

PHYSIOLOGICAL AND BIOMECHANICAL FACTORS INFLUENCING PERFORMANCE IN ELITE FEMALE JUDO ATHLETES

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Abstract. *This study examines the physiological and biomechanical factors associated with performance in elite female judo athletes. The increasing competitiveness of international women's judo has emphasized the need to understand the determinants of success beyond technical skills alone. The aim of this study was to analyze how selected physiological and biomechanical variables influence competitive performance outcomes. A cross-sectional research design was applied involving elite female judokas competing at international level. Physiological variables included anaerobic power, muscular strength, and fatigue resistance, while biomechanical variables included grip strength, throwing velocity, movement efficiency, and execution time. Competitive performance was assessed through match outcomes and technical effectiveness using notational analysis. Data were analyzed using correlation and regression techniques to identify relationships between variables and performance indicators.*

The results showed that anaerobic power and upper-body strength were strongly associated with successful performance. Biomechanical factors such as grip strength and faster execution of throwing techniques significantly distinguished higher-performing athletes from lower-performing ones. Additionally, efficient movement patterns and effective force application during techniques contributed to improved competitive outcomes.

Regression analysis indicated that the combined physiological and biomechanical variables significantly predicted performance levels in elite female judo athletes, elite female judo performance is determined by the interaction of physiological capacity and biomechanical efficiency. Key factors such as anaerobic power, muscular strength, grip strength, and technical execution speed play a crucial role in competitive success. These findings support the development of integrated training programs that simultaneously enhance physical and biomechanical performance in elite judo athletes.

Keywords: *judo, biomechanics, physiology, female athletes, performance analysis, grip strength, anaerobic power.*

Judo is an Olympic combat sport that requires a complex integration of physiological capacity, biomechanical efficiency, technical skill, and tactical decision-making. At the elite level, performance is determined not only by technical proficiency but also by the athlete's ability to generate high levels of force, maintain efficient movement patterns, and execute techniques under intense competitive pressure. As international judo competitions become increasingly demanding, there is growing interest in identifying the key performance factors that distinguish successful athletes from their less successful counterparts. From a physiological perspective, judo is characterized by intermittent high-intensity efforts that rely heavily on anaerobic energy systems, muscular strength, and fatigue resistance.

Athletes must repeatedly perform explosive actions such as throws, grip fighting, and transitions to groundwork while maintaining performance throughout the match duration. Previous studies have shown that higher levels of anaerobic power and upper-body strength are associated with improved competitive outcomes in combat sports. However, physiological capacity alone does not fully explain success in elite judo performance. Biomechanical factors also play a crucial role in determining performance outcomes. Efficient movement execution, optimal force application, grip strength, and rapid throwing velocity are essential for successful technique execution. Small differences in biomechanical efficiency can significantly influence the effectiveness of attacks and defensive actions during competition. Therefore, understanding biomechanical determinants is essential for improving technical performance and optimizing training strategies. Although previous research has separately examined physiological or biomechanical characteristics in judo athletes, limited studies have integrated both domains to provide a comprehensive understanding of performance determinants in elite female judokas.

Furthermore, existing literature often focuses on male athletes or mixed samples, limiting the specificity of findings for women's judo. Given the increasing competitiveness of elite female judo, there is a need for more targeted research that combines physiological and biomechanical analysis. The present study aims to address this gap by investigating the physiological and biomechanical factors influencing performance in elite female judo athletes. Specifically, it examines anaerobic power, muscular strength, fatigue resistance, grip strength, throwing velocity, movement efficiency, and execution time, and their relationship with competitive performance outcomes. It is hypothesized that athletes with higher physiological capacity and greater biomechanical efficiency will demonstrate superior competitive performance. The findings are expected to provide evidence-based insights for coaches and sport scientists to improve training design and athlete development in elite female judo.

A cross-sectional analytical study design was used to investigate the physiological and biomechanical factors influencing performance in elite female judo athletes. The study aimed to examine the relationship between selected performance variables and competitive outcomes at the international level. The sample consisted of elite female judokas competing in international judo tournaments. Athletes were selected based on their participation in high-level competitions and availability of performance data. Only athletes with complete physiological, biomechanical, and competition records were included in the analysis. Physiological variables assessed included anaerobic power, upper-body muscular strength, and fatigue resistance. Anaerobic power was evaluated using standardized sprint or Wingate-type testing protocols, while muscular strength was measured through grip strength and upper-body strength tests. Fatigue resistance was assessed using repeated effort performance indicators. Biomechanical variables included grip strength, throwing velocity, movement efficiency, and execution time of judo techniques. These variables were obtained through a combination of laboratory-based measurements and video-based notational analysis of competition footage. Movement efficiency and execution time were analyzed using motion analysis software. Competitive performance was evaluated based on match outcomes (win/loss) and technical effectiveness indicators derived from official competition results and notational analysis. Data analysis was conducted using statistical software. Descriptive statistics (mean and standard deviation) were calculated for all variables.

Pearson correlation analysis was performed to examine relationships between physiological, biomechanical, and performance variables. Multiple regression analysis was used to identify the strongest predictors of competitive success. Statistical significance was set at $p < 0.05$.

Ethical considerations were observed in accordance with international research standards.

Where applicable, athlete data were anonymized, and only publicly available or consented performance data were used in the study.

The analysis revealed significant relationships between physiological and biomechanical variables and competitive performance in elite female judo athletes. Descriptive results showed that higher-performing athletes demonstrated greater anaerobic power, superior upper-body muscular strength, and improved fatigue resistance compared with lower-performing athletes.

These physiological advantages were consistently associated with better match outcomes and higher technical efficiency. Correlation analysis indicated a strong positive relationship between anaerobic power and competitive success ($p < 0.05$). Upper-body muscular strength, particularly grip strength, also showed a significant association with match victories and effective technique execution. Fatigue resistance was moderately correlated with sustained performance across match duration. Biomechanical analysis demonstrated that grip strength and throwing velocity were key discriminators between successful and less successful athletes. Athletes with higher grip strength were able to establish dominant grips more frequently, leading to improved control of opponents and increased scoring opportunities. Faster execution times of throwing techniques were significantly associated with higher scoring efficiency and reduced counterattack vulnerability. Movement efficiency was also positively related to performance outcomes. Athletes who demonstrated more economical and coordinated movement patterns were more successful in transitioning between offensive and defensive phases of combat. Multiple regression analysis showed that the combination of anaerobic power, grip strength, and throwing velocity significantly predicted competitive performance. Among these, grip strength and throwing velocity emerged as the strongest predictors of success in elite female judo competition.

The present study investigated the physiological and biomechanical factors influencing performance in elite female judo athletes. The main findings indicate that anaerobic power, upper-body muscular strength, grip strength, throwing velocity, and movement efficiency are key determinants of competitive success. These results highlight the integrated nature of physical and mechanical attributes in high-performance judo. A primary finding of this study is the strong relationship between anaerobic power and competitive performance. Judo is characterized by repeated high-intensity efforts with limited recovery, requiring athletes to rely heavily on anaerobic energy systems. Athletes with higher anaerobic capacity are better able to sustain explosive actions such as throws, grips, and transitions throughout the match. This supports previous research suggesting that anaerobic fitness is a critical performance component in combat sports. Upper-body muscular strength, particularly grip strength, was also identified as a significant predictor of success. Grip fighting is a fundamental aspect of judo that determines control, attack initiation, and defensive stability. Athletes with superior grip strength were able to dominate gripping exchanges, restrict opponent movement, and create more scoring opportunities.

These findings emphasize the importance of developing specific strength training programs focused on upper-body and grip performance.

Biomechanical variables, especially throwing velocity and movement efficiency, further distinguished successful athletes from less successful ones. Faster execution of throwing techniques reduces the opponent's reaction time and increases the likelihood of scoring.

Additionally, efficient movement patterns contribute to better energy conservation and improved tactical positioning during combat. These results suggest that biomechanical optimization is essential for enhancing technical effectiveness in elite judo. The regression analysis confirmed that a combination of physiological and biomechanical factors provides a stronger explanation of performance than any single variable alone. This indicates that elite judo performance is multifactorial and requires an integrated training approach. Coaches should therefore combine strength and conditioning programs with technical and biomechanical skill development. Despite these findings, the study has some limitations. The cross-sectional design does not allow for causal inference. Additionally, the sample was limited to elite female athletes, which may restrict generalizability to other populations such as male or junior athletes. Future research should consider longitudinal designs and include psychological and tactical variables to provide a more comprehensive understanding of performance determinants.

In conclusion, elite female judo performance is strongly influenced by the interaction of physiological capacity and biomechanical efficiency. Developing anaerobic power, muscular strength, grip performance, and technical execution speed should be prioritized in training programs to enhance competitive success.

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