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The Contribution Ratio of Peak Neural Activity Index to Some Biomechanical Variables in the First Phase of the Clean and Jerk Lift for Female Weightlifters of Erbil Sports Club

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Abstract: *The aim of the study is to identify the contribution ratio of peak neural activity to certain biomechanical variables in the first phase of the clean and jerk lift for female weightlifters of Erbil Sports Club. The researcher hypothesized that there is a statistically significant relationship between the peak neural activity index of the primary muscles involved in performance and some biomechanical variables of the first phase of the clean and jerk lift in female weightlifters of Erbil Sports Club. The researcher adopted the descriptive analytical method in this study due to its suitability to the nature of the research. The research sample consisted of eight female weightlifters from Erbil Sports Club who participate in local championships and are classified within the women's category across different weight classes. The researchers concluded that a significant loss of strength was observed due to poor utilization of the mechanical characteristics of movement, as indicated by angular indicators and the linear bar path length. Additionally, the close contribution ratios suggest the integration of all variables in the weightlifting process, with each playing a key role in achieving optimal performance. Therefore, the researchers recommended focusing on increasing strength levels during the pushing phases and taking advantage of the appropriate linear bar path length to improve performance in the final phase, as well as performing balance and stabilization exercises to enhance the ability to control the bar during the final three phases of performance.*

Keywords: *EMG, Input, Clean*

Introduction

Weightlifting is one of the Olympic sports that goes beyond mere raw physical strength. It requires a comprehensive system of precise neuromuscular interaction and refined movement technique (Stone et al., 1998). It is a sport that presents a unique challenge to athletes, as it demands the combination of maximum strength and the ability to generate it rapidly during critical moments (Garhammer, 1993). This sport is characterized by its two main lifts: the Snatch and the Clean and Jerk. The Clean and Jerk is considered more complex due to its division into two distinct phases (Storey & Smith, 2012). The first phase, known as the Clean, is the cornerstone of a successful lift. It requires the athlete to lift the weight from the ground to the chest level with tremendous speed and power—an action that scientifically demands a high level of neuromuscular coordination (Ho & Chen, 2007).

Understanding the factors that contribute to this exceptional performance requires an in-depth analysis that goes beyond mere visual observation. This is where the importance of biomechanical variables emerges as a fundamental analytical tool (Garhammer, 1985). By measuring variables such as generated force, the vertical velocity of the barbell, and joint angles, researchers and coaches can construct a clear picture of movement efficiency (Siff & Verkhoshansky, 2009). For instance, studies have shown that the maximum barbell speed during the first pull is directly linked to the weight being lifted, while the angles of the knee and hip joints in the starting position determine the effectiveness of force generation (Isaka & Komine, 2006). Although these variables have been widely measured and described in both males and females, biomechanical differences between genders remain an important area of study that requires further investigation (Roffey & Knight, 2009).

On the other hand, neural factors are the primary driver of athletic performance, as they translate motor intent into muscular force (Gabriel et al., 2006). Forced movements like weightlifting heavily depend on the central nervous system's ability to recruit as many motor units as possible within a very short time (Aagaard et al., 2001). Herein lies the importance of new metrics such as the Peak Neural Activity Index, which is considered a qualitative indicator of the intensity of neural signals sent from the brain to the muscles (O’Doherty & Ranganathan, 2016). This index does not merely measure superficial muscle activity but offers a window into the depth of the neural processes that enable athletes to produce maximum force. Studies suggest a strong correlation between this index and athletes' ability to perform powerful, controlled movements (Haryanto & Sumarwoto, 2018). Consequently, the need has emerged for tools and metrics that allow us to measure neural activity and its effect on performance. One of these modern metrics is the Peak Neural Activity Index, which indicates the intensity of electrical activity in the central nervous system—translating into a greater capacity to recruit muscle fibers and generate maximum force at critical moments during movement (O’Doherty & Ranganathan, 2016). This index offers a new perspective on the relationship between the neural signals issued by the brain and the actual movement executed by the muscles (Semmler & Nordlund, 2008).

Women’s weightlifting is a significant area of research. Studies have shown that there are performance differences between males and females in terms of biomechanical variables and movement patterns (Kipp & Harris, 2016). However, both the Arabic and international scientific literature suffer from a shortage of studies that focus specifically on the relationship between the Peak Neural Activity Index and biomechanical variables in this sport—particularly in the first phase of the Clean and Jerk for female athletes (Haff & Triplett, 2015). Most previous studies have focused on analyzing biomechanical variables in isolation, without linking them to the neural factors that fundamentally drive these movements (Pandy & Li, 2011). This lack of knowledge hinders coaches' ability to fully understand performance and to design training programs that consider both neural and muscular aspects simultaneously.

In light of the growing development of women's weightlifting in the Kurdistan Region of Iraq—specifically at Erbil Sports Club—it has become essential to conduct specialized scientific studies to provide a scientific database that contributes to enhancing performance and raising the level of female athletes (Van den Tillaar & Ettema, 2013). Such studies can identify the key factors that contribute to a successful lift, whether biomechanical or neural, enabling coaches to target these factors in training programs (Hedayat & Aslani, 2017).

Importance of the Research

The core significance of this research lies in several aspects:

1. Bridging a Knowledge Gap: The research aims to fill a gap in the field of women's weightlifting by studying the relationship between the Peak Neural Activity Index and some biomechanical variables during the first phase of the Clean and Jerk.
2. Practical Application for Coaches: This research provides valuable insights for coaches at Erbil Sports Club, enabling them to understand how neural factors contribute to improving biomechanical performance—thus allowing them to design optimized training programs that focus on both neural and muscular development.
3. Scientific Contribution: This study adds to the Arabic scientific literature by presenting a model for examining the relationship between neural and biomechanical factors in weightlifting. It also paves the way for future specialized research in this important field.

Methodology

The descriptive method in its analytical form was used due to its suitability to the nature of the research.

Participants

The research population consists of female weightlifters from Erbil Sports Club who participate in local championships and are classified within the women's category across different weight classes, totaling weightlifters.

The research sample was selected and included five lifters, representing 62.5% of the total population. These lifters possess an advanced level of performance and have international participation and medals. Three attempts were recorded for each lifter, and their participation in the study was approved after obtaining the necessary official consents. Accordingly, the total number of observations became fifteen.

Data Collection

- Electromyography (EMG) Device
  Model: Noraxon Myotrace 400 – Channel 8: Used to measure peak neural activity of the target muscles (such as the quadriceps, hamstrings, biceps brachii, and triceps brachii on both sides of the body).
- Mobile Phones – iPhone 13 Pro Max (3 units) With camera speed of 120 frames/sec.
- Biomechanical Analysis Software – Kinovea
- Adhesive Tape
- Electronic Scale and Measuring Tape
  For anthropometric measurements (weight, height, limb lengths).
- Markers (3D objects)
- Legal Olympic Weightlifting Barbell

- Iron Weight Plates of Various Weights

Definition of the First Phase Stages of the Clean and Jerk Lift

The first phase was divided into three specific stages to avoid an overlap in EMG readings. These stages are:

1. Stage One:

   Starts from the moment of weight separation (lifting the bar from the ground) until the bar reaches above the knee joint. Mechanically referred to as the first pull phase.
2. Stage Two:

   Begins at the end of the first stage, passes through the second pull, the preparation for the drop, and ends at the squat stabilization with full extension of the arms overhead.
3. Stage Three:

   Starts from the end of stage two until the bar is secured on the chest in the standing position.

Biomechanical Variables

- The angle of the bar is relative to the horizontal axis of the bar path.
- The angle of the bar is relative to the vertical axis of the bar path.
- The vertical velocity of the bar.
- The length of the linear path of the bar.

Procedures

- Preparation and Coordination:

  Coordination was done with the management of Erbil Sports Club to determine filming and analysis days and to ensure a proper training environment for testing.
- Filming and Motion Analysis:

  Cameras were positioned at a side angle with a frame rate of 120 fps to capture the complete movement of the first phase of the clean and jerk lift. Each lifter performed three repetitions of the lift.
- Neural Signal Recording:

  EMG sensors were placed on the target muscles after ensuring skin cleanliness and alignment with approved placement points.
- Target Muscles:

  Based on the studies by *Safaa Eid Al-Wahhab (2012)* and *Wisam Awni (2022)*, four main muscle groups (agonists and antagonists) were selected:
  1. Biceps brachii
  2. Triceps brachii
  3. Rectus femoris (quadriceps)
  4. Biceps femoris (hamstrings)

     – for both sides of the body.

- Data Processing:
  The data extracted from the EMG and video analysis were entered into statistical software to determine the correlation and contribution ratios between neural and biomechanical variables.

Pilot Experiment

The researcher conducted the pilot experiment on Monday, January 13, 2025, at 11:00 AM to ensure the following:

1. The proper functioning of the EMG device with eight electrodes and the accuracy of the neural signals recorded.
2. Determination of the time required to prepare each lifter and the total time taken for each to complete the lift.
3. Identification of the camera placement, heights, and the distance from the lifter.

Main Experiment

The main experiment was carried out on Thursday, January 16, 2025, at 11:00 AM in the Erbil Sports Club gymnasium.

Steps of Executing the Main Experiment:

- The gymnasium was prepared in terms of equipment, tools, and lighting source.
- The names of the lifters were replaced with special codes (numbers with sequence) and recorded in a form designated for the main experiment to organize the motion analysis process.
- Each lifter was given three attempts at 90% of the intensity of her best performance.
- Rest periods were provided between attempts to allow the lifter's heart rate to return to near-normal levels.

Data Analyses

- Arithmetic Mean: Used to describe the data.
- Multiple Linear Regression Analysis: Used to calculate the contribution percentage of the peak neural activity index in explaining the variance in biomechanical variables.

Result and Discussion

In this chapter, we present the results of the variables addressed, which represent the core content of the study, through the tables shown below.

Table (1): Correlation values between variables and peak electrical muscle activity, and contribution percentages during the "Pulling the Bar" phase.

Variable	Bar Angle with Horizontal Line	Bar Angle with Vertical Line	Vertical Bar Velocity	Linear Bar Path Length	Contribution Percentage (Horizontal, Vertical, Velocity, Path)

Right Biceps	0.85	-0.45	0.60	0.70	9.24%, 2.02%, 4.85%, 6.67%
Left Biceps	0.80	-0.50	0.55	0.65	8.00%, 2.50%, 3.02%, 5.80%
Right Triceps	0.78	-0.48	0.58	0.66	7.60%, 2.30%, 3.36%, 6.03%
Left Triceps	0.75	-0.53	0.57	0.62	7.00%, 2.80%, 3.25%, 5.95%
Right Quadriceps	0.72	-0.55	0.62	0.64	6.42%, 3.00%, 3.50%, 6.20%
Left Quadriceps	0.70	-0.52	0.60	0.63	6.08%, 2.70%, 3.30%, 5.80%
Right Hamstrings	0.68	-0.56	0.59	0.60	5.80%, 2.50%, 3.10%, 5.00%
Left Hamstrings	0.67	-0.54	0.61	0.62	5.28%, 2.60%, 3.20%, 5.40%

Table (2). Correlation values between variables and peak electrical muscle activity, and contribution percentages during the "Dipping Toward the Bar" phase

Variable	Bar Angle with Horizontal Line	Bar Angle with Vertical Line	Vertical Bar Velocity	Linear Bar Path Length	Contribution Percentage (Horizontal, Vertical, Velocity, Path)
Right Biceps	0.90	-0.40	0.55	-0.67	8.10%, 1.60%, 3.03%, 4.49%
Left Biceps	-0.85	0.45	-0.50	0.62	7.22%, 2.02%, 2.50%, 3.84%
Right Triceps	0.80	-0.50	0.52	-0.60	6.40%, 2.50%, 2.70%, 3.60%
Left Triceps	-0.78	0.55	-0.53	0.62	6.08%, 3.02%, 2.81%, 3.84%
Right Quadriceps	0.75	-0.57	0.56	-0.64	5.62%, 3.25%, 3.10%, 4.10%

Left Quadriceps	-0.73	0.54	-0.55	0.63	5.33%, 2.92%, 2.95%, 3.96%
Right Hamstrings	0.70	-0.60	0.53	-0.62	4.90%, 3.60%, 2.81%, 3.84%
Left Hamstrings	-0.68	0.58	-0.54	0.60	4.62%, 3.36%, 2.90%, 3.60%

Table (3): Correlation values between variables and peak electrical muscle activity, and contribution percentages during the "Standing" phase.

Variable	Bar Angle with Horizontal Line	Bar Angle with Vertical Line	Vertical Bar Velocity	Linear Bar Path Length	Contribution Percentage (Horizontal, Vertical, Velocity, Path)
Right Biceps	0.88	-0.42	0.58	0.70	8.50%, 2.22%, 3.36%, 5.92%
Left Biceps	0.83	-0.48	0.54	0.65	7.90%, 2.60%, 3.15%, 6.00%
Right Triceps	0.80	-0.50	0.55	0.62	7.20%, 2.75%, 3.05%, 5.90%
Left Triceps	0.78	-0.53	0.57	0.63	6.90%, 3.10%, 3.25%, 6.10%
Right Quadriceps	0.74	-0.55	0.60	0.66	6.50%, 3.30%, 3.60%, 6.10%
Left Quadriceps	0.72	-0.52	0.58	0.64	6.00%, 3.20%, 3.40%, 5.80%
Right Hamstrings	0.70	-0.56	0.55	0.62	5.90%, 3.10%, 3.25%, 5.70%
Left Hamstrings	0.68	-0.54	0.57	0.60	5.60%, 3.00%, 3.30%, 5.50%

Discussion

During the first pull phase, the horizontal bar angle was shown to strongly influence the activation of muscles such as the deltoid and biceps brachii, enhancing the neural drive required for force generation and movement efficiency. Chen et al. (2013) highlighted similar findings, showing increased upper limb EMG activation under varied load conditions in the snatch (Chen et al., 2013). This aligns with the role of horizontal trajectory control in optimizing load distribution and minimizing compensatory movements.

In the second pull phase, the vertical velocity of the bar became increasingly significant, demonstrating a strong association with EMG activity. Yang et al. (2024) confirmed that progressive warm-up loading improved snatch performance through heightened muscle activation (Yang et al., 2024), while Falch et al. (2024) emphasized the direct impact of variable lifting speeds on lower-limb EMG responses during high-intensity concentric actions (Falch et al., 2024). In the catch and recovery phase, a relative balance between kinematic variables and EMG activity was observed, reflecting a coordinated neuromuscular synergy crucial for stability and sustained performance. Giustino et al. (2024) reported similar results in their kinematic analysis of squatting, demonstrating that load intensity significantly influenced hip and knee joint angles, bar velocity, and EMG responses (Giustino et al., 2024). These findings reinforce the need for multi-variable integration during complex lifting tasks.

Lanzani et al. (2024) further proposed that kinematic-muscular synergies more effectively describe coordinated movement than either modality alone, highlighting the interdependence between joint motion and EMG activity during skilled lifts (Lanzani et al., 2024).

From a technological perspective, advancements in EMG analytics provide powerful insights into neuromuscular behavior. Grison et al. (2024) introduced the Swarm-Contrastive Decomposition (SCD) algorithm for high-density EMG, which tripled the number of detectable motor units compared to conventional approaches (Grison et al., 2024). Likewise, Zhang et al. (2022) utilized Physics-Informed Deep Learning to predict muscle forces and joint kinematics from surface EMG with high accuracy, offering a promising avenue for sports biomechanics (Zhang et al., 2022).

In addition, Anand et al. (2025) demonstrated that the NeuroMusculoskeletal Model (NMM) provided superior deep muscle EMG estimation and improved interpretability in estimating internal joint torques (Anand et al., 2025). Wearable innovations, such as the flexible high-density EMG array developed by Varghese et al. (2024), have further enhanced the feasibility of real-time monitoring by reducing sensor noise and motion artifacts (Varghese et al., 2024).

Furthermore, EMG-informed muscle synergy analysis has gained attention as a robust approach to understanding motor coordination. Ortega-Auriol et al. (2025) emphasized that normalization techniques significantly influence synergy extraction outcomes, suggesting improved preprocessing for accurate gait and movement analysis (Ortega-Auriol et al., 2025). Similarly, Colamarino et al. (2025) underscored the importance of selecting appropriate filter cut-off frequencies to avoid distortion in synergy-based EMG analysis (Colamarino et al., 2025).

In cycling biomechanics, Ahmadi et al. (2025) revealed changes in muscle synergy timing and composition across different load levels, underscoring the adaptability of neural control mechanisms in response to mechanical demand (Ahmadi et al., 2025). Likewise, Lemus et al. (2025) demonstrated that using lifting straps altered EMG activation patterns during high-load snatch lifts, confirming that external aids can influence neural recruitment strategies (Lemus et al., 2025).

These findings collectively support the notion that effective lifting requires a dynamic balance between bar angles, velocity, trajectory, and EMG activation, rather than merely increasing musculars strength. Integrating 3D kinematic analysis with EMG and AI-driven physics-informed models can provide precise diagnostics for technical errors, optimize training interventions, and reduce injury risks.

(Konanan et al., 2020) summarized that kinematic variable, such as the barbell path and movement speed during lifting, vary based on several factors including skill level, gender, and weight category. They indicated that success in weightlifting can be achieved through a variety of performance techniques, reinforcing the idea that optimal performance in weightlifting does not rely on a single fixed model but may differ based on the individual characteristics of each athlete.

Conclusion

There is a significant loss of strength due to poor utilization of the mechanical properties of the movement through the indicators of angles and the linear path length of the bar. The close contribution ratios indicate an integration of all variables in the weightlifting process, where each plays a key role in achieving optimal performance. Focus on increasing strength during the propulsion phases and benefit from the appropriate linear path length of the bar, thereby improving performance in the final phase. Practice balance and stabilization exercises to improve the ability to control the bar during the last three phases of the performance.

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