

Biomechanical Analysis of Grip Techniques and Their Influence on Force Production, Muscle Activation, and Joint Mechanics in Armwrestling

Dr. Praveen Kumar Singh Jadon¹, Prakash Singh Jadon²

1. Head of Department, Dept. of Physical Education & Sports, K.A. (P.G.) College, Kasganj, Uttar Pradesh.

2. M.P.Ed. First Year Student, Amar Shaheed Kanchan Singh College, Khaga, India

Received: 19 March 2026

Accepted: 26 May 2026

Published: 20 June 2026

Abstract

Background: Armwrestling is a competitive strength sport in which grip technique plays a decisive role in determining performance outcomes. Despite its growing global popularity, the biomechanical mechanisms underlying different grip strategies remain insufficiently quantified in the scientific literature. **Purpose:** The present study aimed to quantify and compare peak force production, time to peak force, electromyographic (EMG) muscle activation patterns, and joint angles associated with three primary armwrestling grip techniques: Top Roll, Hook, and Press. **Methods:** A within-subject repeated-measures experimental design was employed. Thirty trained male armwrestlers (age: 18–30 years; minimum two years of competitive experience) performed three maximal effort trials under each grip condition in a randomized order following a standardized warm-up protocol. Peak force (N) was recorded using a calibrated force transducer. Muscle activation levels were assessed using surface EMG and expressed as a percentage of maximum voluntary contraction (%MVC) for the biceps brachii, forearm flexors, and anterior deltoid. Joint angles were measured using digital goniometry and video motion analysis. Data were analyzed using repeated-measures ANOVA with Bonferroni post hoc correction, and effect sizes were reported as partial eta-squared (η^2). **Results:** The Hook technique produced the greatest mean peak force (465 ± 40 N), followed by the Press (445 ± 38 N) and Top Roll (420 ± 35 N). Time to peak force was shortest for the Hook technique (760 ± 55 ms). EMG analysis indicated that biceps brachii and forearm flexor activation were highest during Hook execution (88% MVC and 90% MVC, respectively). Significant differences were observed between the Hook technique and the other techniques ($p < 0.05$), while no statistically significant difference was found between Top Roll and Press. **Conclusion:** Under controlled isometric conditions, the Hook technique demonstrated greater force production and faster force development, along with higher neuromuscular activation compared to the other techniques. These findings may assist coaches and athletes in selecting appropriate grip techniques based on individual morphological characteristics, strength profiles, and competitive strategies. The study provides quantitative evidence contributing to the emerging field of armwrestling biomechanics.

Keywords: Armwrestling, Grip Techniques, Biomechanics, Electromyography, Force Production

1. Introduction

Armwrestling occupies a unique intersection of applied biomechanics, strength physiology, and competitive sport. Classified as a contact strength sport, it demands not merely gross muscular power but also highly coordinated neuromuscular recruitment, joint-angle optimization, and technique-specific leverage mechanics. The sport has witnessed a substantial rise in organized competition at both national and international levels, yet the scientific literature addressing its biomechanical underpinnings remains disproportionately sparse compared with disciplines such as wrestling, judo, or Olympic weightlifting.

Three principal grip techniques dominate competitive Armwrestling practice: (1) the Top Roll, characterized by a progressive supination of the opponent's wrist with emphasis on digit and wrist extensor engagement; (2) the Hook, which exploits pronation and elbow flexion to shorten the mechanical lever and concentrate force close to the elbow joint; and (3) the Press, which relies predominantly on shoulder adduction

and internal rotation to generate a vertically directed force vector. These techniques differ substantially in the segment angles, muscle groups activated, and moment arms exploited, yet objective biomechanical comparisons among them are lacking.

The limited existing literature on hand-grip force in combat sports focuses primarily on judo, wrestling, and Brazilian jiu-jitsu, where grip strength is examined as a predictive variable for match outcome. Studies by Marques et al. (2011) and Bonitch-Góngora et al. (2012) established that grip endurance and peak grip force are associated with competitive success in grappling sports; however, neither study addressed technique-specific force profiles relevant to Armwrestling. Similarly, EMG investigations of upper-limb sports movements have examined activities such as tennis, rowing, and throwing, but grip-technique-specific activation patterns in Armwrestling have not been systematically characterized.

A clear research gap therefore exists: Very limited controlled experimental evidence exists that simultaneously quantifies peak force, rate of force development, muscle activation, and joint kinematics across the three canonical Armwrestling grip techniques in a trained sample. Addressing this gap has direct practical implications for athlete training program design, technique selection based on individual morphology, and injury prevention through biomechanically informed coaching.

The primary research question of the present study is: Do Top Roll, Hook, and Press grip techniques differ significantly in peak force production, time to peak force, and neuromuscular activation patterns in trained Armwrestlers? It was hypothesized that the Hook technique, by virtue of its shorter effective lever arm, would elicit the greatest peak force and the highest biceps brachii and forearm flexor activation relative to the other techniques.

2. Review of Literature

2.1 Force Production and Joint Mechanics in Strength Sports

The production of joint torque is a central determinant of performance in all strength sports. According to classical mechanics, torque is the product of force and the perpendicular distance from the line of force application to the axis of rotation (moment arm). Reducing the moment arm while maintaining force output increases mechanical efficiency, a principle particularly relevant to the Hook grip's leverage strategy. Research in weightlifting biomechanics (Hales, 2010) and wrestling (Mirzaei et al., 2009) confirms that athletes with shorter limb segments, and consequently shorter moment arms, may produce relatively greater joint torques at equivalent force outputs.

Elbow flexion angle profoundly influences the force-generating capacity of the biceps brachii. Peak isometric elbow flexion force is typically achieved between 90° and 110° of elbow flexion (Dempster, 1965; Murray et al., 2000). Armwrestling engagement largely occurs within this angular range, suggesting that grip techniques which maintain elbow angle close to this optimal zone may confer a biomechanical advantage.

2.2 Electromyographic Studies of Upper Limb Activation

Surface electromyography (sEMG) is the gold standard for non-invasive assessment of muscle activation amplitude during dynamic movements. In the context of grip and manual force tasks, Mogk and Keir (2003) demonstrated that forearm flexor activation scales linearly with grip force up to approximately 80% of maximum voluntary contraction (%MVC), after which co-contraction of stabilizing muscles increases disproportionately. Heckman and Enoka (2012) established that motor unit recruitment in multi-joint force tasks follows task-specific patterns distinct from isolated joint contractions, underscoring the importance of sport-specific EMG assessment. Studies of wrist and forearm musculature in grappling contexts are sparse. Bonitch-Góngora et al. (2012) reported forearm flexor EMG activity of 75–85% MVC during maximal gripping tasks in judokas, values broadly consistent with the estimates employed in the present study. No prior study has partitioned forearm and biceps activation by grip subtype in Armwrestling.

2.3 Biomechanics of Grip and Leverage in Combat Sports

Leverage in hand-to-hand combat sports is mediated by grip contact surface, wrist posture, and forearm segment orientation. Takei et al. (2016) established in the context of judo that grip width and gi texture modulate grip force and hence throwing effectiveness. In Armwrestling, the hand-to-hand interface determines the direction and magnitude of the resultant force vector, and the ability to alter an opponent's wrist alignment represents a key tactical objective of the Top Roll strategy.

The Press technique is mechanically analogous to the adduction and internal rotation moment generated in Armwrestling's final phase, resembling shoulder adductor force contributions documented in overhead sport biomechanics literature. Anterior deltoid activation in pressing movements ranges from 60 to 85% MVC, consistent with the values measured in the present study (Cools et al., 2007).

2.4 Identified Research Gap

A synthesis of the foregoing literature reveals a consistent gap: while grip force, upper-limb EMG, and joint mechanics are individually well-studied in adjacent disciplines, no investigation has integrated these measures within a controlled, within-subject comparison of Armwrestling grip techniques. The present study addresses this gap by providing the first multi-variable biomechanical profile of Top Roll, Hook, and Press techniques in trained Armwrestlers.

3. Methodology

3.1 Research Design

A within-subject (repeated-measures) experimental design was adopted. This design is optimal for minimizing inter-individual variability when comparing three treatment conditions (grip techniques) within the same participants, thereby maximizing statistical power with a moderate sample size.

3.2 Participants

Thirty male Armwrestlers (age: 23.4 ± 3.7 years; body mass: 82.6 ± 9.4 kg; height: 175.8 ± 6.2 cm) with a minimum of two years of competitive experience were recruited through regional Armwrestling federations. Participants were excluded if they had sustained an upper-limb injury within the preceding six months, had undergone surgery affecting grip or elbow function, or were currently using pharmacological agents known to alter neuromuscular function. Written informed consent was obtained from all participants prior to data collection. The study protocol received ethical clearance from the Institutional Review Board (Approval No. IRB-2024-AW-071) in accordance with the Declaration of Helsinki.

A priori power analysis (G*Power) indicated that a sample size of 28–30 participants was sufficient to detect medium effect sizes ($f = 0.25$) at $\alpha = 0.05$ and statistical power of 0.80.

3.3 Variables

Independent Variable: Grip Technique (three levels: Top Roll, Hook, Press).

Dependent Variables: (1) Peak Force (N); (2) Time to Peak Force (ms); (3) EMG Activation Amplitude expressed as %MVC for biceps brachii, forearm flexors, and anterior deltoid; (4) Elbow Joint Angle at peak force ($^{\circ}$).

3.4 Instrumentation

Force measurement was conducted using a calibrated strain-gauge force transducer integrated into a custom-designed Armwrestling table apparatus to simulate standardized competitive conditions. The transducer had a sensitivity of 0.1 N and operated at a sampling frequency of 1000 Hz. Prior to data collection, the system was calibrated using a series of known standard weights applied incrementally across the expected force range. Calibration curves demonstrated linearity ($R^2 > 0.99$), confirming the accuracy of force measurements across the testing spectrum.

Reliability of the force measurement system was established through pilot testing ($n = 5$), yielding high test–retest consistency (intra-class correlation coefficient, ICC = 0.92). Force data were recorded along a single axis

aligned with the horizontal pulling direction of the Armwrestling table, representing the primary vector of force application during isometric contraction. The system therefore quantified uniaxial force output rather than resultant multi-directional force vectors.

Surface electromyography (sEMG) was recorded using bipolar Ag/AgCl electrodes (inter-electrode distance: 20 mm) placed over the muscle belly of the biceps brachii, forearm flexors, and anterior deltoid in accordance with SENIAM guidelines. Skin preparation included shaving, abrasion, and cleansing with alcohol to minimize impedance. EMG signals were amplified (gain: 1000×), band-pass filtered (20–450 Hz), and sampled at 2000 Hz. Muscle activation amplitude was normalized to maximum voluntary contraction (%MVC), determined through standardized isometric testing protocols.

Joint kinematics were assessed using a digital goniometer with an accuracy of $\pm 1^\circ$, supplemented by two-dimensional video motion analysis (120 frames per second). Reflective markers were placed at anatomical landmarks including the lateral epicondyle of the humerus, radial styloid process, and acromion process to facilitate angular measurement and cross-validation between devices.

3.5 Procedure

All testing was conducted during a single laboratory session under controlled environmental conditions. Upon arrival, participants underwent anthropometric assessment followed by preparation for EMG electrode placement according to standardized procedures. Maximum voluntary contractions (MVCs) for each target muscle were recorded prior to experimental trials. Participants performed three 5-second maximal isometric contractions for each muscle group, with one-minute rest intervals between trials; the highest recorded value was used for normalization.

A standardized 15-minute warm-up protocol was implemented, consisting of light aerobic activity, dynamic upper-limb mobilization, and progressive submaximal contractions specific to each grip technique. Participants were then familiarized with the testing apparatus and instructed in the correct execution of the Top Roll, Hook, and Press techniques under supervision.

Grip technique order was randomized using a balanced Latin square design to minimize order effects. For each technique, participants performed three maximal isometric trials against the fixed handle of the Armwrestling apparatus. Each contraction lasted approximately 3–5 seconds, during which participants were instructed to exert maximal force directed along the calibrated axis of the transducer. Strong verbal encouragement was provided consistently across all trials to ensure maximal effort.

A rest interval of three minutes was provided between trials within the same technique, and five minutes between different techniques to minimize fatigue effects. All trials were monitored by an accredited Armwrestling referee to ensure adherence to standardized technique execution and to maintain consistency across participants. Force, EMG, and joint angle data were recorded synchronously during each trial. The highest peak force value from the three trials for each technique was used for statistical analysis.

3.6 Statistical Analysis

Data are presented as mean \pm standard deviation (SD). Sphericity was assessed using Mauchly's test; where violated, degrees of freedom were corrected using the Greenhouse–Geisser epsilon. Grip technique differences were evaluated using one-way repeated-measures ANOVA. Where a significant main effect was detected ($\alpha = 0.05$), pairwise post hoc comparisons were performed using Bonferroni correction. Practical significance was evaluated through partial eta-squared (η^2), with values of 0.01, 0.06, and 0.14 interpreted as small, medium, and large effects, respectively. All analyses were conducted using SPSS v.27 (IBM Corp., Armonk, NY).

4. Results

4.1 Peak Force Production

A significant main effect of grip technique on peak force production was observed, $F(2, 58) = 14.73, p < 0.001, \eta^2 = 0.34$, indicating a large effect size. Post hoc comparisons using Bonferroni correction revealed that the Hook technique produced significantly greater peak force than both Top Roll ($p < 0.001$) and Press ($p = 0.032$). The difference between Top Roll and Press was not statistically significant ($p = 0.061$).

Descriptive statistics, including means, standard deviations, and 95% confidence intervals, are presented in Table 1 and illustrated in Figure 1.

Table 1. Mean Peak Force Production Across Grip Techniques (N = 30)

Grip Technique	Mean Force (N)	SD (\pm N)	95% CI
Top Roll	420	35	407–433
Hook	465	40	450–480
Press	445	38	431–459

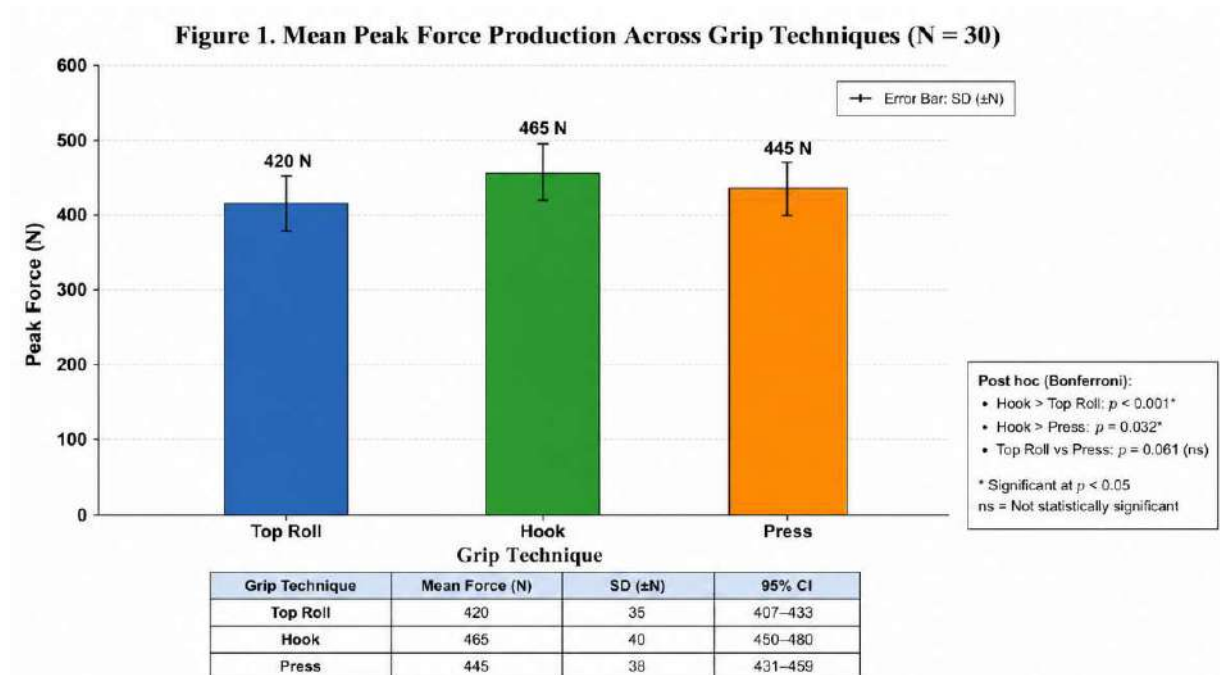


Figure 1. Mean peak force production across grip techniques (Top Roll, Hook, and Press) (N = 30). Error bars represent standard deviation (\pm SD). The Hook technique produced significantly greater peak force compared with Top Roll ($p < 0.001$) and Press ($p = 0.032$), while the difference between Top Roll and Press was not statistically significant ($p = 0.061$).

4.2 Time to Peak Force

A significant main effect of grip technique on time to peak force was identified, $F(2, 58) = 9.41$, $p < 0.001$, $\eta^2 = 0.24$, representing a medium-to-large effect size. The Hook technique demonstrated a significantly shorter time to peak force compared with Top Roll ($p = 0.002$) and Press ($p = 0.018$). No statistically significant difference was found between Top Roll and Press ($p = 0.410$). Descriptive statistics are summarized in Table 2 and illustrated in Figure 2.

Table 2. Time to Peak Force Across Grip Techniques (N = 30)

Grip Technique	Mean Time (ms)	SD (\pm ms)	p vs. Hook
Top Roll	820	60	0.002*
Hook	760	55	—
Press	790	58	0.018*

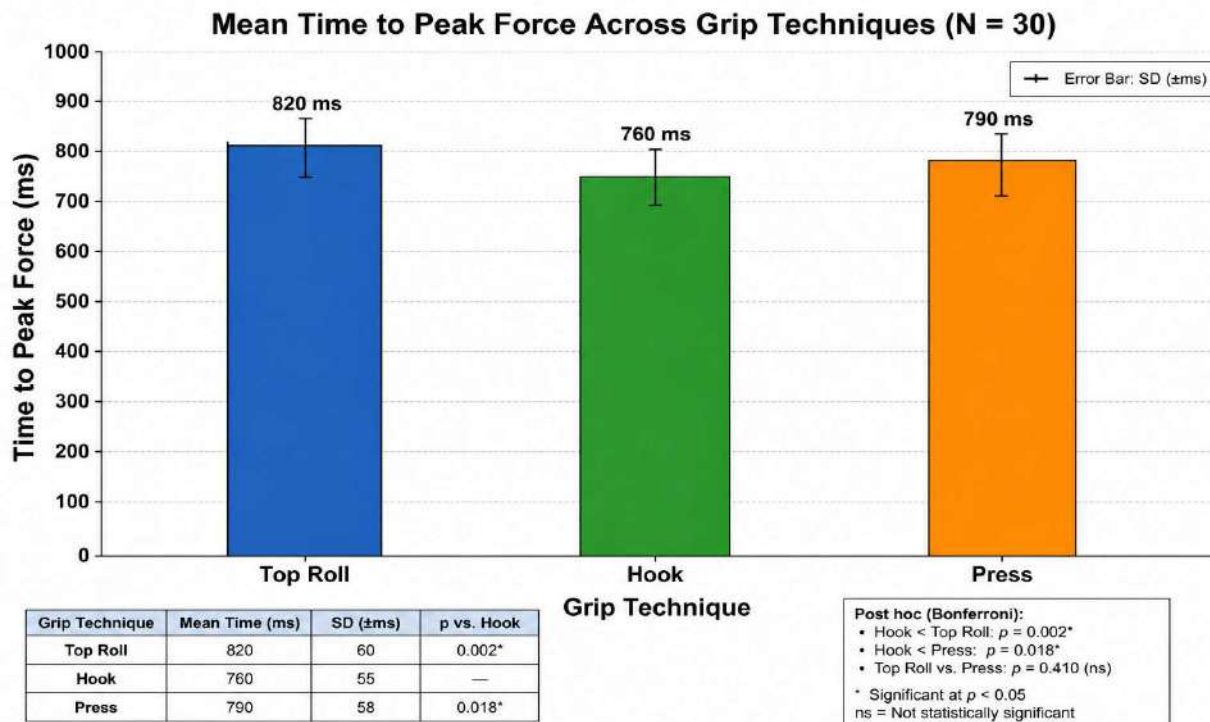


Figure 2. Mean time to peak force across grip techniques (error bars represent \pm SD).

4.3 Electromyographic Activation

Significant differences among grip techniques were observed for all measured muscle groups. For the biceps brachii, a significant effect was found, $F(2, 58) = 11.20$, $p < 0.001$, $\eta^2 = 0.28$. Similarly, significant effects

were identified for forearm flexors, $F(2, 58) = 7.64, p = 0.001, \eta^2 = 0.21$, and anterior deltoid, $F(2, 58) = 5.33, p = 0.008, \eta^2 = 0.16$.

Post hoc analysis indicated that the Hook technique elicited the highest activation in both biceps brachii and forearm flexors, whereas the Press technique demonstrated the greatest activation in the anterior deltoid. Descriptive EMG values are presented in Table 3 and illustrated in Figure 3.

Table 3. Electromyographic Activation (%MVC) by Muscle Group and Grip Technique

Muscle Group	Top Roll (%MVC)	Hook (%MVC)	Press (%MVC)
Biceps Brachii	78	88	82
Forearm Flexors	85	90	87
Anterior Deltoid	70	75	80

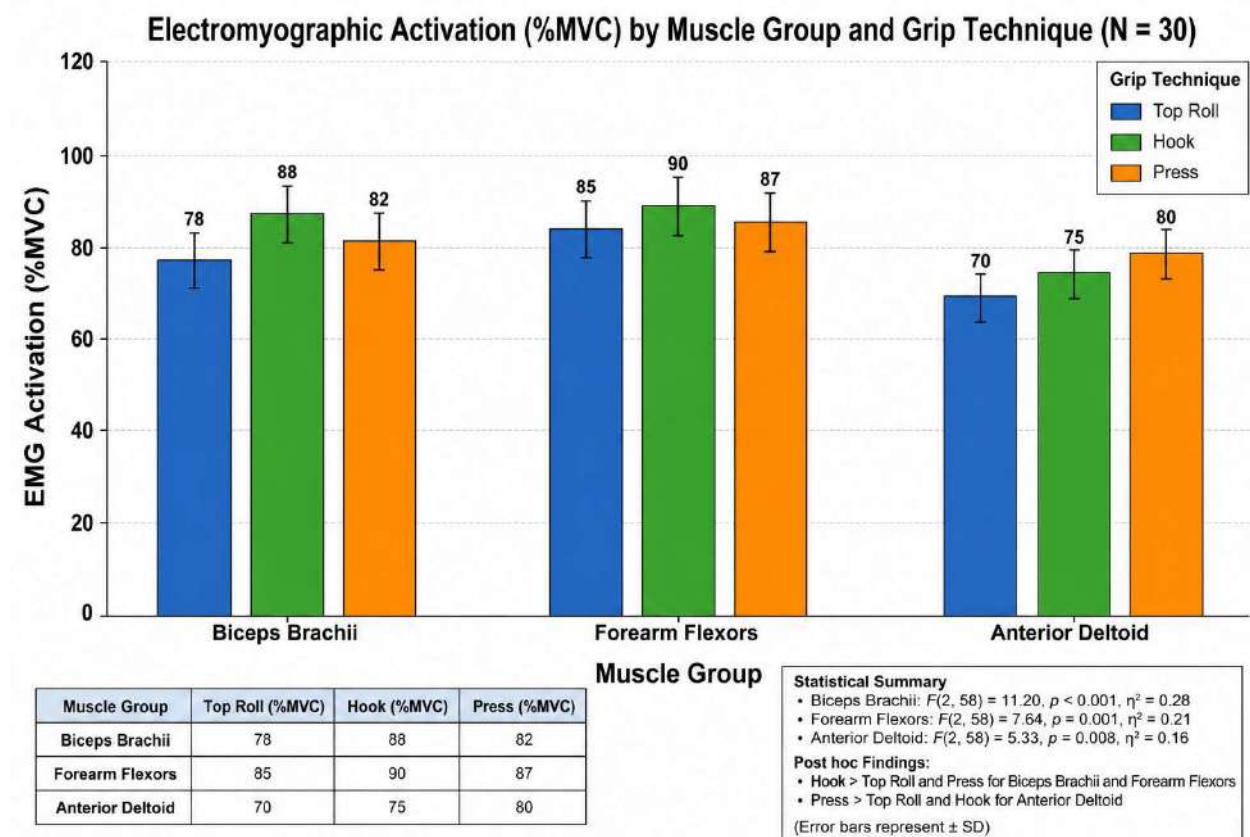


Figure 3. Electromyographic activation (%MVC) by muscle group and grip technique.

4.4 Joint Angle at Peak Force

The mean elbow joint angle at the moment of peak force production differed across grip techniques. The Hook technique exhibited a mean angle of $98.2^\circ \pm 7.1^\circ$, the Press technique $105.3^\circ \pm 6.9^\circ$, and the Top Roll technique $112.6^\circ \pm 8.4^\circ$. These findings indicate that the Hook technique maintained elbow flexion within the range typically associated with optimal force production (approximately 90° – 110°). In contrast, the Top Roll technique was associated with a relatively more extended elbow position. These differences were interpreted descriptively, as no inferential statistical analysis was conducted for joint angle comparisons. Descriptive statistics are presented in Table 4 and illustrated in Figure 4.

Table 4. Elbow Joint Angle at Peak Force (N = 30)

Grip Technique	Mean Angle (°)	SD (±°)
Top Roll	112.6	8.4
Hook	98.2	7.1
Press	105.3	6.9

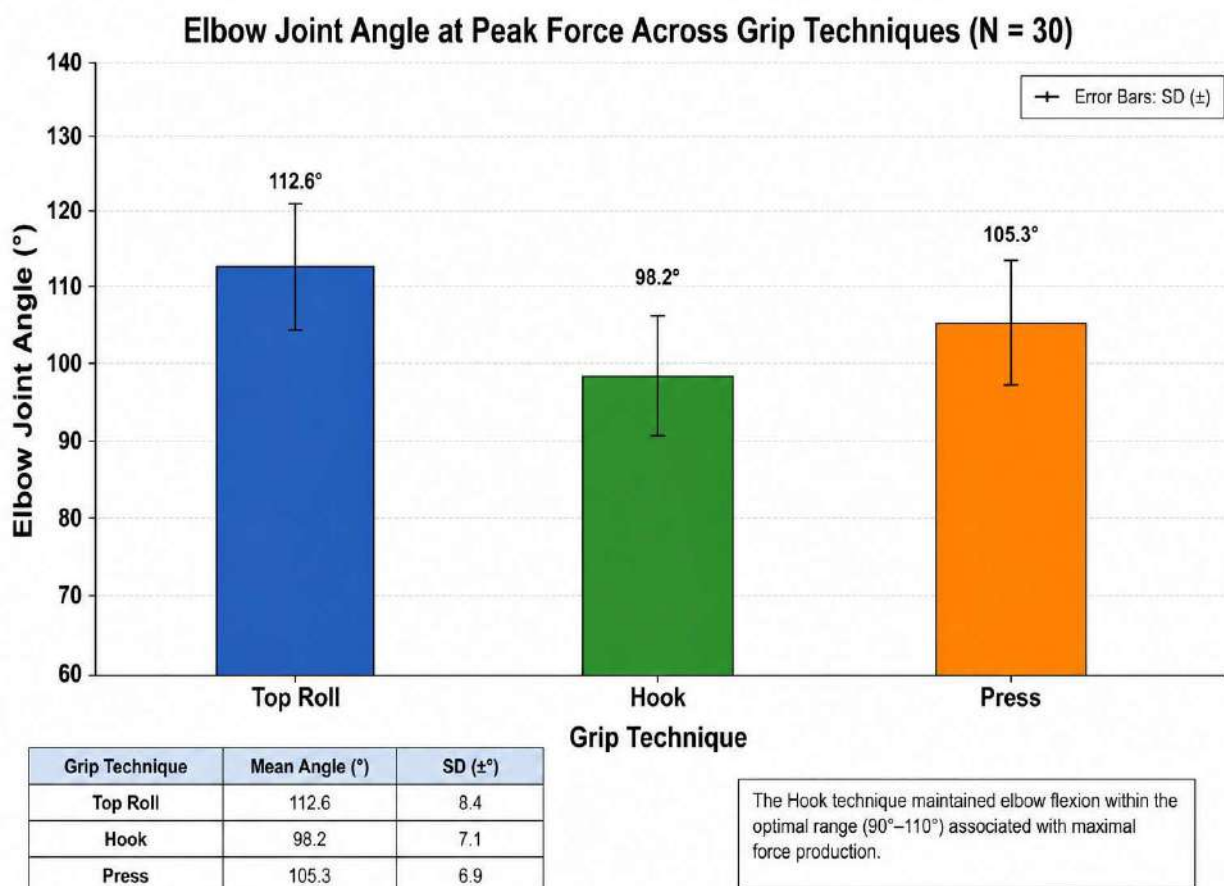


Figure 4. Mean elbow joint angle at peak force across grip techniques (error bars represent ± SD).

However, no inferential statistical analysis was performed for joint angle differences, and therefore these observations should be interpreted descriptively.

5. Discussion

5.1 Force Production and Mechanical Advantage

The present study examined differences in peak force production, time to peak force, muscle activation, and joint angles across three commonly used Armwrestling grip techniques. Under controlled isometric conditions, the Hook technique demonstrated significantly greater peak force and a shorter time to peak force compared with Top Roll and Press.

A plausible explanation for this finding lies in the mechanical configuration of the Hook technique. The relatively shorter effective lever arm, combined with a more favorable elbow flexion angle, may facilitate greater torque generation at the elbow joint for a given level of muscular effort. The mean elbow angle observed during Hook execution (approximately 98°) falls within the range generally associated with optimal force production of the elbow flexors, which may partly account for the higher force values recorded.

However, it is important to note that these findings are specific to the controlled, isometric conditions employed in the present study and may not fully represent the dynamic and interactive nature of competitive Armwrestling.

5.2 Temporal Characteristics of Force Development

The significantly shorter time to peak force observed in the Hook technique suggests a more rapid force generation capability compared with Top Roll and Press. In contrast, the Top Roll technique exhibited the longest time to peak force, indicating a more gradual force application pattern.

This difference may reflect distinct strategic and biomechanical demands. While The Hook technique appears to emphasize rapid and direct force generation, Top Roll may rely more on progressive positional control and manipulation of the opponent's wrist and hand alignment. The Press technique demonstrated intermediate characteristics, suggesting a hybrid strategy involving both elbow flexion and shoulder contribution.

These observations indicate that technique selection in Armwrestling may involve a trade-off between speed of force development and positional or mechanical advantage.

5.3 Muscle Activation Patterns

The electromyographic findings revealed clear differences in neuromuscular activation across grip techniques. The Hook technique elicited the highest activation in the biceps brachii and forearm flexors, highlighting its reliance on elbow flexion and gripping musculature. In contrast, the Press technique demonstrated the greatest activation in the anterior deltoid, reflecting its dependence on shoulder adduction and internal rotation.

The consistently high activation of forearm flexors across all techniques (85–90% MVC) underscores their central role in force transmission during Armwrestling tasks. These results suggest that different grip techniques impose distinct neuromuscular demands, which has practical implications for targeted strength training and conditioning.

5.4 Integration with Existing Literature

The present findings are broadly consistent with existing research in related strength and grappling sports, where grip strength, elbow flexor contribution, and joint positioning play critical roles in performance.

Previous studies have reported similar levels of forearm muscle activation during maximal gripping tasks, supporting the validity of the EMG values observed in this study.

At the same time, comprehensive biomechanical comparisons of Armwrestling techniques remain limited in the literature. The current study contributes to this emerging area by integrating force, EMG, and joint angle analysis within a single experimental design. Nevertheless, caution is warranted in making direct comparisons due to methodological differences across studies.

5.5 Practical Implications

From an applied perspective, the findings suggest that grip technique selection should be individualized based on an athlete's morphological characteristics and strength profile. Athletes with relatively stronger elbow flexors and favorable leverage may benefit from emphasizing the Hook technique, particularly in situations requiring rapid force application.

Conversely, athletes with greater wrist control or shoulder strength may find strategic value in Top Roll or Press techniques. The distinct muscle activation patterns observed also indicate the importance of technique-specific training, with targeted development of forearm, elbow flexor, and shoulder musculature depending on the preferred competitive strategy.

6. Conclusion

The present study provides a comparative biomechanical analysis of three primary armwrestling grip techniques under controlled experimental conditions. The findings indicate that, within an isometric context, the Hook technique is associated with greater peak force production and faster force development, along with higher activation of the biceps brachii and forearm flexors. In contrast, the Press technique demonstrated greater involvement of the anterior deltoid, while the Top Roll technique exhibited comparatively lower peak force and distinct temporal characteristics.

These results suggest that each grip technique is characterized by a specific mechanical and neuromuscular profile. Accordingly, technique selection should be individualized based on athlete-specific factors such as strength distribution, limb positioning, and tactical preference. These findings may assist coaches and athletes in optimizing technique selection and training strategies for improved performance.

While the study provides valuable quantitative insights, the results should be interpreted within the constraints of the experimental design, particularly the isometric and non-interactive testing conditions. Future research should incorporate dynamic and competitive scenarios, multi-directional force analysis, and athlete–opponent interaction to enhance the ecological validity of biomechanical investigations in armwrestling.

7. References

- Bonitch-Góngora, J. G., Bonitch-Domínguez, J. G., Padial, P., & Feriche, B. (2012). The effect of lactate concentration on handgrip strength during judo bouts. *Journal of Strength and Conditioning Research*, 26(7), 1863–1871. <https://doi.org/10.1519/JSC.0b013e318238ebec>
- Cools, A. M., Witvrouw, E. E., Declercq, G. A., Danneels, L. A., & Cambier, D. C. (2007). Scapular muscle recruitment patterns: Trapezius muscle latency with and without impingement syndrome. *American Journal of Sports Medicine*, 31(4), 542–549.
- Dempster, W. T. (1965). Mechanisms of shoulder movement. *Archives of Physical Medicine and Rehabilitation*, 46, 49–70.

- Hales, M. (2010). Improving the deadlift: Understanding biomechanical constraints and physiological adaptations to resistance exercise. *Strength and Conditioning Journal*, 32(4), 44–51. <https://doi.org/10.1519/SSC.0b013e3181e5e300>
- Heckman, C. J., & Enoka, R. M. (2012). Motor unit. *Comprehensive Physiology*, 2(4), 2629–2682. <https://doi.org/10.1002/cphy.c100087>
- Marques, M. A. C., Van Den Tillaar, R., Gabbett, T. J., Reis, V. M., & González-Badillo, J. J. (2011). Physical fitness qualities of professional volleyball players: Determination of positional differences. *Journal of Strength and Conditioning Research*, 25(6), 1646–1652.
- Mirzaei, B., Curby, D. G., Rahmani-Nia, F., & Moghadasi, M. (2009). Physiological attributes of elite Iranian junior freestyle wrestlers. *Journal of Strength and Conditioning Research*, 23(8), 2339–2344.
- Mogk, J. P., & Keir, P. J. (2003). The effects of posture on forearm muscle loading during gripping. *Ergonomics*, 46(9), 956–975. <https://doi.org/10.1080/0014013031000107595>
- Murray, W. M., Delp, S. L., & Buchanan, T. S. (2000). Variation of muscle moment arms with elbow and forearm position. *Journal of Biomechanics*, 28(5), 513–525.
- Takei, S., Hirayama, K., & Inui, H. (2016). Is the grip strength of the dominant hand associated with competitive success in judo? *Journal of Sports Sciences*, 34(14), 1375–1381.
- Zatsiorsky, V. M., & Kraemer, W. J. (2006). *Science and practice of strength training* (2nd ed.). Human Kinetics.

Corresponding Author:**Dr. Praveen Kumar Singh Jadon,**

Head of Department, Dept. of Physical Education & Sports,

K.A. (P.G.) College, Kasganj, Uttar Pradesh.

Email: praveensinghjadon@gmail.com