. Toussaint, "Stoop or squat: A review of biomechanical studies on lifting technique," Clin. Biomech., vol. 14, no. 10, pp. 685–696, 1999.

[5] J. Wasilewski, "To stoop or squat, a thorough analysis. KNPE 450 - Ergonomics," 2014.

[6] and J. W. C. Jonathan C. Gullett, Mark D. Tillman, Gregory M. Gutierrez, "A Biomechanical Comparison of Back and Front Squats in Healthy Trained Individuals," pp. 284–292, 2008.

[7] L. R. Released et al., "proEMG 2.0 - How do you do?," no. March, pp. 1–51, 2013.

[8] M. Kaur, S. Nara, D. Shaw, and D. Bhatia, "EMG Asymetricity of Selected Knee Extensor Muscles in Sustained Squat Posture (A Yogic Posture) of Athletes in Relation to their Gender and Performance," vol. 7, pp. 1–6, 2016.

[9] G. B. Shane Schwanbeck,Philip D.Chilibeck, "a C Omparison of F Ree W Eight S Quat To S Mith," 2009.

[10] B. A. DeForest, G. S. Cantrell, and B. K. Schilling, "Muscle Activity in Single- vs. Double- Leg Squats.," Int. J. Exerc. Sci., vol. 7, no. 4, pp. 302–310, 2014.

[11] Gregory. J. Hoyme. and J. J. J. James W. Youdas, John H. Hollman, James R. Hitchcock, "comparison of hamstring and quadriceps femoris between men and women.pdf," J. Strength Cond. Res., 2007.

[12] L. Del Vecchio, "Choosing a Lifting Posture: Squat, Semi-Squat or Stoop," MOJ Yoga Phys. Ther., vol. 2, no. 2, pp. 1–7, 2017.