Relationship between electromyography (EMG) as an indicator of muscle fatigue and archers' accuracy

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ABSTRACT:

This study investigates the connection between muscle fatigue, measured by electromyography (EMG), and shooting accuracy in archers. Eight muscles of a National Egyptian archer were measured using EMG during two shooting rounds. Muscle activity and shooting scores were compared between rounds to assess fatigue and its impact on accuracy. Results of the study showed muscles decreased activity in the second round, indicating fatigue, Biceps, and extensor digitorum muscles showed increased activity in the second round, but negatively impacted accuracy, The decrease in score may not be solely due to EMG changes, The Egyptian national team, known for high-level performance, maintained accuracy, suggesting potential reliance on different muscle groups to resist fatigue. These Monitor and manage muscle fatigue, focus on proper technique, not overusing fewer effective muscles, explore alternative muscle groups for fatigue resistance, consider a holistic approach to optimize performance, including biomechanics and mental focus. This study supports a link between muscle fatigue and archery accuracy. Monitoring fatigue, choosing appropriate muscle groups, and exploring alternative techniques are crucial for archers seeking to improve performance under fatigue conditions. Further research is needed to understand how high-level archers maintain accuracy despite fatigue.

INTRODUCTION:

Previous studies have mentioned the electromyographic activity of muscles and the contribution of certain muscles to the skill performance of archery, as well as the impact of various electromyographic variables on performance, force balance, and shooting accuracy. These studies have been utilized in numerous scientific and applied research, especially with national teams in Egypt and Saudi Arabia, ranging from youth teams to elite levels. In this study, the researchers present the relationship between electromyographic activity as an indicator of muscle fatigue and the accuracy of shooting for high-level archers.

Muscle fatigue is a complex physiological phenomenon that occurs when muscle tissue becomes less capable of generating force or maintaining the desired level of performance during repeated or continuous activity. It is a common experience for athletes and individuals engaged in demanding physical tasks. The impact of muscle fatigue on sports performance has been extensively

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studied in various fields, including archery.

Archery is a sport that requires a high level of accuracy, involving the use of a bow and arrow to hit a specific target. Consistent accuracy in archery is influenced by several factors, such as equipment, technique, skill, focus, and physical fitness. Among these factors, muscle fatigue can significantly affect the archer's ability to maintain proper shooting form and execute shots accurately.

When archers perform repetitive shooting motions, the muscles involved in drawing the bowstring and stabilizing the body are subjected to continuous stress and tension. Over time, this can lead to muscle fatigue, which manifests as a decrease in muscle strength, coordination, and overall shooting performance. Muscles responsible for maintaining proper posture and stability, such as the back muscles, shoulder muscles, and core muscles, play a crucial role in arrow accuracy.

Archers may experience a decline in their ability to hold the bow steadily, resulting in variations in arrow release and trajectory. Additionally, fatigue-related changes in muscle activation patterns and neuromuscular control can also affect the consistency and timing of archers' movements, leading to deviations in shot execution and a reduction in accuracy.

Fatigue is a temporary condition resulting in a sense of tiredness and accompanied by difficulty in performance. (6)

It arises from a decrease in energy production in response to muscle contraction and can originate from central and peripheral fatigue. (4)

The mechanism of muscle contraction is responsible for directing the production of force in skeletal muscles. (7)

Central neurotransmitters play an important role during performance and also in fatigue, as central fatigue arises through changes occurring in the concentrations of these neurotransmitters, affecting neuromuscular communication. (8, 15)

The central nervous system, through a central neurotransmitter, provides different excitatory and inhibitory inputs to motor neurons in the spinal cord, thereby activating motor units (MUs) to produce force at frequencies of 5-8 Hz during short voluntary contractions, with average motor unit firing rates of 50-60 Hz. (3)

Motor unit recruitment or derecruitment is organized based on motor neuron cell size, primarily controlling the amount of muscle tissue activated. (5,16)

Understanding the impact of muscle fatigue on accuracy in sports such as archery can help improve training and design physical preparation programs and individual tactics. Additionally, paying attention to proper nutrition and adequate rest can play a crucial role in reducing muscle fatigue and enhancing shooting accuracy.

To further clarify, it is possible to divide the characteristics of fatigue in non-aerobic and aerobic energy production systems in archery according to the average performance time as follows:

-Fatigue resulting from work for 15-20 seconds:

During short-duration performances in archery, lasting no more than 15-20 seconds, energy production relies on non-aerobic processes to produce ATP (adenosine triphosphate) through creatine phosphate (CP) without the involvement of oxygen. The primary cause of fatigue in this case is attributed to neural processes in the central nervous system. Motor neural centers are maximally activated, creating a continuous flow of neural signals, particularly directed towards fast-twitch muscle fibers. This leads to rapid fatigue occurrence primarily through the central nervous system. Additionally, the consumption of phosphagen sources, especially phosphocreatine (PC), responsible for replenishing the energy-rich compound ATP, contributes to fatigue.

-Fatigue resulting from work for 30-80 minutes:

The duration of archery competitions typically approaches this timeframe. Muscle work in this case is associated with oxygen consumption and relies on muscle glycogen as a source for ATP replenishment and energy production, as well as blood glucose. Therefore, the causes of fatigue in this scenario are related to the consumption of glycogen stores in the muscles and liver.

The researchers observed differences in recorded scores among high-level archers during the 2023 Riyadh Arab Championship between the first and second shooting rounds, as shown in the following table:

The 13 Riyadh Arab Championship Results Table

No	RANK	CONTRY	70m-1st R	70m-2nd R	Differences	Sample count
1	28	ALG	283	289		
2	22	ALG	302	284	-18	1
3	8	ALG	314	314		
4	2	ALG	323	314	-9	2
5	39	BRN	239	263		
6	30	BRN	268	301		
7	24	BRN	292	291	-1	3
8	7	**EGY**	307	321		
9	5	**EGY**	314	320		
10	1	**EGY**	321	319	-2	4
11	12	**EGY**	306	319		
12	17	IRQ	289	319		

The 13 Riyadh Arab Championship Results Table

No	RANK	CONTRY	70m-1st R	70m-2nd R	Differences	Sample count
13	26	IRQ	290	284	-6	5
14	25	IRQ	293	289	-4	6
15	27	IRQ	294	279	-15	7
16	38	JOR	264	259	-5	8
17	4	KSA	310	325		
18	3	KSA	317	319		
19	14	KSA	320	303	-17	9
20	6	KSA	323	310	-13	10
21	34	KUW	263	274		
22	36	KUW	270	261	-9	11
23	13	KUW	305	318		
24	9	KUW	316	312	-4	12
25	33	MAR	266	278		
26	35	MAR	266	266		
27	29	MAR	279	291		
28	31	MAR	279	280		
29	21	QAT	295	301		
30	16	QAT	309	309		
31	10	QAT	319	308	-11	13
32	18	SUD	294	305		
33	23	SUD	299	286	-13	14
34	11	SUD	318	308	-10	15
35	40	SYR	236	258		
36	32	SYR	263	296		
37	19	TUN	304	294	-10	16
38	37	UAE	268	258	-10	17
39	20	UAE	303	293	-10	18
40	15	UAE	314	306	-8	19
41	42	YEM	218	204	-14	20
42	41	YEM	243	230	-13	21

The previous table demonstrates that:

- 50% of male archers participating in the 13th Arab Championship in Riyadh 2023 experienced a decrease in their recorded scores in the second shooting group compared to the first group.
- The decrease ranged from one (1) point to (18) points.
- The Egyptian national team (EGY) maintained a good performance, with most archers improving their scores except for one shooter.
- The decrease in scores was evident among both the highest-ranked and lowest-ranked participants.

This prompted the researchers to investigate the correlation or relationship between electromyographic activity as an indicator of muscle fatigue and the accuracy of shooting for archers.

OBJECTIVE:

This study aims to identify the relationship between electromyographic muscle activity as an indicator of muscle fatigue in a group of muscles involved in archery shooting and the accuracy of shooting for archers.

HYPOTHESES:

1- Is there a relationship between electromyographic muscle activity, which serves as an indicator of muscle fatigue, and the accuracy of shooting among archers?

2- Which group of muscles experiences the most fatigue and affect score?

TERMINOLOGY:

1. **EMG** stands for **Electromyography** and is defined by Carbovetich (1971) as the recording of electrical changes occurring in muscles during muscle contraction.
2. **Muscle fatigue** is a temporary decrease in muscle performance.
3. Muscle fatigue indicator: It is a measure or criterion used to estimate the level of muscle fatigue and assess the impact of exercises on muscles.
4. **Accuracy** refers to the ability of archers to hit the target's bullseye.
5. **Hz** (**hertz**) unit in electromyography (EMG) refers to the frequency of the motor unit action potentials detected by EMG electrodes.

Studies that relied on measuring electromyographic muscle activity in the field of archery include:

-study by Zul-Amer Hamdan, ZulKefili Ahmed, and Nasr Al-Hadi Juhairi in 2022 titled "Investigation of muscle fatigue of the archer’s during endurance shooting." focused on muscle fatigue in archers during shooting exercises. They monitored the fatigue in specific muscles involved in shooting and recorded surface electromyographic signals during the exercises. The results showed that certain muscles experienced fatigue towards the end of each shooting round. However, there was no significant correlation between muscle fatigue and the archer's performance. The study provides valuable insights for archers and coaches to identify muscles used in shooting and take precautionary measures to manage fatigue. (17)

-The study by Mohamed Hassan Mostafa Abdelgawad 2021 titled "The

Relationship between Electromyographic Muscle Activity Variables and Archers' Balance of Forces" aimed to understand the relationship between muscle activity and the balance of forces in archers' bow and arrow arms. The research examined four muscles in an Olympic archer and measured drawing forces and muscle activity. The study found that there was an inverse relationship between the maximum drawing force of the right arm and muscle activation in the upper trapezius. Additionally, there was a direct relationship between the lifting force of the left bow arm and muscle activation in the middle deltoid. The study also noted that the bow-holding arm exhibited higher muscle activity than the drawing arm and that the muscles on the right side did not work in a balanced manner compared to the left side. These findings have implications for training and rehabilitation programs in archery, highlighting the need to address muscle imbalances and optimize performance. (12)

-The study by Mohamed Hassan Mostafa Abdelgawad 2021 Titled : " INFLUENCE OF EMG ON ARCHER'S AIMIG ACCURACY "aimed to investigate the relationship between muscular electrical activity and shooting accuracy in archers. The research involved measuring the electrical activity of four muscles (right and left rectus abdominis, left triceps brachii with three heads, and right triceps brachii with two heads) in members of the Egyptian national archery team. The findings revealed an inverse relationship between muscular electrical activity and accuracy, with lower electrical activity associated with higher accuracy. The rectus abdominis muscles exhibited higher electrical activity compared to the triceps brachii muscles. The left rectus abdominis muscle had the highest electrical activity and was identified as crucial for skilled archery performance. The study recommended coordinated training methods for efficient muscle contractions and suggested further research on other muscle groups, additional variables related to electrical activity, the effect of arrow release velocity on accuracy, and the influence of muscle fatigue indicators on shooting accuracy. Overall, the study provides valuable insights into the impact of muscular electrical activity on archers' accuracy and highlights areas for further investigation and training approaches.(11)

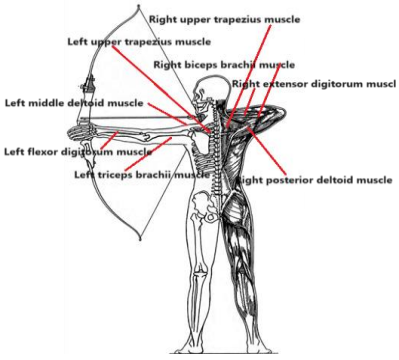
-The study by Mohamed Hassan Mostafa Abdelgawad 2018 Titled: "The Electromyographic Activity of Wrist Extensors and Surface Finger Muscles during Archery and Elbow Bruising" aimed to investigate the electromyographic activity of wrist extensors and surface finger muscles in the hand holding the bow during archery among professionals and beginners. Additionally, the study compared the electromyographic activity of wrist extensors and surface finger muscles in the hand holding the bow between professionals and beginners. The study also aimed to utilize the electromyographic information of the selected groups to prevent elbow bruising in novice archers by guiding trainers on proper

wrist and finger positioning. The results indicated the presence of contractions in wrist extensors and surface finger muscles that drew the attention of professionals in the field of training and rehabilitation for archers. These contractions had an impact on the angle of grip, the distance between the forearm and elbow, and the trajectory of arrow release, ultimately affecting shooting accuracy. (10)

-The study by Mohamed Hassan Mostafa Abdelgawad 2016 Titled: "Functional Study of Muscular Work as the Basis for Archery Injury Prevention Exercises". aimed to investigate the electromyographic activity of specific muscles involved in archery performance. The goal was to develop an injury prevention program based on these findings. The study included two international archers, and a total of 24 arrows were measured at a distance of 30 meters. The targeted muscles were the right and left rectus abdominis, triceps brachii with two heads, triceps brachii with three heads, posterior deltoid, middle deltoid, finger flexors, and wrist extensors. The study aimed to gather electromyographic data on these muscles during archery performance to inform the development of an injury prevention program. One significant finding was that the middle deltoid muscle in the bow hand exhibited the highest performance among the muscles studied. The researcher recommended giving special attention to this muscle in injury prevention programs. Overall, the study provides valuable insights into the electromyographic activity of muscles in archery and highlights the importance of addressing specific muscles in injury prevention efforts.(9)

- The study by Deniz Simsek and Hayri Ertan 2014 titled "Different Release Techniques in Elite Archers: A Comparative Study." aimed to compare the finger hook release strategy in elite archers and its impact on technical performance. The study analyzed the two-finger and three-finger draw techniques and measured electromyographic activity in the drawing arm muscles. The results showed that both techniques resulted in similar muscle contractions before the bowstring movement, but the three-finger draw technique effectively reduced lateral bowstring oscillation.(1)

-The study by Edin Suwarganda 2012 titled "The Impact of Muscular Activity on Performance in Archery." The research examined specific muscles, including the triceps brachii with two heads, triceps brachii with three heads, left deltoid, and right infraspinatus. The findings highlighted



1. Research Muscle Subjects Figure

that different muscles or groups of muscles contributed to speed and outcome variation among archers. For archers with low arrow speed, the level

of muscle activity determined the outcome, while for those with higher speed, the variation in muscle activity played a significant role. The study emphasized the individualized nature of muscular activity and its impact on archery outcomes. (2)

METHODS:

The researchers used the descriptive research method by presenting the results of the electrical activity analysis using the surface measurements of electrodes for EMG device.

SUBJECTS:

The study focused on eight muscles of a national Egyptian archer.

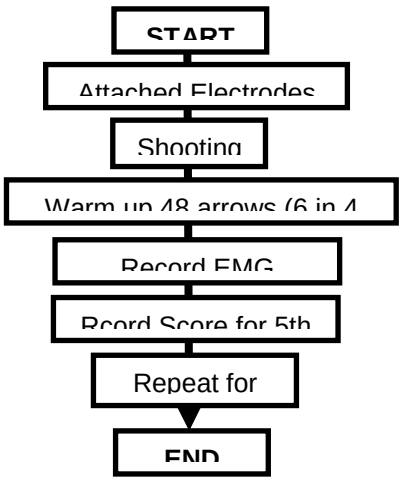
The muscles are:

1. Right upper trapezius muscle (RT TRAPS M)
2. Left upper trapezius muscle (LT TRAPS M)
3. Right biceps brachii muscle (RT BI M)
4. Left triceps brachii muscle (LT TRI M)
5. Right posterior deltoid muscle (RT P DELTS M)
6. Left middle deltoid muscle (LT M DELTS M)
7. Right extensor digitorum muscle (RT E D M)
8. Left flexor digitorum muscle (LT F DM)
9. **Measurement Execution Steps:**

- Shooting was performed at a temperature of 34 degrees Celsius and humidity of 53%.
- Electrodes were securely attached to the selected muscle locations of the archer, and the archer wore their clothing.
- The archer shot a complete round of 36 arrows in 6 ends, with 6 arrows in each end. This was done for warm-up, adjustment of the measurement ruler, and reaching a level close to tournament shooting.
- Measurement started with the beginning of the fifth round, by turning on the device at the start whistle and continuing until the end of the sixth arrow of the round. The results of the total six arrows were recorded.
- This process was repeated in the sixth round.
- 30 meters was chosen with an 80 cm square target face.
- The MEGA WIN E 6000 electromyographic analysis device was used.

The following figure illustrates the map of the execution steps:

RESULTS The researchers relied on the results of the statistical coefficients of the muscle electrical activity analysis device, which the device produced based on the variables that were identified and the graphical forms of the outputs.



2. Flow chart of experiment conducted. Figure

Researchers will present results according to study's question as following:

1-Is there a relationship between electromyographic muscle activity, which serves as an indicator of muscle fatigue, and the accuracy of shooting among archers?

The following table shows the results of the two attempts on the muscles of the study sample of the selected international archer

Table (2)

The results of the two attempts on the subject muscles and archer accuracy

	channels/ muscles	1 rt traps	2 lt traps	3 rt delts posterioir	4 lt delts medial	5 lt triceps	6 rt biceps	7 rt extensors of wrist	8 lt flexor degitorum superficialis	score
Archer Performance results	1st Round MF(Hz)	39	41	42	39	34	20	93	35	56
	2nd Round MF(Hz)	33	31	37	16	32	37	80	52	54

The table shows the results of electrical activity readings at the average frequency level in Hz for the muscles of the study sample, and archer accuracy.

The following figure (3) also shows the difference between the two attempts:

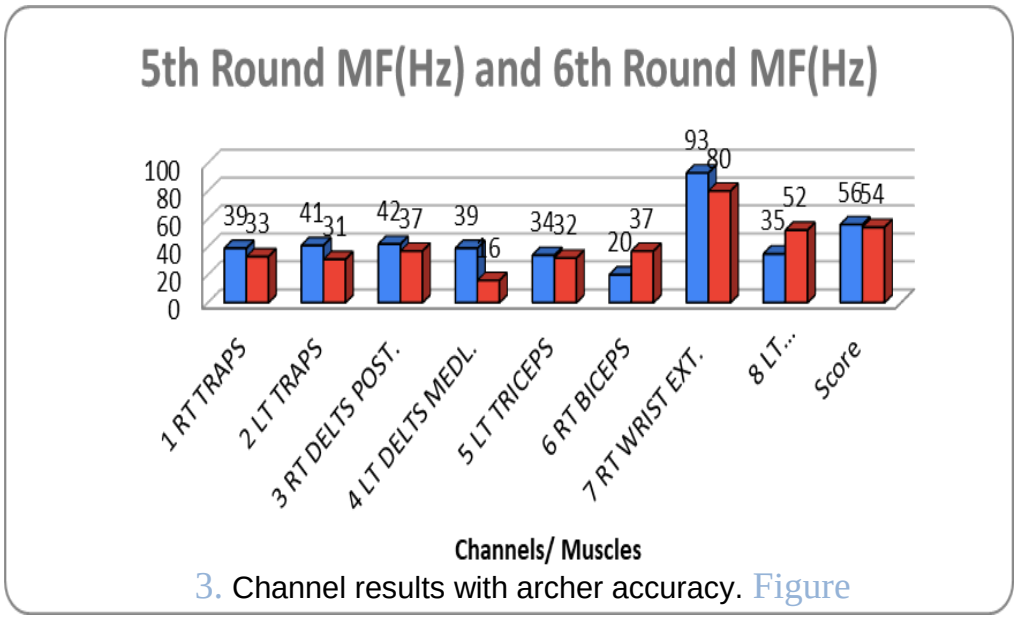


Figure 3. Channel results with archer accuracy.

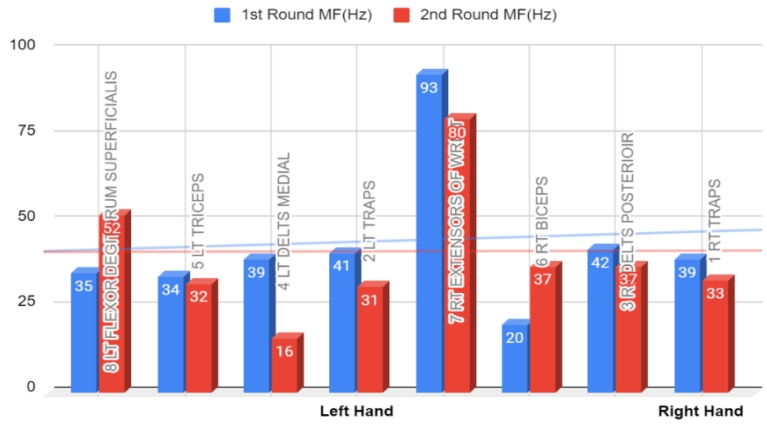
2-Which group of muscles experiences the most fatigue and affect score?

Table (3)

The difference between Right and left hand

Hands	Channels/ Muscles	1st Round MF(Hz)	2nd Round MF(Hz)
Right Hand	1- rt traps	39	33
	3-rt delts posterioir	42	37
	6- rt biceps	20	37
	7- rt extensors of wrist	93	80
Left Hand	2- lt traps	41	31
	4- lt delts medial	39	16
	5- lt triceps	34	32
	8- lt flexor degitorum superficialis	35	52

following figure (4) also shows the difference between Right and Left hand:



4. The difference between Right and left hand. Figure

DISCUSSION

-From Table (2) and Figure (3), it is evident that the average electromyographic frequency of the selected muscles in channels 1, 2, 3, 4, 5, 7 decreases relatively between the fifth and sixth ends, indicating the onset of muscle fatigue.

-However, the results show that the average electromyographic frequency for channels 6 and 8 of the biceps brachii and extensor digitorum muscles displayed higher activity in the sixth end compared to the fifth end. This suggests that these muscles may have started to contribute to energy production for performance. However,

archers should not rely on these muscles for their technical performance due to their negative impact on achieved scores.

-The difference in scores between the sixth and fifth ends coincided with the relative decrease in the average electromyographic frequency of the mentioned channels. However, the slight decrease in muscle electromyographic frequency may not be the sole cause of the score decrease between the sixth and fifth ends.

-During the Arab Championship results, it became apparent that the Egyptian team achieved the best results between the first and second attempts. This indicates that high-level archers may rely on a different muscle group to resist fatigue, maintain performance stability, and prevent a decline in achieved scores.

-From Table (2) and Figure (3) The results show that both arms, or the right and left sides, were affected by muscle fatigue together, and this appeared in the results of the three channels No. 1, 3, and 7 for the right side, as well as the results of channels 2, 4, and 5 for the left side.

Recommendations:

Based on the presented results, the following recommendations can be made:

1. Monitoring and managing muscle fatigue: Since the average electromyographic frequency of the selected muscles decreased between the fifth and sixth ends, indicating the onset of muscle fatigue, it is crucial for archers to monitor their muscle activity throughout the competition. Coaches and athletes should implement strategies to manage and minimize muscle fatigue, such as incorporating adequate rest periods and optimizing training programs to improve endurance.

2. Focus on technical performance: Although channels 6 and 8 showed higher muscle activity in the biceps brachii and extensor digitorum muscles in the sixth end compared to the fifth end, relying on these muscles for technical performance had a negative impact on achieved scores. Therefore, archers should prioritize using the appropriate muscle groups and techniques that have been proven to result in better accuracy and shooting performance.

3. Explore alternative muscle groups: The observation that the Egyptian team achieved the best results between the first and second attempts suggests that high-level archers may rely on a different muscle group to resist fatigue, maintain performance stability, and prevent a decline in achieved scores. Further research and training should be conducted to identify and develop effective techniques that utilize alternative

muscle groups to enhance performance during prolonged competitions.

4. Holistic approach: It is important to consider other factors that can affect archery performance, such as biomechanics, mental focus, and training techniques. A comprehensive approach that addresses these aspects in addition to muscle activity can contribute to improved overall performance. Coaches and athletes should work together to develop training programs that encompass all relevant factors and optimize performance in a holistic manner.

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