



Stable technical profile despite increasing technical diversity across the last three Olympic cycles in elite female extra-lightweight judo

Perfil técnico estable pese al incremento de la diversidad técnica durante los tres últimos ciclos olímpicos en el judo femenino de élite de peso extraligero

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Abstract

Objective: To analyze the technical-tactical behavior and scoring effectiveness of techniques in elite female extra-lightweight (≤ 48 kg) judo across the last three Olympic cycles (2016, 2020, and 2024).

Methods: A retrospective observational study which analyzed 159 official International Judo Federation World Circuit contests (53 per cycle) involving athletes ranked among the top 20 in the World Ranking. A total of 107 scoring techniques were identified according to the *Kodokan* classification and the official IJF rules applicable to each Olympic cycle.

Results: No significant differences were observed in the distribution of technical groups across Olympic cycles ($\chi^2=3.109$, $p=0.927$; Cramér's $V=0.121$). Likewise, the distribution of techniques resulting in *Ippon* ($\chi^2=3.637$, $p=0.888$) and *Waza-ari* ($\chi^2=6.383$, $p=0.604$) remained stable. Although the overall technical profile was preserved, the diversity of individual scoring techniques increased from 17 techniques in the 2016 Olympic cycle to 24 in the 2020 cycle, and remained high in 2024 (23 techniques). *Sode-tsuri-komi-goshi* predominated in 2016, whereas *Ouchi-gari* became the most frequent scoring technique in 2020 and remained among the leading techniques in 2024. *Katame-waza* consistently produced most *Ippon*, whereas *Ashi-waza* and *Te-waza* remained the principal sources of *Waza-ari*.

Conclusions: Despite successive IJF rule modifications, the technical profile of elite female extra-lightweight judo remained remarkably stable across the last three Olympic cycles. Elite athletes expanded their technical repertoire while maintaining the effectiveness of the principal scoring strategies, providing coaches with evidence to optimize weight category-specific technical and tactical training.

Keywords

Judo; combat sports; technical-tactical analysis; Olympic Games; performance analysis; women.

Resumen

Objetivo: Analizar el comportamiento técnico-táctico y la eficacia de las técnicas de puntuación en el judo femenino de élite de peso extraligero (≤ 48 kg) durante los tres últimos ciclos olímpicos (2016, 2020 y 2024).

Métodos: Se realizó un estudio observacional retrospectivo con 159 combates oficiales del Circuito Mundial de la Federación Internacional de Judo (53 por ciclo), disputados por atletas clasificadas entre las 20 mejores del ranking mundial. Se identificaron 107 técnicas de puntuación según la clasificación Kodokan y el reglamento oficial vigente de la FIJ en cada ciclo.

Resultados: No se observaron diferencias significativas en la distribución de los grupos técnicos entre los ciclos olímpicos ($\chi^2=3.109$, $p = 0.927$; V de Cramér=0.121). La distribución de las técnicas que obtuvieron *Ippon* ($\chi^2=3.637$, $p=0.888$) y *Waza-ari* ($\chi^2=6.383$, $p=0.604$) también permaneció estable. Aunque el perfil técnico general se conservó, la diversidad de las técnicas de puntuación aumentó de 17 en 2016 a 24 en 2020 y se mantuvo elevada en 2024 (23). *Sode-tsuri-komi-goshi* predominó en 2016, mientras que *Ouchi-gari* fue la técnica más frecuente en 2020 y siguió entre las principales en 2024. *Katame-waza* produjo la mayoría de los *Ippon*, mientras que *Ashi-waza* y *Te-waza* fueron las principales fuentes de *Waza-ari*.

Conclusiones: A pesar de las sucesivas modificaciones del reglamento de la FIJ, el perfil técnico del judo femenino de élite de peso extraligero permaneció estable durante los tres últimos ciclos olímpicos. Las atletas ampliaron su repertorio técnico sin perder la eficacia de las principales estrategias de puntuación, proporcionando evidencia para optimizar el entrenamiento técnico-táctico específico de la categoría.

Palabras clave

Judo; deportes de combate; análisis técnico-táctico; Juegos Olímpicos; análisis del rendimiento; mujeres.



Introduction

The spread of female judo worldwide occurred later than that of men's judo, mainly due to prejudice regarding women's participation in combat sports (Kavoura, Kokkonen, Chroni, & Ryba, 2018). The first World Judo Championship was held in 1956 and was exclusively for men; women were only allowed to compete in 1980, when an individual tournament was organized for them, and championships for both sexes were only established in 1987 (Sato, 2013). Female judo debuted as a demonstration sport at the 1988 Olympic Games with 54 competitors, and became an official Olympic sport in 1992 (Kavoura et al., 2018). Since then, Olympic qualification has been based on performance in International Judo Federation (IJF) World Circuit events (Grand Prix, Grand Slam, World Championships, and Masters), in which athletes accumulate ranking points throughout the four-year Olympic cycle (Barreto, Aedo-Muñoz, Sorbazo Sotto, Miarka, & Brito, 2022; Barreto, Aedo-Muñoz, Soto, Miarka, & Brito, 2022).

As the sport has evolved, the IJF has periodically updated its competition rules to improve fairness, athlete safety, and spectator appeal (Barreto, Aedo-Muñoz, Sorbazo Sotto, et al., 2022). These rule modifications directly influence the technical-tactical behavior of elite athletes during competition (Barreto, Aedo-Muñoz, Soto, Miarka, & Brito, 2021; Barreto, Aedo-Muñoz, Soto, et al., 2022; Barreto, Miarka, et al., 2022), reinforcing the need for continuous monitoring of performance indicators across successive Olympic cycles. Despite the remarkable growth of female judo at the competitive level, this evolution has not been accompanied by a proportional increase in scientific evidence. Most previous studies have focused on male athletes, combined data from both sexes, or analyzed female competitors without distinguishing between weight categories, limiting the practical application of their findings (Barreto et al., 2021; Barreto, Miarka, et al., 2022; Błach et al., 2021; Ceylan & Balci, 2021; Ceylan, Balci, Taşkın, & Santos, 2022; Ceylan, Ozturk, & Balci, 2022; Díaz-De-Durana, Bello, Brito, & Miarka, 2018).

Technical and tactical actions are key determinants of competitive success in judo (Balci & Ceylan, 2020; Ceylan & Balci, 2021; Ceylan, Balci, et al., 2022; Díaz-De-Durana et al., 2018; Dopico-Calvo et al., 2023; Krumer, 2017). Athletes score using Nage-waza (throwing techniques) and Katame-waza (grappling techniques), which comprise distinct groups of techniques with different biomechanical demands (Brandão Kashiwagura, Courel-Ibáñez, Brandão Kashiwagura, Agostinho, & Franchini, 2021; Kłys, Sterkowicz-przybycień, Adam, & Casals, 2020). Because female judo comprises seven official weight categories with distinct body profiles, technical-tactical behavior and scoring effectiveness should not be expected to be homogeneous across divisions. Indeed, previous studies have demonstrated that athletes in the ≤ 48 kg category exhibit technical-tactical behaviors that differ from those of other female weight categories during the 2012, 2016, and 2020 Olympic cycles (Barreto et al., 2023; Barreto, Miarka, et al., 2022; Sterkowicz-Przybycień, Miarka, & Fukuda, 2017). These findings reinforce the importance of investigating each female weight category separately rather than extrapolating conclusions across divisions.

Previous studies have substantially advanced understanding of technical-tactical performance in judo by investigating combat dynamics, time-motion characteristics, technical actions, gripping behavior, and performance indicators in female athletes (Kłys et al., 2020; Miarka et al., 2014; Miarka, Pérez, Aedo-Muñoz, da Costa, & Brito, 2020). Other investigations have examined technical efficiency during specific competitions, such as the Olympic Games, or compared technical-tactical profiles according to sex or weight category (Adam, Tabakov, Blach, & Smaruj, 2013; Ahmedov et al., 2024; R. L. Kons, Júnior, Fischer, & Detanico, 2018). However, these studies have generally been limited to a single competition or Olympic cycle, combined athletes from different female weight categories, or described the frequency of technical actions without examining how the effectiveness of scoring techniques evolves within the same weight division under successive IJF rule changes. Furthermore, most available evidence is based on isolated competitions rather than on athletes' performances throughout an entire Olympic qualification cycle. Consequently, there is still a lack of longitudinal evidence describing how the scoring effectiveness of techniques changes across multiple Olympic cycles in elite female judokas from a single weight category.

To the best of our knowledge, no previous study has longitudinally investigated the evolution of scoring technique effectiveness in the female extra-lightweight category (≤ 48 kg) across the last three Olympic cycles using athletes competing at the highest international level throughout the Olympic qualification process. Addressing this gap may provide coaches and athletes with more precise, weight category-



specific evidence to optimize technical training and tactical preparation according to the evolving competitive demands of each Olympic cycle. In order to address this gap, this study aimed to analyze the technical-tactical behavior and the scoring effectiveness of techniques in elite female extra-lightweight (≤ 48 kg) judo across the last three Olympic cycles (2016, 2020, and 2024). We hypothesized that technical effectiveness would differ across Olympic cycles conducted under different IJF competition rules, while Ashi-waza and Te-waza would remain consistently effective scoring actions in the ≤ 48 kg category. This hypothesis is based on the premise that technical variety stems from athletes' learning and adaptation processes throughout Olympic cycles — which would compromise the effectiveness of techniques used in previous cycles — as well as from rule changes (such as the elimination of Yuko scoring and modifications regarding permitted grips and throw-scoring criteria) that drive a renewal of the techniques applied by athletes in each cycle. However, the results of Pinto (2015) already indicate a greater use of Ashi-waza and Te-waza among female judokas (Pinto, 2015), although this analysis does not differentiate between weight categories. Therefore, the results of this study will provide weight category-specific evidence that may support coaches in designing technical training and tactical strategies aligned with the competitive demands of each Olympic cycle.

Method

Experimental approach

This observational, retrospective study employed a technical-tactical performance analysis to investigate the evolution of scoring technique effectiveness in elite female judo across the last three Olympic cycles (2016, 2020, and 2024). In turn, official contests from the International Judo Federation (IJF) World Circuit were analyzed to address the study hypothesis, including Grand Prix, Grand Slam, World Championships, and Masters events that comprised the Olympic qualification process. Only athletes ranked among the top 20 of the IJF World Ranking in each Olympic cycle were included, ensuring that the sample represented the highest competitive level. The analysis exclusively focused on attack techniques that resulted in scores, allowing comparisons of the distribution and effectiveness of technical actions across Olympic cycles conducted under different IJF competition rules. Data were obtained exclusively from publicly available videos, and only variables directly related to the study objective were extracted. Therefore, in accordance with applicable ethical guidelines for research using publicly available data, institutional ethics committee approval was not required.

Video sample

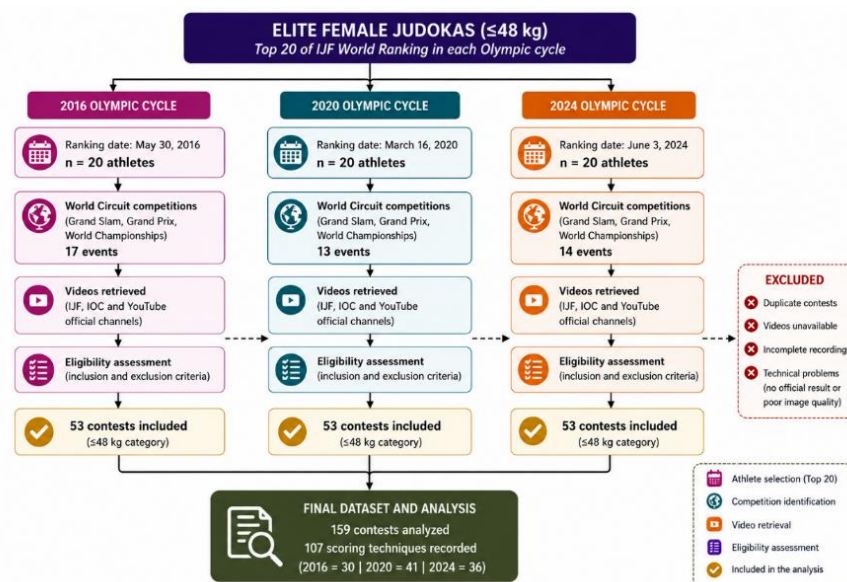
A total of 159 official videos of female judo combats in the extra-lightweight category (≤ 48 kg) were analyzed, comprising 53 combats from each of the last three Olympic cycles (2016, 2020, and 2024). A total of 107 scoring techniques were recorded across these combats (2016 = 30; 2020 = 41; 2024 = 36). The analyzed combats involved athletes ranked among the top 20 of the International Judo Federation (IJF) World Ranking, according to the ranking lists published on May 30, 2016, March 16, 2020, and June 3, 2024 (IJF, 2016, 2020, 2024). Only official IJF World Circuit events that contributed to the Olympic ranking were considered to ensure that the sample represented the highest competitive level throughout each Olympic qualification period.

Videos were obtained from publicly available sources, including the International Judo Federation (IJF), the International Olympic Committee (IOC), and official YouTube channels. In total, combats from 44 international competitions were analyzed, distributed across the three Olympic cycles as follows: (a) 2016 Olympic cycle (17 competitions): five Grand Slams (Abu Dhabi 2016, Baku 2016, Paris 2016, Tokyo 2015, and Tokyo 2016), eleven Grand Prix (Almaty 2016, Budapest 2016, Düsseldorf 2016, Havana 2016, Jeju 2015, Qingdao 2015, Samsun 2015 and 2016, Ulaanbaatar 2016, and Tbilisi 2015 and 2016), and one World Championship (Astana 2015). (b) 2020 Olympic cycle (13 competitions): two Grand Slams (Abu Dhabi 2019 and Baku 2019), ten Grand Prix (Antalya 2019, Budapest 2019, Hohhot 2019, Marrakech 2019, Montreal 2019, Tashkent 2019, Tbilisi 2019, Zagreb 2019, and Tel Aviv 2019 and 2020), and one World Championship (Tokyo 2019). (c) 2024 Olympic cycle (14 competitions): eight Grand Slams (Antalya 2023, Baku 2024, Paris 2023 and 2024, Tashkent 2024, Tbilisi 2023, Tel Aviv 2023, and Tokyo 2023), four Grand Prix (Dushanbe 2023, Portugal 2024, Upper Austria 2023 and 2024), and two World Championships (Doha 2023 and Abu Dhabi 2024).



An a priori contest sample size calculation was performed using G*Power software (version 3.1.9.7; Heinrich-Heine University Düsseldorf, Germany) to ensure adequate statistical power for the planned analyses. Because the contest was considered the experimental unit, the sample size estimation was based on the number of combats required for each statistical procedure. The Kruskal–Wallis test was used to compare variables across the three Olympic cycles, assuming a medium effect size (Cohen's $f = 0.25$; $\epsilon^2 = 0.06$), a significance level of 5%, and a statistical power of 80%, resulting in a minimum required sample of 159 contests (53 contests per Olympic cycle). Chi-squared tests of independence were applied to categorical variables, with the estimated minimum sample size composed of 133 contests, assuming a medium effect size (Cramér's $V = 0.30$, $\alpha = 0.05$, and power = 0.80). Accordingly, the final sample comprised 159 contests (53 per Olympic cycle), exceeding the minimum requirement for all planned analyses and providing sufficient statistical power to detect meaningful differences while minimizing the probability of Type II error. Figure 1 presents the flowchart of the video selection process and the final contest sample.

Figure 1. Flow diagram illustrating the identification, screening, eligibility assessment, and inclusion processes for the judo contests analyzed throughout the 2016, 2020, and 2024 Olympic cycles. Created via Canva (Canva Pty Ltd., Sydney, Australia).



Data collection procedures

Videos were analyzed using VLC Media Player and Frami software (version 1.2.1.1). Each combat was reviewed by a judo specialist (3rd Dan black belt) following a previously validated observational protocol (Miarka, Hayashida, Julio, Calmet, & Franchini, 2011). The executed technique and the corresponding score for each scoring action were recorded according to the Kodokan technical classification (Barreto, Aedo-Muñoz, Sorbazo Sotto, et al., 2022; Miarka, Fukuda, Del Vecchio, & Franchini, 2016) and the official International Judo Federation (IJF) competition rules in force during each Olympic cycle (Barreto et al., 2021; Federation, 2023, 2025). Scores resulting exclusively from penalties (Shido accumulation or Hansoku-make) were not included in the analysis, as the purpose of the study was to evaluate the effectiveness of scoring techniques rather than victories or score advantages obtained through rule infringements.

Following technical identification, each scoring technique was classified according to the score awarded by the referee. Techniques during the 2016 Olympic cycle could be awarded Yuko, Waza-ari, or Ippon. Yuko was removed following the 2017 IJF rule changes, and equivalent actions were incorporated into Waza-ari for the 2020 and 2024 Olympic cycles. Accordingly, the scoring classification adopted in the analyses was consistent with the official IJF rules applicable to each Olympic cycle.

Statistical analysis

All data were organized in Microsoft Excel (Microsoft Corporation, version 2019) before statistical analysis. We assessed the reliability of the expert's analysis using the Intraclass Correlation Coefficient (ICC) to ensure data consistency. The expert analyzed 10 combat videos, which were re-analyzed at random after a 24-hour interval. To classify levels of agreement, we used the classification proposed by Koo and Li (2016). We observed excellent agreement for all analyzed variables (ICC: Ashi-waza = 0.91; Te-waza = 0.9; Koshi-waza = 0.96; Sutemi-waza = 1; Osaekomi-waza = 1; Shime-waza = 1; Kansetsu-waza = 1). Descriptive statistics were used to summarize the data from this study; these are presented as frequencies and percentages values, according to the distribution of each variable. Heat map figures were used to demonstrate the frequency distribution of the analyzed variables. Statistical analyses were performed using Python (version 3.11) with the SciPy and Statsmodels libraries. Associations between Olympic cycle and categorical variables were examined using Chi-squared tests of independence. Effect size was estimated using Cramér's *V* and interpreted as small (≈ 0.1), medium (≈ 0.3), and large (≈ 0.5) (Cramér, 1999). Statistical significance was established at $p < 0.05$ for all analyses.

The contest was defined as the experimental unit for the a priori sample size calculation, whereas scoring techniques constituted the unit of analysis for the subsequent chi-squared tests of independence. A total of 107 scoring techniques were identified across 159 independent contests. All scoring techniques observed within each contest were systematically recorded according to the validated observational protocol. Given that the number of scoring techniques included in the statistical analyses was lower than the number of contests used in the a priori sample size calculation, the initial sample size estimation was considered conservative. Each contest was treated as an independent observational unit.

Results

Figure 2 shows the percentage distribution of the 107 techniques scored in each Olympic cycle, according to technique type. No significant differences were observed in the distribution of technical groups (Ashi-waza, Koshi-waza, Te-waza, Sutemi-waza, and Katame-waza) across the three Olympic cycles ($\chi^2 = 3.109$, $p = 0.927$), with a small effect size (Cramér's *V* = 0.121).

Figure 2. Heatmap showing the frequency distribution of scoring technique groups in elite female extra-lightweight (≤ 48 kg) judo across the 2016, 2020, and 2024 Olympic cycles. Color intensity represents scoring frequency. Sutemi-waza includes Ma-sutemi-waza and Yoko-sutemi-waza, whereas Katame-waza includes Osaekomi-waza, Shime-waza, and Kansetsu-waza. Created using Canva (Canva Pty Ltd., Sydney, Australia).

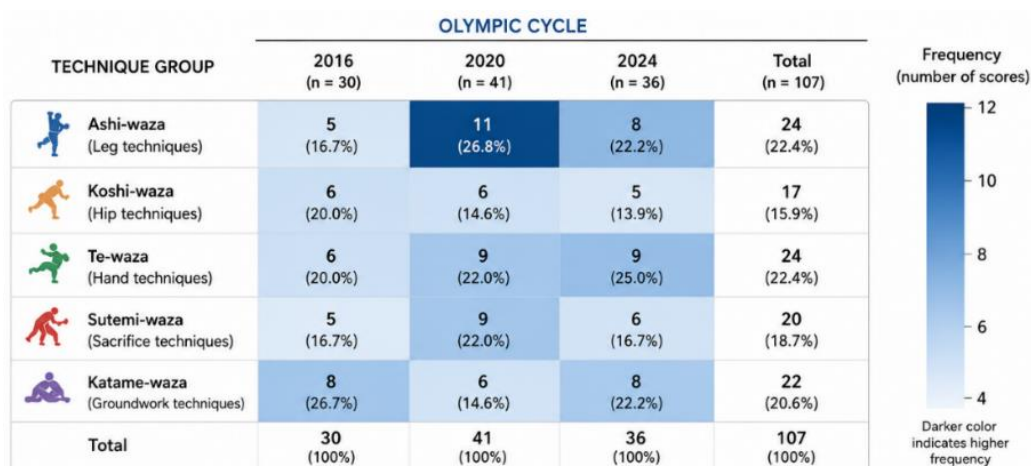
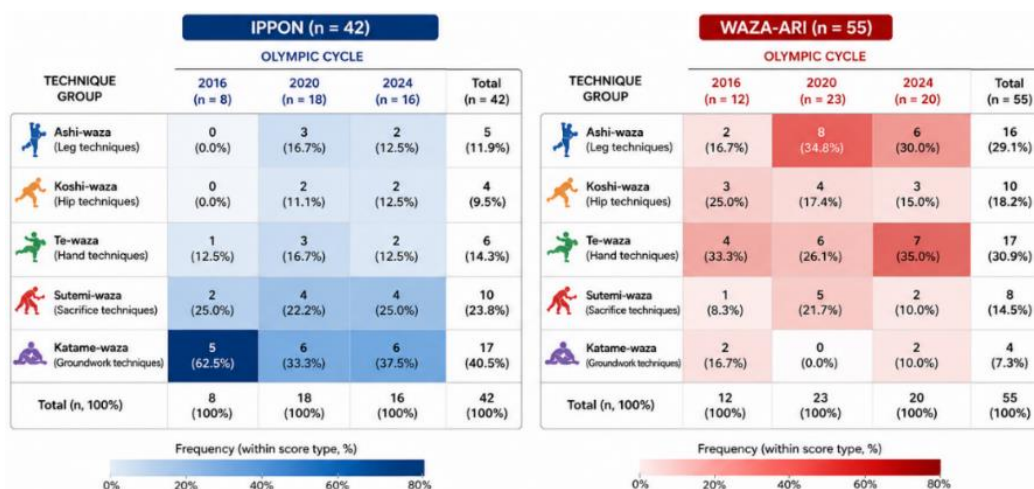


Figure 3 shows the distribution of technique groups resulting in *Ippon* remained stable across the three Olympic cycles, with no significant differences observed between the 2016, 2020, and 2024 cycles ($\chi^2 = 3.637$, $p = 0.888$), and a small effect size (Cramér's *V* = 0.208). Likewise, the distribution of technique groups resulting in *Waza-ari* did not differ significantly across Olympic cycles ($\chi^2 = 6.383$, $p = 0.604$), with a small association (Cramér's *V* = 0.241).



Figure 3. Distribution of technique groups resulting in Ippon and Waza-ari in elite female extra-lightweight (≤ 48 kg) judo across the 2016, 2020, and 2024 Olympic cycles. Values are presented as absolute frequencies and percentages. Color intensity represents relative frequency. Sutemi-waza includes Ma-sutemi-waza and Yoko-sutemi-waza, whereas Katame-waza includes Osaekomi-waza, Shime-waza, and Kansetsu-waza. Created using Canva (Canva Pty Ltd., Sydney, Australia).



Regarding the techniques that scored as *Yuko*, which only existed in the 2016 cycle, *Ashi-waza* and *Koshi-waza* stand out ($n=3$, representing 30% of the techniques scored as *Yuko* for both), followed by *Sutemi-waza* ($n=2$, 20%), *Te-waza* and *Katame-waza* ($n=1$, 10% for both). A total of 107 scoring actions representing 39 individual *Kodokan* techniques were recorded in the ≤ 48 kg category across the 2016, 2020, and 2024 Olympic cycles. Technical diversity increased from 17 different scoring techniques in the 2016 Olympic cycle to 24 in the 2020 cycle and remained high in the 2024 cycle (23 techniques). Despite this increase in technical diversity, the overall distribution of individual scoring techniques remained stable across Olympic cycles ($\chi^2 = 11.013$, $p = 0.881$; Cramér's $V = 0.128$). The complete frequency distribution of individual scoring techniques across the three Olympic cycles is presented in Supplementary Figure S1.

Discussion

The present study analyzed the technical-tactical behavior and scoring effectiveness of elite female extra-lightweight (≤ 48 kg) judo athletes across the last three Olympic cycles (2016, 2020, and 2024). Contrary to our initial hypothesis, the successive modifications to the IJF competition rules did not substantially alter the overall technical profile of this weight category. The distribution of the main technical groups remained stable across the three Olympic cycles, and no significant changes were observed in the techniques responsible for Ippon or Waza-ari scores. Therefore, our hypothesis was only partially supported, since *Ashi-waza* and *Te-waza* remained consistently effective throughout the study period as expected, whereas the overall distribution of scoring techniques did not differ among Olympic cycles. These findings suggest that despite continuous adaptations to the competition rules, the technical characteristics associated with success in elite female extra-lightweight judo have remained remarkably consistent over time (Barreto et al., 2023).

Although the overall technical profile remained stable, an important finding was the increase in the diversity of scoring techniques throughout the study period. The number of different *Kodokan* techniques resulting in scoring actions increased from 17 in the 2016 Olympic cycle to 24 in the 2020 cycle and remained high in the 2024 cycle (23 techniques). This broader technical repertoire indicates that elite athletes progressively expanded the variety of effective scoring actions without modifying the predominant scoring profile of the category. Similar findings were reported by Adam et al. (2013), who observed that the Olympic champion in the ≤ 48 kg category presented one of the highest indices of effective technical versatility among all female weight divisions. Together, these findings suggest that

technical versatility is an important characteristic of successful athletes in the extra-lightweight division, allowing adaptation to evolving competitive demands while preserving the effectiveness of the principal scoring strategies.

Among the individual scoring techniques, noteworthy temporal trends emerged across Olympic cycles. Sode-tsuri-komi-goshi was the most frequent scoring technique during the 2016 Olympic cycle, whereas Ouchi-gari became predominant in the 2020 cycle and remained among the leading techniques in 2024. In contrast, the 2024 Olympic cycle exhibited a more balanced distribution of scoring techniques, with Ouchi-gari and Uki-otoshi presenting similar frequencies. These findings indicate that elite female judokas adjusted their selection of individual techniques over time without substantially changing the broader technical profile of the category, constituting a consistent pattern with previous evidence demonstrating rule-related but weight-specific technical-tactical adaptations in women's judo (Barreto et al., 2023; Barreto, Miarka, et al., 2022).

The predominance of Sode-tsuri-komi-goshi during the 2016 Olympic cycle deserves particular attention because technical preferences in judo are strongly influenced by sex and weight category (Batista, Sequeira, Gancho, & Fernandes, 2022). One plausible explanation is that IJF rule modifications introduced during this period, including the requirement that judogi sleeves cover the arms up to the wrist joint, favored gripping configurations commonly associated with this technique (Ito, Hirose, Maekawa, Tamura, & Nakamura, 2015). Supporting this interpretation, previous investigations demonstrated that athletes in the ≤ 48 kg category exhibited a distinctive gripping behavior compared with the other female weight divisions, characterized by greater use of bilateral sleeve grips, which are classically employed to execute Sode-tsuri-komi-goshi (Barreto et al., 2023; Barreto, Miarka, et al., 2022). Likewise, analyses of the 2017 World Judo Championships identified a predominance of forward rotational techniques supported on both feet, including Sode-tsuri-komi-goshi, O-goshi, Koshi-guruma, Seoi-nage, and Seoi-otoshi, reinforcing the importance of this technical pattern during the Rio Olympic cycle (Barreto, Aedo-Muñoz, Sorbazo Sotto, et al., 2022).

Despite its prominence in 2016, the frequency of Sode-tsuri-komi-goshi declined during the subsequent Olympic cycles. One plausible explanation is the natural adaptation of opponents and coaches, who progressively develop defensive strategies against techniques which prove highly successful in elite competition. Similar adaptation processes have been described following IJF rule modifications, with tactical adjustments representing one of the principal coping strategies adopted by elite athletes (Samuel, Basevitch, Wildikan, Prosoli, & McDonald, 2020). Consistent with this interpretation, athletes in the ≤ 48 kg category maintained their characteristic bilateral sleeve gripping behavior during the 2020 Olympic cycle despite the reduced prominence of Sode-tsuri-komi-goshi, suggesting that the gripping strategy persisted while athletes diversified the techniques executed from these positions (Barreto et al., 2023).

Another factor that may have contributed to this reduction is the evolution of the IJF scoring system. The elimination of Yuko after the 2016 Olympic cycle resulted in actions previously awarded Yuko being incorporated into Waza-ari, directly influencing the interpretation of longitudinal scoring frequencies (Barreto et al., 2023; Katicips, Júnior, Kons, & Detanico, 2018). Consequently, part of the apparent reduction in techniques such as Sode-tsuri-komi-goshi may reflect changes in score attribution rather than a true decline in technical effectiveness (Dopico-Calvo et al., 2023; Katicips et al., 2018). Furthermore, subsequent rule modifications altered the strategic value of penalties and gripping behavior throughout contests (Barreto, Miarka, et al., 2022; Dopico-Calvo et al., 2023). Within this context, the ≤ 48 kg category accumulated a greater number of sleeve-related penalties, suggesting that gripping management became an increasingly important tactical component after the rule modifications (Barreto et al., 2023; Kajmovic, Karpljuk, Kapo, & Simenko, 2022). Collectively, these findings reinforce that apparent changes in technique frequency should be interpreted considering the continuous evolution of the competitive rules.

While Sode-tsuri-komi-goshi declined after 2016, Ouchi-gari became the most frequent individual scoring technique during the 2020 Olympic cycle and remained among the leading techniques in 2024. Previous studies demonstrated that athletes in the ≤ 48 kg category progressively adopted more diverse two-handed gripping configurations, including sleeve-collar, dorsal-collar, and dorsal-dorsal grips, all of which facilitate executing techniques such as Ouchi-gari, Soto-makikomi, and Kata-otoshi (Barreto et al., 2023; Kajmovic et al., 2022). The emergence of Ouchi-gari may therefore represent an adaptation



toward techniques that are compatible with more versatile gripping configurations while maintaining high scoring effectiveness. This interpretation agrees with the overall stability observed in the distribution of technical groups despite subtle modifications in individual technique selection.

Our findings partially agree with those of Ojeda-Aravena, Moronta, Calvo-Rico, Azócar-Gallardo, & García-García (2025), who reported a predominance of Katame-waza for Ippon and Nage-waza for Waza-ari when the ≤ 48 kg and ≤ 52 kg categories were analyzed together across the 2016 and 2020 Olympic Games. Likewise, Moronta et al. (2025) demonstrated structured relationships between score type and technical groups during Olympic competition, whereas R. Kons et al. (2022) observed that medalists presented greater variability in Nage-waza and Katame-waza, particularly among female athletes. Together, these findings support the interpretation that successful athletes expand their technical repertoire rather than relying on a single attack pattern. Nevertheless, important differences regarding the predominant individual techniques were observed between those studies and the present investigation, probably because previous analyses combined adjacent weight categories or different Olympic cycles. The present study demonstrates that even within the lightest female divisions, each weight category exhibits specific technical characteristics that may remain hidden when categories are analyzed together.

Finally, the stability observed in the distribution of Katame-waza, Ashi-waza, and Te-waza reinforces the central finding of the present study. Despite successive IJF rule modifications and the progressive diversification of individual scoring techniques, the main technical groups responsible for successful scoring actions remained remarkably consistent across three consecutive Olympic cycles. To the best of our knowledge, this is the first longitudinal investigation demonstrating that the technical profile of elite female extra-lightweight judo remained stable despite substantial regulatory changes over three Olympic cycles. These findings provide novel evidence that technical adaptation at the highest competitive level primarily occurs through expanding the technical repertoire rather than replacing the main scoring strategies.

A limitation of this study is that only scoring techniques were analyzed. Victories obtained exclusively through opponent penalties or by score advantage at the end of regular time were intentionally excluded because the primary objective was to investigate the evolution of technical scoring effectiveness. Future studies should integrate technical performance with combat outcomes, penalty dynamics, and gripping strategies to provide a more comprehensive understanding of competitive success in elite female judo. Another limitation is that this study analyzed only elite athletes—specifically, the top twenty ranked athletes globally during each Olympic cycle—meaning the results may not be representative of athletes at other competitive levels.

Practical applications

Despite the absence of significant temporal differences in the distribution of technical groups and scoring techniques across the last three Olympic cycles, the present findings provide valuable practical information for coaches and athletes. The stability of the technical profile suggests that Katame-waza remains the most effective strategy for achieving Ippon, whereas Ashi-waza and Te-waza continue to represent the principal standing techniques associated with Waza-ari scoring in elite female extra-lightweight judo. Consequently, these technical groups should remain priorities during long-term technical development.

Furthermore, the increase in the diversity of scoring techniques demonstrates that successful athletes have progressively expanded their technical repertoire while maintaining the effectiveness of the principal scoring strategies. Therefore, coaches should encourage athletes to develop a broad range of offensive options without neglecting the technical groups that have consistently produced scoring actions over multiple Olympic cycles. Finally, the detailed distribution of individual scoring techniques presented in Supplementary Figure S1 provides an evidence-based reference for technical and tactical planning. Coaches may use these data to identify the techniques most frequently associated with successful scoring in each Olympic cycle, assisting in the selection of offensive strategies, the design of individualized training programs, and the preparation of defensive tactics against the techniques most commonly employed by elite opponents in the ≤ 48 kg category.



Conclusions

Despite successive IJF rule modifications, the technical profile of elite female extra-lightweight judokas remained remarkably stable throughout the last three Olympic cycles. Although athletes progressively expanded their repertoire of effective scoring techniques, the distribution of the main technical groups and the techniques responsible for *Ippon* and *Waza-ari* remained consistent over time. These findings suggest that elite athletes adapt by increasing technical diversity rather than replacing the principal scoring strategies. Consequently, coaches should prioritize the continued development of *Ashi-waza*, *Te-waza*, and *Katame-waza* while simultaneously encouraging broader technical versatility to meet the evolving demands of international competition.

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