Assessment of Bicep muscle Fatigue using a low-cost microcontroller-based EMG System

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Abstract
The world of sports medicine is constantly advancing with new treatments and studies to help athletes stay healthy and perform better. One way we can prevent injury is by monitoring the electrical signal of athletes' muscles. A known effect of muscle fatigue is associated with a change in electrical signaling and activity. By using an electromyography (EMG) sensor this change in activity can be measured and is used to show the current state of fatigue in the muscle. In this study, muscle-fatigue of the bicep from 3 subjects (2 male, 1 female), was measured using a low cost EMG-sensor. I utilized the Root-mean-square (RMS) and the average-rectified-value (ARV) to quantify the results of this experiment and assess the degree of fatigue of the muscle. Using this procedure, I was able to identify the state of fatigue in the bicep muscle.

Introduction

Muscle fatigue is defined as a decrease in maximal force or power production in response to contractile activity. During a fatiguing contraction, biological changes happen, such as an increase in metabolite concentrations, changes in muscle fiber conduction velocity, and alterations in the number of motor units recruited.

Muscle fatigue is a prevalent problem in sports. When doing almost any everyday activity you use some sort of muscle. When a muscle is overworked it can be more prone to injury. One way to prevent such injuries is by testing which exercises lead to muscle fatigue. By using an EMG sensor, the frequency components of the acquired EMG signal can be used to determine whether the muscle is in a normal or fatigued state. The results of these tests could benefit a multitude of fields, but specifically; athlete performance and sports medicine.

By using electrodes and a myosensor, we can measure the EMG signal of a muscle to determine when the muscle is fatigued and which exercises lead to muscle fatigue.

Muscle fatigue can be divided into 2 categories: Fatigued and non-fatigued. When a muscle is in the non-fatigued state, it is able to apply its maximum force, but as the muscle starts the transition to the fatigued state, it begins to "recruit" new muscle fibers. Other authors classify this process as a third level called the "transition to fatigue." When the muscle enters this stage of "transition to fatigue" there is a dip in the myoelectric power from the muscle due to the loss in muscle conduction velocity. The EMG sensor detects this dip in frequency which is how we know when the muscle is fatigued.

In this project, the EMG signal will be acquired by non-invasive methods by placing electrodes on the surface of the bicep muscle; using surface electrodes is preferred as it's less invasive when compared to intramuscular electrodes. The electrical activity of muscle fibers during contractions generates the sEMG signals, and the electrodes attached to the skin record these signals in a non-invasive manner. This project will utilize a low-cost system to collect EMG signal from the quadricep muscle to help prevent sports related injuries. Using a low-cost system greatly expands the application of this project which will further help prevent injury.

It is important to highlight that most researchers on sEMG are focused on isometric contractions [1]. A muscle contraction is defined as isometric when the joint angle is constrained to be fixed and there are no changes in muscle length. This project experiments on only the isometric contraction of the bicep muscle.

Learning more about how to prevent and identify when muscle fatigue occurs can provide many socio-economic benefits. With the use of a low-cost system, this project can be applied to a wide variety of places.

Methods

A. Participants

Participate No.	Male/Female	Age	Height (inches)	Weight (lbs)	Physically Active (Y/N)	Previous injuries or neurological conditions (Y/N)
1	Male	16	73	159.2	Y	N
2	Female	46	64	130.4	Y	N
3	Male	49	75	215.1	Y	N

B. Recording EMG signal
   a. All participants were informed of the general process of the procedure and gave consent to be part of the experiment.
   b. The skin where the electrode was to be applied was prepared by wiping thoroughly with 75% alcohol disinfecting wipes to get rid of any natural oils or anything else that might interfere with the reading of the EMG frequency.
   c. 2 surface electrodes attached to the myoware muscle sensor were placed along the bicep muscle with the first electrode placed at the head of the muscle. A third electrode attached to the sensor was placed away from the bicep muscle. The electrode placement was kept the same for all participants and trials in order to decrease the variance in the results.

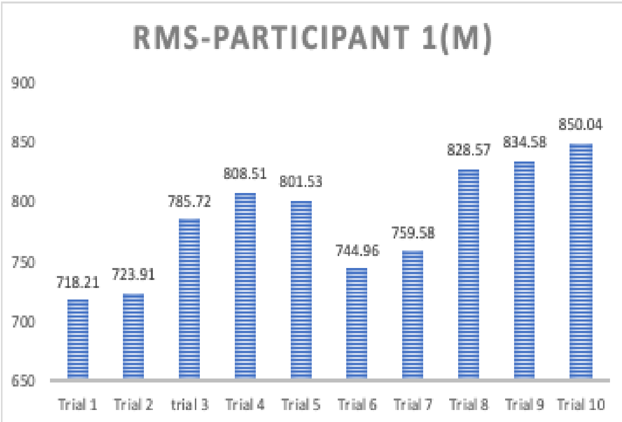
C. Onsetting Fatigue
   a. All participants held a 15 lbs. dumbbell in their right arm for 20 seconds. The participants did their best to keep a 90° angle. Over the course of the 20 seconds the myoware muscle sensor recorded the frequency of the EMG signal.
   b. Participants did this same protocol for 10 trials each in order to reach 30 trials total.

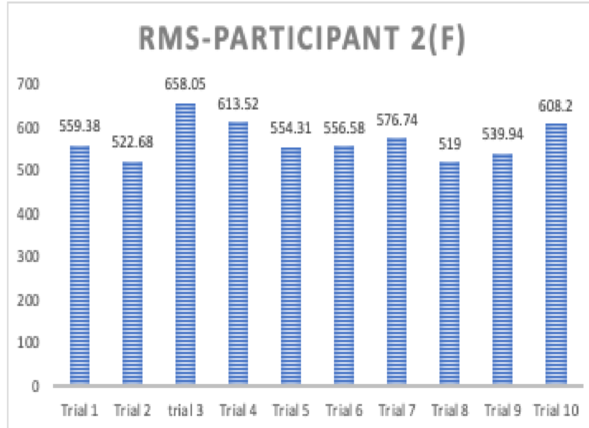
Results

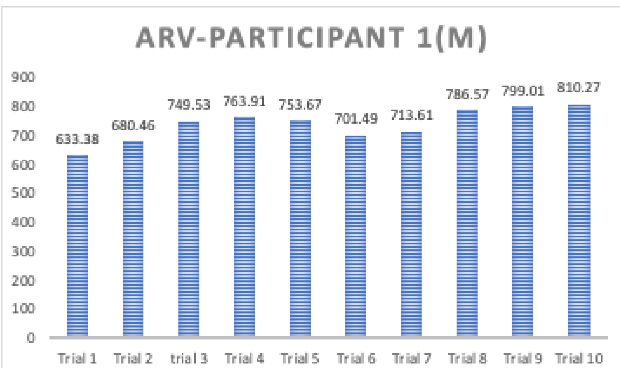
The RMS for participant 1 ranged from 718.21 to 850.04. The ARV of participant 1 ranged from 633.38 to 810. 27. The RMS of participant 2 ranged from 519 to 658.05. The ARV of participant 2 ranged from 477.9 to 620.15. The RMS of participant 3 ranged from 642.06 to 842.77. The ARV of participant 3 ranged from 604.01 to 808.36. For this experiment, I used 2 techniques to analyze the data collected by the myoware muscle sensor. The first technique I used was finding the RMS of a data set of EMG frequency. RMS was used as an indicator for this amplitude modulation, and the change of RMS values with time ∆RMS was a parameter for fatigue assessment [2]. RMS shows the average power of a constantly varying data set over a period of time, in this case it was the EMG signal recorded over a period of 20 seconds. Using RMS allowed me to determine the average power of the electrical signals in the muscle to help determine the state of fatigue of the muscle. Essentially, the higher the RMS, the more fatigued the muscle is.

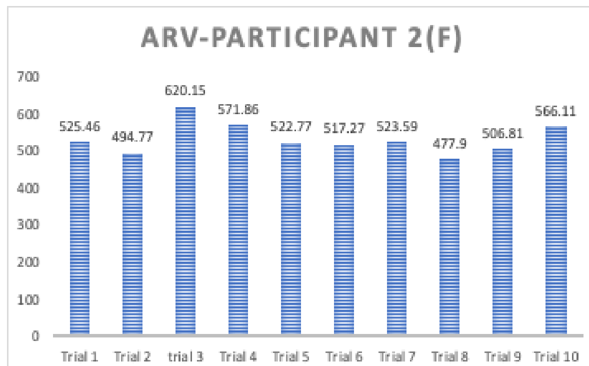
The second technique I used was to find the ARV of a data set of EMG frequency. The ARV of a quantity is the average of the absolute value of each unit in a data set. Using the ARV allowed me to find the average EMG frequency in hertz of each data set. This also helped me understand the state of fatigue the muscle is in. The first participant's ARV value ranged from 633.38 to 810.27. The second participant's ARV value ranged from 477.9 to 620.15. The third participant's ARV value ranged from 604.01 to 808.36

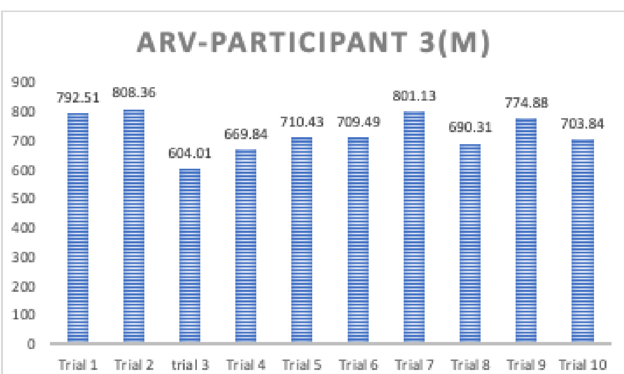
In addition to using both of these techniques to measure EMG frequency, I also used a t-test to determine whether the difference in both of these tests were reliable. The t-test provides a "p-value" or probability number. If the p number is below 0.05, then the data is considered to be reliably different. In this experiment the p number of the 10 trials of the RMS and ARV values for the first participant was 0.029097432. This shows that RMS and ARV are reliable ways of measuring EMG signals because they correspond to each other in a predictable and reliable manner. The X axis of the graphs represents the trial number, and the Y axis of the graphs represents the average RMS value for each trial.


RMS-PARTICIPANT 1(M)
900
850
800
750
700
650
718.21
723.91
785.72
808.51
801.53
744.96
759.58
828.57
834.58
850.04
Trial 1
Trial 2
trial 3
Trial 4
Trial 5
Trial 6
Trial 7
Trial 8
Trial 9
Trial 10


RMS-PARTICIPANT 2(F)
700
600
500
400
300
200
100
0
559.38
522.68
658.05
613.52
554.31
556.58
576.74
519
539.94
608.2
Trial 1
Trial 2
trial 3
Trial 4
Trial 5
Trial 6
Trial 7
Trial 8
Trial 9
Trial 10


ARV-PARTICIPANT 1(M)
900
800
700
600
500
400
300
200
100
0
633.38
680.46
749.53
763.91
753.67
701.49
713.61
786.57
799.01
810.27
Trial 1
Trial 2
trial 3
Trial 4
Trial 5
Trial 6
Trial 7
Trial 8
Trial 9
Trial 10


ARV-PARTICIPANT 2(F)
700
600
500
400
300
200
100
0
525.46
494.77
620.15
571.86
522.77
517.27
523.59
477.9
506.81
566.11
Trial 1
Trial 2
trial 3
Trial 4
Trial 5
Trial 6
Trial 7
Trial 8
Trial 9
Trial 10


ARV-PARTICIPANT 3(M)
900
800
700
600
500
400
300
200
100
0
792.51
808.36
604.01
669.84
710.43
709.49
801.13
690.31
774.88
703.84
Trial 1
Trial 2
trial 3
Trial 4
Trial 5
Trial 6
Trial 7
Trial 8
Trial 9
Trial 10

Discussion

Analysis of the results and critique of the work, including limitations and how other researchers can improve on your work.

One important aspect of this data that can be discussed is the difference between the maximum and minimum RMS and ARV values for each of the participants, and how this relates to the participants' physical characteristics such as their sex, age, height, and weight. Partially explained earlier, the large difference between the maximum RMS and ARV between the male participants and the female participant can be traced to the size of the bicep muscle. The larger the muscle, the more muscle fibers there are, the more reactions there are at any given moment, causing more electricity to be produced at any given period in time. Age seems to also have played another factor because the minimum values for both RMS and ARV were much greater in the younger subject (16 yo.) versus the two older subjects (49 & 46 yo.) . As we age, less electricity is produced because the biological processes within the muscle become less effective and efficient. One point of further research to look into would be to see how height and weight affect the production of electrical signals by our muscles.

One thing I would've changed in this experiment is the amount of weight the participant's were holding. It would've been interesting to see if holding a heavier or lighter weight made a difference in the electrical activity of the muscle.

One limitation this experiment had is that every part of this experiment was wired. This limits the range of motion of participant's and it also makes the device that is used to capture the EMG signal less applicable in real life. If I could have, I would have used a wireless myo sensor to capture the EMG instead of the wired myoware sensor that had to be connected to the arduino uno which was then connected to a laptop.

A topic I would further research is the other ways EMG can be measured/displayed. This experiment used RMS and ARV, but what other ways are there to measure EMG signals? This experiment could also be done in different muscles in different parts of the body. It would be interesting to see how the results varied from muscle to muscle.

Conclusion

In conclusion, differences in sex and age played a major role in the difference of the average RMS and ARV values that the EMG sensor recorded. The results of the experiment show that the low cost EMG-sensor reliably measured the electrical activity of the muscle in a way that can be widely applied to sports medicine.

References

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