

International Journal of Physiology, Sports and Physical Education



ISSN Print: 2664-7710
ISSN Online: 2664-7729
Impact Factor: RJIF 8.28
IJPSPE 2025; 7(2): 293-293
www.physicaleducationjournal.net
Received: 16-07-2025
Accepted: 18-08-2025

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Quantitative indicators of the contribution ratios of electromyographic activity in the working muscles during the actual performance of the shot put event in athletics

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DOI: <https://www.doi.org/10.33545/26647710.2025.v7.i2d.168>

Abstract

The present study aimed to investigate the levels of maximal strength and muscular electrical activity, and to determine the quantitative indicators of the contribution ratios of electromyographic (EMG) activity of the working muscles during the actual performance of the shot put event in athletics.

The results revealed a strong correlation between performance achievement, maximal strength, and the EMG activity of the working muscles during the execution of the shot put, particularly in the trunk muscles, followed by the right thigh, left thigh, right arm, and finally the left arm. It was found that a higher level of electromyographic activation (EMG) is associated with achieving a greater throwing distance.

The main conclusions indicated that explosive power in the shot put event depends on the efficiency of neuromuscular activation of the major muscle groups. Moreover, EMG technology can serve as a predictive indicator of performance level among throwers.

The most important recommendations emphasize the necessity of identifying the value of EMG activity of the working muscles during performance and determining their relative contribution to the overall achievement. Training programs should be designed and regulated according to the obtained findings to ensure the correct direction of the training process.

Keywords: Contribution ratios, electromyography (EMG), shot put, athletics

Introduction

Athletics competitions are characterized by creativity and excellence in the performance of their various events, which necessitates continuous development in training programs and the adoption of modern training technologies (Rahi & Sagheer, 2020) ^[7]. Among the throwing events, the shot put is considered one of the most significant disciplines in athletics, as it largely depends on factors such as muscular strength, explosive power, and neuromuscular coordination.

It is well known among many track and field athletes, particularly throwers, that different types of strength exercises are performed prior to their attempts in order to enhance performance. This practice is based on the post-activation potentiation (PAP) phenomenon, which improves performance in strength-demanding activities through specific pre-activation exercises (Kontou *et al.*, 2018) ^[3].

The shot put performance involves a complex motor sequence beginning with the preparation phase, followed by the power position, and concluding with the release phase, during which the final discharge of energy occurs. Shot putters utilize their strong quadriceps, hamstrings, and upper limb muscles to push from the rear of the circle, generating the initial impulse required to propel the heavy shot forward (Thaqi *et al.*, 2020) ^[9].

The use of advanced sports technologies has greatly contributed to analyzing and understanding motor performance, thereby overcoming many challenges faced in developing athletic performance, especially in athletics events (Lami *et al.*, 2023) ^[4]. The advancement of devices such as Electromyography (EMG) has enabled the study of neuromuscular activity during actual performance. Coaches have linked this biological factor to the concept of specific strength, defined as the strength produced by a specific muscle group during actual

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athletic performance (Terzis *et al.*, 2007) ^[8]. In shot put, the athlete's muscles are responsible for generating the impulses required to move the body and project the shot into the air (Howard *et al.*, 2017) ^[2].

This study provides an EMG-based analysis of the muscular activity of shot putters, offering an opportunity to examine the efficiency, timing, and intensity of activation of the working muscles. Such an analysis contributes to improving performance by assessing the efficiency of muscle activation during movement through an experimental approach using a portable neuromuscular stimulator that delivers square-wave impulses to activate the muscles during actual performance, thereby identifying the potential to enhance the quantitative indicators of motion (Podlivaev *et al.*, 2014) ^[6].

From this perspective, the significance of the current study arises from its aim to examine the contribution ratios of electromyographic activity of the working muscles during the shot put performance, in order to understand the mechanisms influencing achievement and to guide training in a scientifically grounded manner.

Problem Statement

Despite numerous studies addressing the physical and technical aspects of the shot put event, there remains a clear gap in research that connects quantitative indicators of muscular performance with electrical muscle activity (EMG) during actual execution, particularly in the explosive phase of the movement. Therefore, this study seeks to answer the following central question:

Can EMG measurements be relied upon as an indicator of performance or as a tool for guiding the training process?

Research Objectives

The study aims to

1. Analyze the level of maximal strength of the working muscles in shot putters.
2. Analyze the level of electromyographic (EMG) activity of the working muscles in shot putters.
3. Determine the quantitative indicators of the contribution ratios of EMG activity in the working muscles during the actual performance of the shot put.

Research Questions

1. What is the level of maximal strength of the working muscles in shot putters?
2. What is the level of electromyographic activity (EMG) of the working muscles in shot putters?
3. What are the quantitative values of the contribution ratios of EMG activity in the working muscles during the actual performance?

Research Methodology and Field Procedures

Research Design: The researcher employed the descriptive method using the correlational approach, as it was deemed suitable for the nature of the research problem.

Population and Sample

The research population consisted of Iraqi club athletes competing in the shot put event under the age of 17 years. The study sample included 10 male throwers who voluntarily participated in the research.

Instruments and Equipment Used

- Tests of maximal strength for the target muscles involved in the study.
- Electromyography (EMG) device for measuring muscular electrical activity.

Field Procedures

- Electrodes were placed on the selected muscles according to standardized biological and anatomical guidelines.
- EMG measurements were recorded during three actual shot put trials for each participant.
- Maximal strength was assessed using the appropriate strength tests.
- The collected data were processed and statistically analyzed using the Statistical Package for the Social Sciences (SPSS) software.

Tests Utilized in the Study

- **Maximal Strength Test for Arm Flexor and Extensor Muscles**
- **Purpose:** To measure the maximal strength of the arm muscles.
- **Instrument:** A dynamometer equipped with a calibrated gauge and specialized steel cables.

Leg Muscle Strength Test

- **Purpose:** To assess the strength of the anterior and posterior thigh muscles.
- **Instrument:** A "Kiel Larry" device fitted with a dynamometer and special steel cables.

Trunk Muscle Strength Test

- **Purpose:** To evaluate the strength of the trunk muscles.
- **Instrument:** A dynamometer designed specifically for measuring trunk muscle strength.

Performance (Achievement) Test

- **Purpose:** To measure the throwing distance achieved in the shot put.
- **Instrument:** A standard athletics shot put field in accordance with official regulations.

Presentation, Analysis, and Discussion of Results

After conducting the tests, collecting the data, and processing them using the SPSS statistical package, the researcher obtained the results presented in the following tables.

Table 1: Descriptive Statistics of the Study Variables

Target Muscles	Electromyographic Activity (Mean ±SD)	Skewness	Maximal Strength (Mean ±SD)	Skewness
Right Arm (Biceps)	391±28.56	0.767	33.66±1.95	-0.522
Right Arm (Triceps)	287±19.23	0.454	23.60±1.72	0.143
Left Arm (Biceps)	298±16.10	0.445	33.33±1.54	-0.159
Left Arm (Triceps)	276±12.22	0.193	23.13±1.46	-0.744
Right Thigh (Anterior)	1009±16.01	0.853	62.47±2.10	0.187

Right Thigh (Posterior)	887±22.22	0.323	33.53±1.92	0.580
Left Thigh (Anterior)	709±22.09	0.667	62.13±2.26	0.578
Left Thigh (Posterior)	623±18.09	0.322	33.13±1.77	0.037
Abdominal Muscles	809±20.09	0.509	53.47±2.53	0.274
Dorsal Muscles	798±13.99	0.127	33.73±3.35	0.531

Observation: The mean values for the arm muscles (right and left), thigh muscles (right and left), and trunk muscles were higher than their respective standard deviations. The

skewness coefficients for all study variables ranged between ± 1 , indicating a normal distribution of scores among the sample participants.

Table 2: Correlations between Performance Achievement, Muscle Strength, and Electromyographic Activity

Variables	Correlation with Achievement	Contribution Ratio	F-value	Significance (p-value)	Significance Level	Result
Left Arm (Triceps/Biceps)	0.522 / 0.272	0.272	5.515	0.027	Significant	✓
Right Arm (Triceps/Biceps)	0.635 / 0.132	0.404	9.720	0.004	Significant	✓
Right Thigh Muscles	0.715 / 0.108	0.607	5.597	0.027	Significant	✓
Left Thigh Muscles	0.607 / 0.096	0.511	5.289	0.030	Significant	✓
Trunk Muscles	0.834 / 0.089	0.696	6.470	0.019	Significant	✓

The results indicate strong and significant correlations between performance achievement and both maximal muscle strength and electromyographic activity, particularly for the trunk muscles, followed by the right thigh, left thigh,

and the arm muscles. These findings confirm that higher levels of EMG activation correspond to greater throwing distances in the shot put.

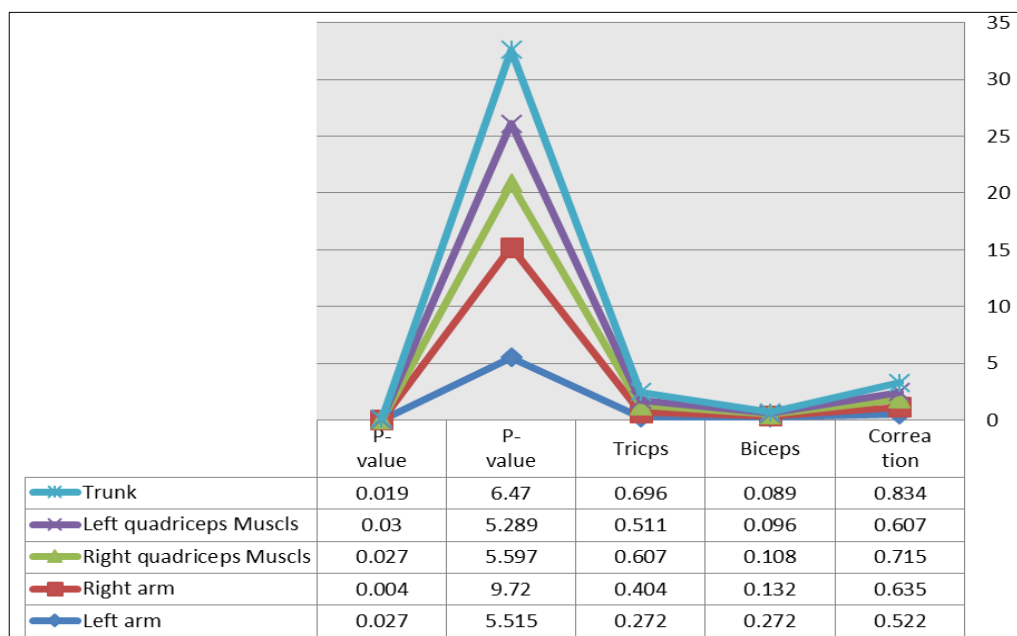


Fig 1: Shows the correlations and contribution ratios of the research variables.

Analytical Interpretation of Results

The analytical representation of the results presented above illustrates the correlational relationships between performance achievement, muscular strength, and electromyographic (EMG) activity. The correlation coefficients with performance ranged between 0.522 and 0.834, indicating relatively strong associations.

The contribution ratios (cumulative and partial) reflect the extent to which each variable explains variations in performance achievement. All contribution values were found to be statistically significant ($\text{Sig} < 0.05$). The highest correlation with achievement was observed for the trunk muscles ($r = 0.834$), followed by the right thigh muscles ($r = 0.779$), whereas the lowest correlation was found for the left arm muscles ($r = 0.522$).

Both cumulative and partial contributions indicate that the

trunk and thigh muscles play a greater role in performance compared to the arm muscles.

Discussion of Results

The findings presented in the results tables indicate significant correlations between maximal muscular strength (as represented by EMG activity) and performance achievement. All studied variables including the left and right arms, right and left thighs, and trunk muscles contributed significantly to explaining the variance in performance levels.

The researcher attributes the observed differences in strength symmetry and EMG activity among muscles during specialized performance to variations in the balance between agonist and antagonist muscle groups. From a biomechanical perspective, the force generated by agonist

muscles during movement was greater than that of the antagonists.

Regarding electrical activity, Table (1) confirms that the working muscles exhibited higher EMG activation, which strongly indicates that the level of EMG reflects the degree of motor unit recruitment. This supports the notion that balanced muscular development through strength training positively affects maximal force production (Farina *et al.*, 2014) ^[1].

Conversely, if the EMG activity of the antagonist muscles were abnormally high, it would result in increased neuromuscular inhibition, which was not observed in this study's sample. Had such inhibition occurred, it would have appeared during the main execution phase, leading to a loss of movement fluidity, greater energy expenditure, and possibly injury due to excessive resistance.

In contrast, if the EMG activity of the antagonist muscles were lower than that of the agonists, the working muscles would move more freely, but end-range control would decrease. This could allow the muscle to reach its full natural length, confirming the mechanical principle that muscle work = muscle force × distance of contraction. Therefore, an ideal balance between agonist and antagonist muscles ensures smooth and progressive braking, providing joint protection and greater movement precision (McArdle *et al.*, 2010) ^[5].

Other factors also influence performance achievement, in addition to peak EMG activity. These include the amplitude of electrical activation, anthropometric characteristics, muscle fiber composition, and even psychological factors such as adrenaline secretion, all of which may affect neuromuscular performance capacity.

Conclusions

1. Maximal strength in the shot put event depends on the efficiency of neuromuscular activation of both the working and assisting muscles, as well as on the inhibition of antagonist muscles during the main execution phase.
2. Electromyography (EMG) technology can be used as a predictive indicator of performance level among shot put athletes.

Recommendations

1. It is essential to identify and quantify the EMG activity of the working muscles during performance and determine their contribution ratios to overall achievement.
2. Training programs should be standardized and designed according to the findings obtained to ensure an optimal and scientifically guided training process.

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