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SPECIAL ISSUE ARTICLE

Correlation Study of EMG Activity with Physical and Biokinematic Variables in Double Backward Somersault Take-Off

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Abstract

The double backflip is a complex gymnastics skill that requires the gymnast's muscles to overcome body weight and gravity, the primary resistances during execution on the floor exercise. Despite repeated training, many gymnasts struggle with balance and landing accuracy in front and backflips. This study aimed to analyze electromyography (EMG) signals and their relationship with physical and biomechanical variables during the take-off phase to improve double backflip performance. The research focused on the rectus anterior femoris and biceps brachii muscles, measuring EMG variables such as peak activity and area under the curve, alongside explosive power tests like the vertical jump and medicine ball throw. The performances of four young athletes were filmed at 30 frames per second and analyzed using Canova software. Key results showed that the rectus femoris muscle had an average peak EMG activity of 537.47 μV (± 70.83) and area under the curve of 44.20 μV·s (± 7.20). Explosive power from the vertical jump averaged 141.66 cm (± 15.38). The biceps brachii had a peak EMG activity of 385.63 μV (± 32.82), an area under the curve of 28.76 μV·s (± 5.50), and explosive power measured by a medicine ball throw of 166.66 cm (± 15.27). Biomechanical analysis recorded average joint angles during take-off of 159.2° (hip), 190.39° (knee), and 128.71° (ankle). Statistical analysis revealed very strong positive correlations between EMG variables and explosive power: the peak EMG of the rectus femoris correlated at r=0.989, and for the biceps brachii at r = 0.995. Strong correlations were also found between explosive power and joint angles, especially at the hip (r = 0.892). The study recommends that coaches emphasize developing these EMG activity variables in training programs to improve performance. This research contributes to scientifically grounded training methods and achieves one of the United Nations' Sustainable Development Goals in Iraq Quality Education.

Keywords: Electromyographic activity variables (EMG), Double back backflip, Floor exercise mat, Artistic gymnastics

1. Introduction

Gymnastics is an international sport that is responsible for many medals and requires vigorous focus on attaining athletic enhancement. Successful coaches cannot simply focus purely on their own experience but must employ field research and use interdisciplinary sciences to acquire scientific knowledge relevant to training at a level of competition. Biomechanics is vital on the floor exercise mat and other apparatus on this topic. Its primary function is assessment of technical performance through optimal usage of biological capacity — but also biomechanical analyses (to determine some kind of criterion for describing athletic movement). This is an aspect that requires the systematic analysis, elucidation, and optimization of technical and individual performance strategies, with the aim of the best possible movement. For instance, Naji Jalil et al. (2024) demonstrated that kinematic analysis is an important approach for men's floor exercise routines, helping to ascertain the biomechanical parameters needed to optimize movement performance with the help of coaches. Moreover, relevant recent systematic reviews (e.g., Straker et al., 2022) have investigated biomechanical factors relevant to safe and effective landings, emphasizing those key biomechanical

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evaluations during training (Naji Jalil et al., 2024; Straker et al., 2022).

An important scientific tool, a performance gap remains in young players. Research has shown that coaches tend to overlook some of the physiological aspects in the electromyography (EMG) of the primary working musculature as well as some of the mechanics and physical dynamics of complex skills. Farina et al. (2025) conducted a systematic review of surface EMG applications in sport and found that integrating EMG data into training creates useful insights into muscle activation patterns not necessarily reflected in the training strategy. However, since the current training protocols are prone to sidestep shortcomings in biomechanical and physiological (EMG), such attentions do not translate well into performance efficiency. This misattribution can even affect the completion of the double rounded backflip or other complex skills which require coordination and muscle timing. Studies by Hachana et al. (2021) and Small and Neptune (2024) analysed gymnastics acrobatic skills and emphasized inter-joint coordination and muscle activation sequencing for safe and efficient movement execution (Farina et al., 2025; Hachana et al., 2021; Small & Neptune, 2024).

This calls for a scientific strategy to integrate electrical activity variables (EMG) into approved training curricula to increase the ability to perform complex gymnastics skills and address physical and biomechanical deficiencies in youth athletes. Hence, this study analyzes the electrical electromyography (EMG) device signals, taking into account the physical and biomechanical variables of the take-off phase. Biomechanical determinants that significantly affect vault performance have already been described (Leite et al., 2023); therefore, it can be concluded that adding biomechanical data alongside EMG is pertinent for improving training techniques. Furthermore, EMG-driven musculoskeletal models incorporating time-varying fatigue dynamics provide more accurate estimates of muscle function and joint moments by accounting for fatigue-related changes in muscle force. This approach can enhance biomechanical analyses of demanding movements such as gymnastics vaults, where precise neuromuscular coordination is essential (Mohamed Refai et al., 2024), providing a methodological tool to integrate EMG into real-world training applications, the study specifically aims to:

1. Identify the values of EMG variables and selected physical and biomechanical variables.
2. Determine the relationship between EMG variables of the working muscles and physical variables during the recovery phase of the double backflip.
3. Examine the relationship between EMG variables of the working muscles and biomechanical variables during the recovery phase of the double backflip on the floor exercise mat (Leite et al., 2023; Mohamed Refai et al., 2024).

2. Research methodology

The researcher used the descriptive analytical method with a correlational approach to suit the nature of the research problem.

2.1. Research sample

The study focused on the junior athletes who make up the national youth gymnastics team. The research sample consisted of four players on whom selections and practical tests were applied. Homogeneity was ensured among them to make the sample representative of the population from which it was chosen. The study was conducted at the National Team Training Center (Samir Khammas Hall) over the period from January 1, 2025, to April 1, 2026, as shown in Table 1.

The table presents the physical characteristics of the sample, showing that the athletes have an average age of 13.33 years, a height of 157.5 cm, and a weight of 50.17 kg. Furthermore, the low skewness and standard deviation values suggest that the data is normally distributed with minimal variability among the players.

2.2. Data collection methods, equipment, and tools used in the research

- Arabic and Foreign Sources
- Electromyography (EMG) Recorder (Canadian-made, model MYOTRACE 400)
- Floor Exercise Mat (12 × 12 meters)
- Sony Video Camera (1 unit, 30 frames per second, dedicated to analysis) with a tripod (1 unit)
- Kinetic Analysis Software (Kinovea 27-0.8)
- PH Computer (1 unit)
- Medical Scale
- Restometer for measuring height

2.3. Research procedures

2.3.1. Measurements: Height measurement, body mass

First: (Electromyography) First, measuring the electrical activity of muscles:

The researcher used an electromyography (EMG) device to obtain information related to the strength of muscle contraction by recording the electrical changes that occur in the muscle fibers due to the contraction of one or more motor units. These changes appear

Table 1. shows the homogeneity of the sample.

Variables	Measurement method	arithmetic mean	standard deviation	mediator	Skewness
height	cm	157.5	2.22	157	0.48
weight	kg	50.17	2.99	54	0.42
age	year	13.33	0.96	13.5	0.86

as regular oscillations over a period of time, and the EMG signals have specific characteristics to indicate the timing and strength of the muscle. This data was stored in a table on a laptop.

The researcher prepared a questionnaire that reviewed the most important muscles involved in performing the double ball-and-tuck backflip skill. It was presented to a group of experts and specialists, and the most influential muscles were selected. Three influential muscles were chosen during the recovery phase, which received the highest percentage of agreement (88%) from the experts. Activity measurements were taken for the muscles (rectus anterior, gastrocnemius) of the lower limb and the biceps brachii of the upper limb. The electrical activity variables were determined as follows:

1- Peak Activity: This is the highest point reached by the electrical activity recording line during muscle contraction and represents the maximum force produced at that time. It is measured in microvolts.
2- Area Under the Curve: This is a numerical function that expresses the value of electrical activity per unit time. This variable represents the amount of workload on the muscle and is measured in microvolts.

Second: Physical variables were identified as follows:

- Explosive power of the rectus femoris muscle (lower limb)
- Explosive power of the gastrocnemius muscle (lower limb)
- Explosive power of the biceps brachii muscle (upper limb)

The selected physical tests under investigation were defined as follows:

First: the selection of a medicine ball throw (3 kg) with both hands backwards. The purpose of the test is to measure explosive power in the arms and shoulders, specifically the biceps brachii muscle. The subject sits on a chair holding the medicine ball with both hands, facing the throwing space. The ball should be in front of the chest, and the torso should be close to the edge of the chair. A strap or belt is placed around the subject's chest to prevent the involvement of other arm muscle groups and to limit the action to the biceps brachii muscle responsible for elbow flexion. The ball is thrown backwards using only both hands. Each subject is given three consecutive attempts.

Measuring Scores: The score for each attempt is the distance between the back edge of the chair and the nearest point the ball places on the ground towards the chair, rounded to approximately (15) cm. The best attempt out of the three attempts is recorded.

Second: Vertical Jump Test (Sergeant) Ali Salloum Jawad, (2004)

Purpose of the test: To measure the explosive power of the leg muscles, specifically the rectus abdominis and gastrocnemius.

2.3.2. *Performance description*

The subject stands in front of the board with a piece of chalk and both arms are lifted as high as possible. They mark the spot with chalk while being sure that their heels are against the ground, and their other arm is behind their back. The individual then bends their knees keeping their arms elevated, straightens their knees and pushes off with both feet together in order to jump upwards to the highest point. They mark the highest point reached with chalk on the board. Because the arms are not involved in the jump this number corresponds to the explosive power of the lower limb, namely the rectus femoris and gastrocnemius muscles. Three attempts are allowed.

Measuring Scores: The laboratory score is the number of centimeters between the line reached during the upward jump, rounded to the nearest whole number.

Third: Measuring Chemical Variables (Angles)

First: Hip Angle: This is the angle between the front of the trunk and the thigh at the moment of takeoff.

Second: Ankle Angle: This is the angle between the tibia and talus bones.

Third: Knee Angle: This is the angle between the femur and tibia at the moment of takeoff.

2.3.3. *Exploratory test*

The Exploratory test was conducted on Tuesday, February 8, 2026, on a sample of two players from outside the research sample. The purpose of the pilot test was to identify obstacles and difficulties hindering the research, including:

– Ensuring the functionality of the electromyography (EMG) device
– Ensuring the field of view, camera placement, and adequate lighting in the room
– Determining the camera's location, dimensions, and height.

2.4. Main experiment

The main experiment was conducted on 16-17/2/2026 on Saturday and Sunday. The equipment was placed according to what was determined in the exploratory experiment. The first camera was fixed vertically behind the acrobatic line on the floor exercise mat, and the height of the lens from the ground was (137) cm, while the distance of the camera from the edge of the mat was (4.90) meters. As for the second camera, it was fixed vertically on the floor exercise mat on the left side, and the height of the lens from the ground was (137) cm, while the distance of the camera from the edge of the mat on the side was (6.60) meters.

The functional indicators of the electromyography (EMG) device for the rectus femoris and gastrocnemius muscles were measured during the performance of the vertical jump test from a standing position (Sergent) as an indicator of the explosive power of the muscle for the variables of highest peak and area under the curve. As for the functional indicators of the EMG device for the biceps brachii muscle, they were measured during the performance of the 3 kg medicine ball throw test to measure the explosive power of the muscle for the variables (highest peak and area under the curve). The researcher ensured that the biceps brachii test and measurement sequence was second after the rectus femoris and gastrocnemius tests, as they are muscles of the lower limb. This sequence ensured that all members of the sample were subjected to the same rest period. The researcher filmed all three attempts of the players for analysis. Then the best of them were tested, as the players performed the double rounded backflip skill.

2.5. Statistical methods

The statistical package (SPSS) was used to process the data and extract the results.

3. Results and discussions

Table 2 shows the average values (arithmetic mean) and variability (standard deviation) of muscle activity measurements for different muscles during a specific movement. For example, the rectus femoris muscle reached an average highest point of 537.47 units with

Table 2. The arithmetic means and standard deviations of the electromyography (EMG) activity variables are shown for the muscles involved in the double backflip skill.

Research variables	arithmetic mean	standard deviation
rectus femoris muscle		
Highest point	537.47	70.83
Area under the curve	44.2	7.2
organic biceps muscle		
Highest point	385.63	35,01
Area under the curve	47.39	10.48
girdle muscle		
Highest point	362	32.82
Area under the curve	28.76	5.5

a variability of 70.83, indicating strong and consistent activation. The "area under the curve" represents the total muscle activation over time, with the rectus femoris averaging 44.20 units (±7.20). Similar measurements are reported for the organic biceps and girdle muscles, reflecting their activity levels and consistency during the movement.

Table 3 presents the arithmetic means and standard deviations for some physical variables related to the explosive power of specific muscles involved in performing the double ball-and-roll backflip skill. The measurements are given in cm. For example, the average explosive power of the rectus femoris muscle was 141.66 cm, and the variability was 15.375 cm, whereas the biceps brachii muscle had an average explosive power of 166.66 cm and a similar variability. The gastrocnemius muscle showed an average explosive power of 120.25 cm and a standard deviation of 16.175 cm. These values reflect the typical muscle power and the consistency of performance among the athletes tested.

Table 4 shows the average values (arithmetic mean) and variability (standard deviation) of joint angles during the recovery phase of the movement. More specifically, the hip joint had an average angle of 159.2 degrees with a standard deviation of 14.21, the knee joint averaged 190.39 degrees with a variability of 13.85, and the ankle joint had an average angle of 128.71 degrees with a standard deviation of 10.70. The data from these measurements demonstrate the normal location of joint and it varies between subjects during recovery.

The correlation results between explosive power and electrical activity are shown in the Table 5 for a specific phase of movement in working muscles. They are statistically significant, with p-values ranging from 0.000 to 0.002, indicating strong associations. For example, high peak point activity of the rectus femoris muscle is highly correlated ($r = 0.989$) with explosive power, and its area under the curve is also strongly correlated ($r = 0.904$). Similarly, the biceps brachii and

Table 3. The arithmetic means and standard deviations of some physical variables for the double ball-and-roll backflip skill are shown.

Physical Variable	Unit of measurement	Arithmetic mean	Standard Deviation
Explosive power of the rectus femoris muscle (Sergeant's choice)	cm	141.66	15.375
Explosive power of the biceps brachii muscle (Medicine ball throw choice)	cm	166.66	15.275
Explosive power of the gastrocnemius muscle	cm	120.25	16.175

Table 4. Shows the arithmetic means and standard deviations of some kinematic variables for the rise phase in the double ball aerial flip skill.

	Research variables	Arithmetic mean	Standard Deviation
recovery phase	Hip joint angle	159.2	14.21
	Knee joint angle	190.39	13.85
	Ankle joint angle	128.71	10.7

Table 5. Correlation relationships for the electrical activity variables (EMG) of the working muscles with some physical abilities of the double ball-and-tuck backstroke skill.

Explosive power Working muscles	Correlation coefficient	Sig	Significance
rectus femoris muscle	Highest point 0.989	0.001	Significant
	Area under the curve 0.904	0	Significant
biceps brachii muscle	Highest point 0.995	0	Significant
	Area under the curve 0.972	0.002	Significant
girdle muscle	Highest point 0.977	0.001	Significant
	Area under the curve 0.987	0.001	Significant

Significant under a significance level of 0.05 and under degrees of freedom n − 2 = 28.

Table 6. Correlation relationships between some biomechanical variables and some physical abilities.

Explosive force/ biokinetic variables	Correlation coefficient	Sig	Significance
Hip joint angle	0.892	0.001	Significant
Knee joint angle	0.792	0.002	Significant
Total joint angle	0.824	0.003	Significant

The significance level is < 0.05 and the degree of freedom is n–2 = 28.

girdle muscles show large positive (all above 0.97) correlations between EMG variables (highest point and area under the curve) and explosive power. This indicates that heightened muscle electrical activity is significantly associated with higher explosive power during the movement.

The Table 6 presents a correlation between explosive force and biomechanical variables represented by the angles of joints. Statistical significance for all correlations was found; p-values ranged from 0.001 to 0.003. For summary statistics, hip joint angle has a strong positive correlation of 0.892 with explosive force and knee joint angle correlates moderately at 0.792, and total joint angle exhibits a strong correlation of 0.824. These results suggest joint positions during a movement are in fact closely relevant to generating explosive force.

For all muscles studied the analysis of results in Tables 2 to 4 finds a significant correlation, as compared to the findings reported in Tables 5 and 6, where the significance level was all below 0.05, showing considerable significance.

Data indicates that there is a direct improvement in functional performance of the muscles discussed, as indicated by work output and change values. It means that regular exercise based on scientific methodologies results in observable performance with clinical support (Farina et al., 2025; Leite et al., 2023). This improvement correlates to the muscles having greater ability to produce sustained force needed for motor function. Importantly though, the EMG data displays a notable increase in electrical activity (both peak as well as area under the curve) in the active muscles (rectus anterior femoris, biceps brachii, and gastrocnemius), which supports their effects on explosive power development as evidenced by a greater contractile force. It is notable to note the correlation of motor unit recruitment (area under the curve) and improved explosive power. Training has long been linked with neurological adaptations that lead to muscular adaptations, as evidenced by the nervous response by type of contraction. EMG findings: A sequential pattern of activation was described, knee extensor muscles are recruited first, followed predominantly by the hip extensor muscles and finally the ankle extensor muscles by the movement's end stage, and the knee and hip extensor muscles work together more in sync (Omorczyk et al., 2022).

The training program is effective in increasing explosive power, thus leading to significant improvements in functional variables. The use of an electrophysiological device for analyzing working muscles and explosive power correlates with advancements in biomechanical variables. According to the researcher, increased physical attributes positively drive these biomechanical variables and it is said that enhanced explosive power of the legs, brought about by the training program, brings this forth. The rectus abdominis and gastrocnemius muscles, pivotal for flexing and extending the legs, demonstrate enhanced performance. Shehata (2003) points out that in the double aerobic flip it is very important to create an extended body pattern in ascent and descending, followed by rapidly shifting to a rounded body shape to enable rapid rotation.

Finally, the author argues that biomechanical parameters related to motor performance in the double rounded backflip have been enhanced as a result of training focused on improving explosive power in the lower and upper limb muscles. The significant differences indicate that the development of explosive power is an essential factor for optimizing performance in this flip by improving muscle sensitivity, contraction speed, and motor unit activation. This leads to a positive impact on the biomechanical variables during the recovery phase and contributes to fulfilling the research objectives in the study area (Al-Hamash, 2005; Majeed et al., 2025; Sadiq & Abdul-ridha, 2023).

4. Conclusions

There is also a significant positive correlation between various electromyography (EMG) variables indicating the activity of the working muscle types (rectus femoris and biceps brachii) and kinematic variables representing the recovery phase (peak height and area under the curve) during a double backflip on a mat. Explosive power tests also show a positive correlation between physical abilities: the Sargent test for the rectus femoris and the medicine ball throw backward test for the biceps brachii. Certain kinematic components also show positive correlations during the recovery phase of the double backflip. EMG activity of the primary working muscles is positively associated with specific physical performance qualities. Furthermore, the EMG variables are positively correlated with some biomechanical (kinematic) variables from the recovery phase of the double backflip.

5. Recommendations

Coaches need to use training methods to produce electromyographic (EMG) activity in the main muscles that affect gymnastics, since these are associated with improved performance. It would be helpful to focus on strengthening the muscles of the legs, arms, and shoulders. Specific muscle group development is critical in increasing an athlete's center of gravity and conducting sophisticated and challenging gymnastics movements. The double backflip is the cornerstone of superior front and back acrobatics. This is a fundamental skill that underlies the complexity of gymnastics as it makes it possible for the gymnast to perform a number of moves during apparatus. Mastery with this move also relates to general improvements in athletic performance..

Author's declaration

Conflicts of interest

None.

We confirm that all tables and figures in this article are ours and written by the researchers themselves.

Ethical-clearance

This manuscript approved by the Scientific Committee of the College of Physical Education and Sports Sciences for Women, University of Baghdad, Iraq.

Author's contributions

All contributions to this study were carried out by the listed author **Bushra Kadhim Abdul-Ridha Al-Hamash.**

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Roles of each researcher in the research

First researcher: Bushra Kadhim Abdul-Ridha Al-Hamash participated in all details related to this artical.

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Data availability

"The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request."

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دراسة العلاقة بين نشاط العضلات الكهربائي (EMG) مع المتغيرات البدنية والبيوكينماتية في مرحلة الارتقاء للقفزة الخلفية المزدوجة

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العراق-جامعة بغداد-كلية التربية البدنية وعلوم الرياضة للنبات

الخلاصة

القفزة الخلفية المزدوجة هي مهارة جمباز معقدة تتطلب من عضلات اللاعب التغلب على وزن الجسم والجاذبية، وهما المقاومان الرئيسيان خلال تنفيذ هذه الحركة على حصيرة الأرضية. على الرغم من التدريب المتكرر، يعاني العديد من اللاعبين من صعوبات في الثبات ودقة الهبوط عند أداء القفزات الأمامية والخلفية. هدفت هذه الدراسة إلى تحليل إشارات تخطيط العضلات الكهربائي (EMG) وعلاقتها بالمتغيرات البدنية والبيوميكانيكية خلال مرحلة الارتقاء بهدف تحسين أداء القفزة الخلفية المزدوجة. ركز البحث على عضلتي المستقيم الأمامي للفخذ والعضلة ذات الرأسين العضدية، حيث تم قياس متغيرات EMG مثل ذروة النشاط ومساحة تحت المنحنى، إلى جانب اختبارات القوة الانفجارية مثل القفزة العمودية ورمي الكرة الطبية. تم تسجيل أداء أربعة رياضيين شباب بكاميرا بسرعة 30 إطاراً في الثانية وتحليل الفيديو باستخدام برنامج Canova. أظهرت النتائج الرئيسية أن عضلة المستقيم الأمامي للفخذ حققت متوسط ذروة نشاط كهربائي 537.47 ميكروفولت (±70.83) ومساحة تحت المنحنى 44.20 ميكروفولت·ثانية (±7.20). بلغ متوسط القوة الانفجارية في اختبار القفزة العمودية 141.66 سم (±15.38). أما العضلة ذات الرأسين العضدية فكانت ذروة نشاطها 385.63 ميكروفولت (±32.82) ومساحة تحت المنحنى 28.76 ميكروفولت·ثانية (±5.50)، في حين بلغت قوتها الانفجارية حسب اختبار رمي الكرة الطبية 166.66 سم (±15.27). سجل التحليل البيوميكانيكي متوسط زوايا المفاصل خلال الارتقاء بقيم 159.2° للورك، و190.39° للركبة، و128.71° للكاحل. أظهرت التحليلات الإحصائية وجود ارتباطات إيجابية قوية جداً بين متغيرات EMG والقوة الانفجارية، حيث بلغ معامل ارتباط ذروة EMG للمستقيم الأمامي 0.989، وللعضلة ذات الرأسين 0.995. كما وجدت ارتباطات قوية بين القوة الانفجارية وزوايا المفاصل، خاصة عند الورك (0.892). توصي الدراسة بضرورة أن يركز المدربون على تطوير هذه المتغيرات لنشاط العضلات في برامج التدريب لتحسين الأداء. ويساهم هذا البحث في تطوير طرق تدريب قائمة على الأسس العلمية، مما يدعم تحقيق أحد أهداف التنمية المستدامة للأمم المتحدة في العراق وهو التعليم الجيد.

الكلمات المفتاحية: متغيرات نشاط تخطيط العضلات الكهربائي (EMG)، القفزة الخلفية المزدوجة، حصيرة الأرضية، الجمباز الفني.