Technical-tactical profiles of winners and losers in elite female boxing: insights from the most recent Pan American and Olympic games

Perfiles técnico-tácticos de las boxeadoras ganadoras y perdedoras de élite: perspectivas de los Juegos Panamericanos y los Juegos Olímpicos más recientes

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Abstract

Objective: To compare the technical-tactical profiles of elite female boxers according to competition level (Santiago 2023 Pan American Games vs. Paris 2024 Olympic Games), weight category, round, and bout outcome.
Methods: A retrospective observational study was conducted using official videos from the Santiago 2023 Pan American Games and the Paris 2024 Olympic Games. Thirty bouts were analysed (60 athlete-bout observations; 180 rounds); Round-of-32 bouts were excluded because this phase occurred only in the Olympic tournament. Technical-tactical actions were classified as displacement, attack, defence, clinch, and pause, and normalised by effective bout time (actions·s^{-1}). Data were analysed using linear mixed-effects models accounting for the nesting of rounds within bouts.
Results: Competition level influenced displacement, attack, and defence rates, all of which were higher during the Pan American Games than during the Olympic Games ($p \leq 0.024$). Weight category influenced displacement, attack, and defence rates, with lower- and intermediate-weight categories exhibiting higher values than the higher-weight category ($p \leq 0.022$). Round affected clinch and pause rates, both of which increased from the first to the second and third rounds ($p \leq 0.005$). Bout outcome influenced attack rate, with losers displaying higher values than winners ($p = 0.014$), whereas no outcome-related differences were observed for the remaining variables.
Conclusions: Competition level and weight category influenced the technical-tactical demands of elite female boxing. Higher attack frequency among losers, without corresponding differences in defence or displacement, reinforces that success in elite female boxing depends on the effectiveness of technical execution rather than on action volume.

Keywords

Elite female boxing, Performance indicators, Technical-tactical behavior, Olympic Games, Winning performance.

Resumen

Objetivo: Comparar los perfiles técnico-tácticos de las boxeadoras de élite según el nivel de competición (Juegos Panamericanos Santiago 2023 vs. Juegos Olímpicos París 2024), la categoría de peso, el asalto y el resultado del combate.
Métodos: Se realizó un estudio observacional retrospectivo utilizando vídeos oficiales de los Juegos Panamericanos Santiago 2023 y los Juegos Olímpicos París 2024. Se analizaron 30 combates (60 observaciones atleta-combate; 180 asaltos); los combates de octavos de final fueron excluidos debido a que esta fase se presentó únicamente en el torneo olímpico. Las acciones técnico-tácticas se clasificaron en desplazamiento, ataque, defensa, clinch y pausa, y se normalizaron por el tiempo efectivo de combate (acciones·s^{-1}). Los datos se analizaron mediante modelos lineales mixtos, considerando la estructura jerárquica de los asaltos dentro de los combates.
Resultados: El nivel de competición influyó en las tasas de desplazamiento, ataque y defensa, todas ellas superiores durante los Juegos Panamericanos en comparación con los Juegos Olímpicos ($p \leq 0.024$). La categoría de peso influyó en las tasas de desplazamiento, ataque y defensa, observándose valores superiores en las categorías de menor e intermedio peso en comparación con la categoría de mayor peso ($p \leq 0.022$). El asalto afectó las tasas de clinch y pausa, ambas aumentando del primero al segundo y tercer asalto ($p \leq 0.005$). El resultado del combate influyó en la tasa de ataque, siendo mayor en las perdedoras que en las ganadoras ($p = 0.014$), mientras que no se observaron diferencias relacionadas con el resultado en las demás variables.
Conclusiones: El nivel de competición y la categoría de peso influyeron en las demandas técnico-tácticas del boxeo femenino de élite. La mayor frecuencia de ataques en las perdedoras, sin diferencias correspondientes en defensa o desplazamiento, refuerza que el éxito depende de la eficacia de la ejecución técnico-táctica más que del volumen de acciones.

Palabras clave

Boxeo femenino de élite; indicadores de rendimiento; comportamiento técnico-táctico; Juegos Olímpicos; rendimiento ganador.

Introduction

Olympic boxing requires athletes to continuously adapt their behavior in response to rapidly changing competitive situations, combining offensive and defensive actions while managing physical and cognitive demands throughout the contest. Because boxing performance emerges from the interaction of technical, tactical, physical, and physiological factors, success at the elite level depends not only on athletes' physical capacities but also on their ability to make effective tactical decisions and execute technical actions under pressure(Ruddock et al., 2021; Slimani et al., 2017). These differences can be theoretically framed by ecological dynamics, which conceptualizes combat sports as interpersonal synergies in which technical-tactical behavior emerges from the continuous interaction between athletes and their environment (Araújo et al., 2006; Krabben et al., 2019). Within this perspective, perception-action coupling plays a central role, as boxers perceive and exploit affordances for action—such as punching opportunities constrained by distance and opponent behavior (de Quel & Bennett, 2019; Hristovski et al., 2006). Moreover, elite performance requires effective decision-making under pressure, since time constraints, competitive anxiety, and physiological arousal can alter perceptual strategies and motor execution (Nieuwenhuys & Oudejans, 2017).

These demands are particularly evident in international competitions, where small differences in performance may determine bout outcomes. In recent years, performance analysis has become an essential approach for understanding the competitive demands of Olympic boxing and for supporting evidence-based coaching practices. Through systematic observation of bouts, technical-tactical analysis provides objective information regarding athletes' competitive behavior, allowing coaches and researchers to identify the actions associated with successful performance and to optimize training strategies (Ashker, 2011; Davis et al., 2017). Variables such as offensive activity, defensive behavior, punching effectiveness, and action patterns have been widely investigated because they provide meaningful indicators of competitive performance.

Previous investigations consistently report that successful boxers tend to display greater offensive efficiency, higher punching accuracy, and more effective defensive execution than defeated athletes (Ashker, 2011; Davis et al., 2017; Kruszewski et al., 2016). However, these technical-tactical characteristics are not static and may vary according to the competitive context, tournament characteristics, and the continuous evolution of Olympic boxing (Ashker, 2011; Davis et al., 2017; Deng et al., 2026). Consequently, periodic analyses using recent elite competitions are necessary to update the understanding of the sport and provide practitioners with information that reflects the current competitive environment (Deng et al., 2026). Although the literature describing Olympic boxing performance has expanded considerably, including recent analyses of men's Olympic bouts (Gutiérrez-Santiago et al., 2024; Gutiérrez-Santiago et al., 2023), evidence regarding elite female boxing remains limited (Deng et al., 2026; Martusciello et al., 2025a; Martusciello et al., 2025b; Shtanagei & Saveniuk, 2025). The first detailed technical-tactical analysis of elite female boxing was conducted under the previous 4 × 2 min competition format and included only the three Olympic weight categories contested at the London 2012 Olympic Games (Davis et al., 2016).

More recent investigations have advanced the understanding of women's boxing by examining technical-tactical actions (Deng et al., 2026; Martusciello et al., 2025a; Shtanagei & Saveniuk, 2025), time-motion characteristics (Martusciello et al., 2025a), and key performance indicators within the newly introduced 50 kg Olympic weight category (Deng et al., 2026). However, these studies have generally focused on a single competition, a specific tournament stage (e.g., championship finals), or an individual weight category, limiting the understanding of technical-tactical behavior across the current Olympic structure. Moreover, direct comparisons between major continental competitions and the Olympic Games remain scarce, despite these events representing distinct competitive contexts within the same Olympic cycle and potentially imposing different technical-tactical demands. This gap has important practical implications because the Pan American Games represent one of the highest-level continental competitions and serve as an important milestone in athletes' preparation for Olympic participation, whereas the Olympic Games constitute the highest level of international competition. Understanding how technical-tactical actions vary across these competitive contexts, while considering weight category, round, and bout outcome, may assist coaches in designing representative training tasks, optimizing tactical preparation, and establishing performance benchmarks for elite female boxers transitioning

from continental to Olympic competition. Therefore, the present study aimed to compare the technical-tactical behavior of elite female boxers between the Santiago 2023 Pan American Games and the Paris 2024 Olympic Games, while examining the effects of weight category, competitive phase, and bout outcome. Specifically, we aimed (i) to compare technical-tactical action rates between competitions and across weight categories; (ii) to determine whether technical-tactical behavior differed between winners and losers; and (iii) to examine how technical-tactical behavior varied across competitive phases (Round of 16, quarter-finals, semi-finals, and finals) within each competition, given the progressive demands imposed by single-elimination tournaments as bouts become increasingly decisive. We hypothesized that (i) Olympic bouts would exhibit distinct technical-tactical patterns compared with Pan American bouts, reflecting greater competitive pressure and a more selective and evenly matched field of opponents; (ii) lower- and intermediate-weight categories would show higher action rates than the heaviest category; (iii) winners and losers would not differ substantially in action frequency, given the high and relatively homogeneous skill level of elite athletes; and (iv) technical-tactical activity would vary across competitive phases, with a more conservative pattern characterized by lower action rates and more frequent pauses in the decisive phases (semi-finals and finals), particularly at the Olympic Games.

Method

Experimental approach

This retrospective observational study examined the technical-tactical behavior of elite female boxers competing at two major international events of the current Olympic cycle: the Santiago 2023 Pan American Games and the Paris 2024 Olympic Games. These competitions were selected because they represent distinct competitive contexts, with the Pan American Games constituting a major continental event within the Olympic qualification pathway and the Olympic Games representing the highest level of international amateur boxing competition. Official bout videos were obtained from the Pan American Sports Organization and official Olympic broadcasting platforms and accessed on October 2025. All eligible bouts were systematically analyzed using a validated boxing-specific observational protocol previously described by Lima et al. (2022). The protocol enables the objective quantification of technical-tactical actions through continuous notational analysis throughout the entire duration of each bout.

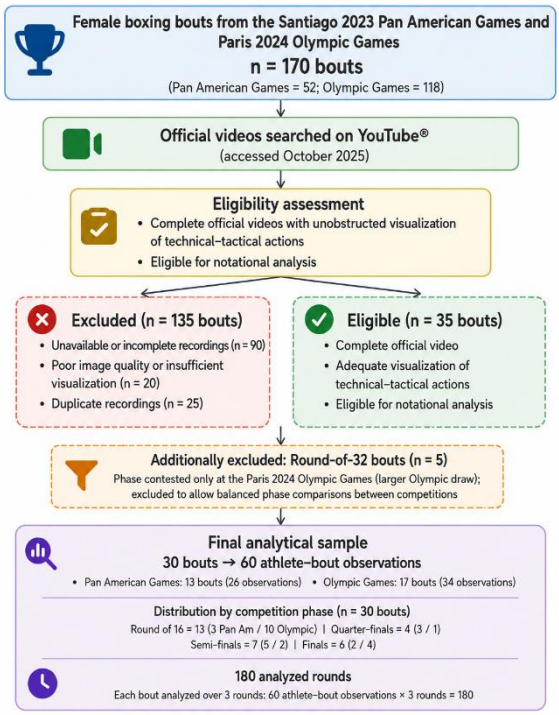
For each athlete, technical-tactical actions were coded across all rounds and subsequently classified according to four contextual factors: (i) competition (Santiago 2023 Pan American Games or Paris 2024 Olympic Games), (ii) weight-category group, (iii) round (first, second, and third), and (iv) bout outcome (winner or loser). The observational protocol quantified five categories of technical-tactical actions: displacement, attack, defense, clinch, and pause. To account for differences in effective fighting time, all variables were normalized according to effective bout duration and expressed as action rates (actions·s^{-1}), allowing standardized comparisons between competitions, weight-category groups, rounds, and bout outcomes. The study was based exclusively on retrospective analysis of publicly available video footage of official competitions broadcast on YouTube®. As no direct contact with athletes, intervention, or collection of identifiable personal data was involved, ethical approval and informed consent were not required. The study complied with applicable institutional and ethical guidelines for research involving publicly available audiovisual data and was exempted from ethical review in accordance with institutional regulations.

Participants and video sample

Official videos of all female boxing bouts contested at the Santiago 2023 Pan American Games (n = 52 bouts) and the Paris 2024 Olympic Games (n = 118 bouts) were systematically screened on YouTube® accessed on October 2025. The selection process followed predefined eligibility criteria. Complete official recordings with unobstructed visualization of the technical-tactical actions were eligible for analysis. Videos were excluded when recordings were unavailable, incomplete, duplicated, or of insufficient quality to allow reliable identification and coding of the technical-tactical actions. Duplicate recordings were identified by comparing event, bout, athletes, round, and video content, and only one complete official recording of each bout was retained.

Of the 170 available female bouts, 135 bouts were excluded, comprising 90 unavailable/incomplete recordings, 20 poor-quality recordings, and 25 duplicate recordings, resulting in 35 eligible bouts with complete data. Additionally, the five bouts from the Round-of-32 phase were excluded because this phase was contested only at the Paris 2024 Olympic Games, reflecting the larger Olympic draw, and its inclusion would prevent balanced phase comparisons between competitions. The final analytical sample therefore comprised 30 bouts, corresponding to 60 athlete-bout observations and 180 analyzed rounds: 13 bouts from the Santiago 2023 Pan American Games (26 athlete-bout observations) and 17 bouts from the Paris 2024 Olympic Games (34 athlete-bout observations). Each bout contributed two athlete performances, one winner and one loser.

Figure 1. Flowchart illustrating the selection process of the female boxing bouts included in the study.



The final sample comprised bouts distributed across the Round of 16, quarter-final, semifinal, and final phases, with 13 (3 Pan-American and 10 Olympic), 4 (3 Pan-American and 1 Olympic), 7 (5 Pan-American and 2 Olympic), and 6 (2 Pan-American and 4 Olympic) bouts, respectively. For analytical purposes, the six Olympic weight categories were grouped into three weight-category groups according to body mass: Lower Weight Categories (LWC; 50 kg and 54 kg), Intermediate Weight Categories (IWC; 57 kg and 60 kg), and Higher Weight Categories (HWC; 66 kg and 75 kg). The distribution of athlete-bout observations and analyzed rounds across competitions and weight-category groups is presented in Table 1. The IWC represented the largest proportion of the sample, whereas the LWC and HWC contributed similar numbers of observations.

Table 1. Distribution of athlete-bout observations and analyzed rounds according to competition and weight-category group.

Weight Category	Pan American Games 2023	Olympic Games 2024	Total
LWC (50 kg and 54 kg)	6 (18)	8 (24)	14 (42)
IWC (57 kg and 60 kg)	14 (42)	18 (54)	32 (96)
HWC (67 kg and 75 kg)	6 (18)	8 (24)	14 (42)
Total	26 (78)	34 (102)	60 (180)

Note: Values are presented as athlete-bout observations (analyzed rounds). LWC = Lower Weight Categories; IWC = Intermediate Weight Categories; HWC = Higher Weight Categories.

Technical-Tactical Performance Assessment

All bouts were processed using Frami® software through frame-by-frame notational analysis. The observational protocol was based on the validated methodology proposed by Lima et al. (2022), which allows systematic quantification of boxing actions throughout the contest. Athletes' behavior was classified into five technical-tactical dimensions: displacement, attack, defense, clinch, and pause. Each action was recorded continuously from the beginning to the end of each round. Displacement included forward, backward, and lateral displacements within the ring. Attacks comprised offensive actions initiated with the intention of scoring, including punches and arm extensions. Defensive actions included movements intended to avoid, neutralize, or reduce the effectiveness of an opponent's attack, such as evasions, slips, blocks, pendulum movements, and guard actions. Clinch situations were recorded when one or both athletes established body contact that prevented immediate offensive exchanges, until separation occurred naturally or through referee intervention. Pause periods comprised official interruptions, including referee stoppages, warnings, equipment adjustments, and medical attention. All variables were expressed as action rates (actions·s^{-1}) and normalized by the effective fighting time of each round. Effective fighting time was defined as the official round duration (180 s) minus the total pause time recorded in that round. Thus, technical-tactical rates were calculated as the cumulative frequency of each action divided by the effective fighting time, providing a standardized measure of action intensity during periods in which the bout was actively underway.

Reliability Procedures

To verify the consistency of the observational analysis, intra-rater reliability was assessed using a test–retest design. The complete dataset was coded by a single analyst with previous experience in boxing performance analysis. After a four-week interval, approximately 10% of the sample was randomly selected and independently reanalyzed to minimize potential recall bias. The reproducibility of continuous variables (technical-tactical action rates) was quantified using the Intraclass Correlation Coefficient (ICC), whereas Cohen's Kappa coefficient was used to evaluate agreement for categorical variables. ICC values ranged from 0.88 to 0.96 across all technical-tactical variables, while Kappa coefficients exceeded 0.90, indicating excellent agreement according to the recommendations of Koo and Li (2016). These results demonstrate high temporal consistency of the observational measurements.

Statistical analysis

Technical-tactical actions were expressed as rates (actions·s^{-1}), normalized by the effective fighting time of each round. The analytical dataset comprised 180 rounds nested within 60 athlete-bout observations, corresponding to 30 bouts, with each bout contributing one winner and one loser. Seven athletes competed in more than one bout. Linear mixed-effects models (LMMs) were used to account for the hierarchical and non-independent structure of the data. Separate models were fitted for each technical-tactical rate (displacement, attack, defense, clinch, and pause), with competition (Santiago 2023 Pan American Games vs. Paris 2024 Olympic Games), weight category (LWC, IWC, and HWC), round (1–3), and bout outcome (winner vs. loser) specified as fixed effects. Random intercepts for bout and athlete were included to account for the dependence between performances within the same bout, the repeated rounds within each performance, and the repeated participation of athletes across bouts. Models were estimated using maximum likelihood, and statistical inference was based on z-tests of the fixed effects. Estimated marginal means were compared using Tukey-adjusted post-hoc tests, and marginal coefficients of determination (R^2m) were reported. Competitive phase was examined as an a priori analytical objective, given the progressive structure of single-elimination tournaments. For each technical-tactical variable, the phase × competition interaction was tested using likelihood-ratio tests comparing models with and without the interaction term. Competitive phase included the Round of 16, quarter-finals, semi-finals, and finals. When a significant interaction was detected, estimated marginal means were compared across phases within each competition using Tukey-adjusted post-hoc tests.

To examine differences between winners and losers at the bout level, two complementary paired approaches were used. First, within-bout comparisons between the winner and loser were performed using paired-samples t-tests or Wilcoxon signed-rank tests, as appropriate, based on the assessment of normality with the Shapiro–Wilk test. Effect sizes were expressed as Cohen's dz. Second, conditional logistic regression stratified by bout was used to examine the association between each technical-tacti-

cal variable and bout outcome. Results were expressed as odds ratios (ORs) with 95% confidence intervals per one-standard-deviation increase in each variable. Both univariable and multivariable models were fitted. All analyses were performed in Python 3.12 using the SciPy and Statsmodels libraries. Statistical significance was set at $p \leq 0.05$.

Results

The linear mixed-effects models (with random intercepts for bout and athlete) indicated that competition influenced displacement ($\beta = 0.03$, $p = 0.024$), attack ($\beta = 0.055$, $p = 0.014$), and defense rate ($\beta = 0.034$, $p = 0.003$). Estimated marginal means showed higher displacement (0.345 vs. 0.315 actions·s^{-1}; $\beta = 0.03$, $p = 0.024$), attack (0.444 vs. 0.389 actions·s^{-1}; $\beta = 0.055$, $p = 0.014$), and defense (0.155 vs. 0.122 actions·s^{-1}; $\beta = 0.034$, $p = 0.003$) rates during the Pan American Games than during the Olympic Games. Across weight categories, the IWC and LWC showed higher displacement, attack, and defense rates than the HWC. For displacement, differences were observed for IWC ($p \leq 0.001$) and LWC ($p = 0.015$); for attack, for IWC ($p \leq 0.001$) and LWC ($p \leq 0.001$); and for defense, for IWC ($p \leq 0.001$) and LWC ($p = 0.013$). Detailed descriptive statistics and pairwise comparisons are presented in Table 2.

Table 2. Technical-tactical action rates (actions·s^{-1}) according to competition, outcome, and weight-category group.

Competition	Outcome	LWC	IWC	HWC
Displacement				
Pan-2023 *	Winner	0.31±0.04 [0.28, 0.35]	0.34±0.07 [0.31, 0.37]	0.26±0.04 [a] [0.23, 0.3]
	Loser	0.33±0.05 [0.29, 0.37]	0.34±0.07 [0.3, 0.38]	0.28±0.06 [a] [0.23, 0.32]
Olympic-2024	Winner	0.28±0.07 [0.24, 0.33]	0.31±0.06 [0.28, 0.34]	0.24±0.03 [a] [0.22, 0.26]
	Loser	0.3±0.06 [0.26, 0.33]	0.3±0.06 [0.28, 0.33]	0.25±0.04 [a] [0.23, 0.28]
Attack				
Pan-2023 *	Winner	0.47±0.09 [0.39, 0.54]	0.41±0.11 [0.37, 0.46]	0.31±0.06 [a] [0.26, 0.36]
	Loser	0.45±0.1 [0.37, 0.54]	0.45±0.09 [0.4, 0.5]	0.33±0.11 [a] [0.24, 0.42]
Olympic-2024	Winner	0.35±0.12 [0.27, 0.43]	0.39±0.11 [0.34, 0.43]	0.26±0.05 [a] [0.23, 0.29]
	Loser	0.39±0.1 [0.33, 0.46]	0.38±0.1 [0.34, 0.42]	0.30±0.1 [a] [0.24, 0.37]
Defense				
Pan-2023 *	Winner	0.18±0.07 [0.12, 0.24]	0.16±0.05 [0.14, 0.18]	0.1±0.05 [a] [0.06, 0.13]
	Loser	0.13±0.03 [0.1, 0.15]	0.17±0.07 [0.14, 0.2]	0.1±0.04 [a] [0.07, 0.14]
Olympic-2024	Winner	0.12±0.03 [0.1, 0.14]	0.12±0.06 [0.1, 0.14]	0.1±0.05 [a] [0.06, 0.13]
	Loser	0.11±0.05 [0.08, 0.14]	0.12±0.06 [0.1, 0.14]	0.08±0.06 [a] [0.04, 0.13]
Clinch				
Pan-2023	Winner	0.04±0.02 [0.02, 0.06]	0.03±0.02 [0.02, 0.04]	0.03±0.03 [0.01, 0.05]
	Loser	0.04±0.02 [0.02, 0.05]	0.03±0.02 [0.02, 0.04]	0.02±0.03 [0.01, 0.05]
Olympic-2024	Winner	0.03±0.02 [0.01, 0.04]	0.03±0.01 [0.02, 0.04]	0.03±0.02 [0.02, 0.05]
	Loser	0.04±0.03 [0.02, 0.05]	0.03±0.02 [0.03, 0.04]	0.02±0.02 [0.01, 0.04]
Pause				
Pan-2023	Winner	0.02±0.01 [0.01, 0.03]	0.02±0.01 [0.01, 0.02]	0.03±0.02 [0.01, 0.04]
	Loser	0.02±0.01 [0.01, 0.03]	0.02±0.01 [0.01, 0.02]	0.02±0.02 [0.01, 0.04]
Olympic-2024	Winner	0.02±0.02 [0.01, 0.03]	0.02±0.01 [0.02, 0.03]	0.02±0.01 [0.01, 0.03]
	Loser	0.02±0.01 [0.01, 0.03]	0.02±0.01 [0.02, 0.03]	0.02±0.01 [0.01, 0.03]

Note: Values are presented as Mean ± SD [95% CI]. LWC = lower weight categories; IWC = intermediate weight categories; HWC = higher weight categories. Pan-2023 – Santiago Panamerican Games, Olympic-2024 – Paris Olympic Games. LWC – lower weight categories; IWC – intermediate weight categories; HWC – higher weight categories. * $p \leq 0.024$ vs. Olympic 2024; [a] $p \leq 0.015$ vs. IWC and LWC.

Clinch rate increased from round 1 to rounds 2 and 3 ($\beta = 0.009$, $p = 0.004$; $\beta = 0.011$, $p \leq 0.001$, respectively), while pause rate increased similarly ($\beta = 0.009$, $p \leq 0.001$; $\beta = 0.011$, $p \leq 0.001$, respectively), consistently across competitions and weight categories (Table 3).

Table 3. Round-by-Round Technical-Tactical Action Rates

Competition	Group	Outcome	Round 1	Round 2	Round 3
Displacement					
Pan-2023	LWC	Winner	0.35±0.03 [0.26, 0.44]	0.3±0.02 [0.24, 0.35]	0.3±0.05 [0.14, 0.46]
		Loser	0.38±0.02 [0.31, 0.44]	0.32±0.03 [0.21, 0.42]	0.29±0.04 [0.17, 0.41]
	IWC	Winner	0.38±0.05 [0.33, 0.44]	0.33±0.07 [0.27, 0.39]	0.31±0.06 [0.25, 0.36]
		Loser	0.36±0.06 [0.29, 0.44]	0.33±0.06 [0.26, 0.4]	0.33±0.08 [0.23, 0.42]
	HWC	Winner	0.27±0.04 [0.2, 0.34]	0.27±0.05 [0.1, 0.43]	0.26±0.03 [0.17, 0.34]
		Loser	0.28±0.07 [0.07, 0.48]	0.28±0.06 [0.1, 0.46]	0.27±0.05 [0.14, 0.41]
Olympic-2024	LWC	Winner	0.29±0.08 [0.15, 0.44]	0.29±0.07 [0.17, 0.41]	0.27±0.05 [0.17, 0.36]
		Loser	0.26±0.06 [0.16, 0.37]	0.33±0.05 [0.24, 0.42]	0.3±0.04 [0.23, 0.36]

	IWC	Winner	0.29±0.06 [0.24, 0.34]	0.31±0.07 [0.25, 0.38]	0.32±0.07 [0.26, 0.38]
		Loser	0.3±0.06 [0.26, 0.35]	0.3±0.07 [0.25, 0.35]	0.31±0.06 [0.26, 0.35]
	HWC	Winner	0.22±0.01 [0.2, 0.24]	0.26±0.03 [0.2, 0.32]	0.25±0.03 [0.2, 0.3]
		Loser	0.26±0.03 [0.21, 0.3]	0.25±0.04 [0.18, 0.33]	0.25±0.04 [0.18, 0.31]
Attack					
Pan-2023	LWC	Winner	0.49±0.04 [0.37, 0.61]	0.44±0.07 [0.24, 0.64]	0.47±0.13 [0.09, 0.86]
		Loser	0.54±0.1 [0.25, 0.84]	0.44±0.09 [0.17, 0.7]	0.38±0.02 [0.34, 0.43]
	IWC	Winner	0.47±0.11 [0.35, 0.58]	0.4±0.11 [0.31, 0.5]	0.38±0.08 [0.31, 0.45]
		Loser	0.5±0.11 [0.38, 0.62]	0.43±0.07 [0.34, 0.51]	0.42±0.08 [0.34, 0.51]
	HWC	Winner	0.30±0.08 [0.16, 0.44]	0.29±0.03 [0.21, 0.38]	0.33±0.06 [0.16, 0.50]
		Loser	0.34±0.13 [0.01, 0.73]	0.31±0.12 [0.01, 0.67]	0.33±0.06 [0.15, 0.51]
Olympic-2024	LWC	Winner	0.38±0.08 [0.23, 0.53]	0.37±0.14 [0.11, 0.62]	0.30±0.11 [0.1, 0.49]
		Loser	0.34±0.07 [0.21, 0.47]	0.42±0.11 [0.21, 0.63]	0.41±0.08 [0.26, 0.56]
	IWC	Winner	0.36±0.07 [0.30, 0.42]	0.40±0.13 [0.29, 0.51]	0.39±0.12 [0.28, 0.50]
		Loser	0.38±0.09 [0.31, 0.45]	0.37±0.10 [0.3, 0.45]	0.39±0.11 [0.30, 0.47]
	HWC	Winner	0.26±0.02 [0.23, 0.29]	0.28±0.06 [0.16, 0.4]	0.24±0.05 [0.15, 0.33]
		Loser	0.27±0.08 [0.12, 0.41]	0.34±0.09 [0.18, 0.51]	0.30±0.10 [0.11, 0.49]
Defense					
Pan-2023	LWC	Winner	0.25±0.07 [0.03, 0.46]	0.14±0.05 [0.01, 0.3]	0.14±0.04 [0.02, 0.26]
		Loser	0.14±0.03 [0.03, 0.24]	0.12±0.02 [0.05, 0.2]	0.12±0.04 [0.01, 0.25]
	IWC	Winner	0.17±0.03 [0.14, 0.2]	0.15±0.05 [0.1, 0.19]	0.16±0.05 [0.11, 0.21]
		Loser	0.19±0.06 [0.12, 0.26]	0.17±0.06 [0.1, 0.23]	0.15±0.07 [0.07, 0.23]
	HWC	Winner	0.11±0.03 [0.05, 0.17]	0.11±0.06 [0.01, 0.29]	0.06±0.03 [0.01, 0.15]
		Loser	0.12±0.00 [0.1, 0.13]	0.10±0.06 [0.01, 0.28]	0.09±0.04 [0.01, 0.21]
Olympic-2024	LWC	Winner	0.12±0.05 [0.03, 0.2]	0.12±0.03 [0.07, 0.16]	0.13±0.01 [0.11, 0.16]
		Loser	0.11±0.03 [0.05, 0.17]	0.14±0.05 [0.05, 0.23]	0.08±0.03 [0.01, 0.14]
	IWC	Winner	0.11±0.06 [0.06, 0.16]	0.11±0.04 [0.07, 0.15]	0.13±0.06 [0.08, 0.18]
		Loser	0.12±0.04 [0.09, 0.15]	0.12±0.05 [0.08, 0.15]	0.12±0.07 [0.07, 0.17]
	HWC	Winner	0.06±0.02 [0.03, 0.09]	0.12±0.04 [0.05, 0.18]	0.11±0.06 [0.01, 0.22]
		Loser	0.14±0.07 [0.02, 0.27]	0.06±0.04 [0.01, 0.13]	0.05±0.02 [0.01, 0.08]
Clinch					
Pan-2023	LWC	Winner	0.03±0.01 [0.01, 0.06] [a]	0.06±0.03 [0.01, 0.13]	0.04±0.02 [0.01, 0.12]
		Loser	0.02±0.01 [0.01, 0.06] [a]	0.05±0.02 [0.01, 0.1]	0.04±0.02 [0.01, 0.09]
	IWC	Winner	0.01±0.02 [0.01, 0.03] [a]	0.03±0.02 [0.02, 0.05]	0.04±0.02 [0.02, 0.06]
		Loser	0.02±0.02 [0.01, 0.05] [a]	0.03±0.02 [0.01, 0.05]	0.04±0.03 [0.01, 0.07]
	HWC	Winner	0.02±0.02 [0.01, 0.07] [a]	0.04±0.04 [0.01, 0.16]	0.03±0.03 [0.01, 0.11]
		Loser	0.01±0.02 [0.01, 0.07] [a]	0.02±0.03 [0.01, 0.13]	0.04±0.03 [0.01, 0.14]
Olympic-2024	LWC	Winner	0.02±0.01 [0.01, 0.05] [a]	0.03±0.02 [0.01, 0.06]	0.04±0.03 [0.01, 0.09]
		Loser	0.04±0.03 [0.01, 0.09] [a]	0.04±0.03 [0.01, 0.09]	0.03±0.02 [0.01, 0.07]
	IWC	Winner	0.03±0.01 [0.02, 0.04] [a]	0.03±0.01 [0.02, 0.04]	0.03±0.02 [0.01, 0.04]
		Loser	0.03±0.02 [0.02, 0.04] [a]	0.04±0.02 [0.02, 0.05]	0.03±0.01 [0.03, 0.04]
	HWC	Winner	0.04±0.02 [0.00, 0.09] [a]	0.02±0.01 [0.01, 0.05]	0.03±0.03 [0.00, 0.08]
		Loser	0.02±0.02 [0.01, 0.06] [a]	0.03±0.02 [0.01, 0.06]	0.02±0.02 [0.01, 0.06]
Pause					
Pan-2023	LWC	Winner	0.01±0.01 [0.01, 0.02] [a]	0.02±0.01 [0.01, 0.05]	0.02±0.01 [0.01, 0.04]
		Loser	0.01±0.01 [0.01, 0.02] [a]	0.02±0.01 [0.01, 0.05]	0.02±0.01 [0.01, 0.04]
	IWC	Winner	0.01±0.01 [0.01, 0.01] [a]	0.02±0.01 [0.01, 0.03]	0.02±0.01 [0.01, 0.03]
		Loser	0.01±0.01 [0.01, 0.02] [a]	0.02±0.01 [0.01, 0.02]	0.02±0.01 [0.01, 0.03]
	HWC	Winner	0.02±0.01 [0.01, 0.04] [a]	0.03±0.01 [0.01, 0.07]	0.03±0.03 [0.00, 0.12]
		Loser	0.01±0.01 [0.01, 0.06] [a]	0.03±0.02 [0.01, 0.08]	0.03±0.03 [0.00, 0.13]
Olympic-2024	LWC	Winner	0.01±0.01 [0.01, 0.02] [a]	0.03±0.02 [0.01, 0.06]	0.02±0.01 [0.00, 0.05]
		Loser	0.01±0.01 [0.01, 0.03] [a]	0.03±0.02 [0.01, 0.05]	0.02±0.02 [0.00, 0.05]
	IWC	Winner	0.03±0.01 [0.02, 0.04] [a]	0.02±0.01 [0.01, 0.03]	0.02±0.01 [0.01, 0.03]
		Loser	0.02±0.01 [0.01, 0.03] [a]	0.02±0.01 [0.01, 0.04]	0.02±0.01 [0.01, 0.03]
	HWC	Winner	0.01±0.01 [0.01, 0.02] [a]	0.02±0.01 [0.01, 0.04]	0.03±0.01 [0.00, 0.05]
		Loser	0.01±0.01 [0.00, 0.02] [a]	0.02±0.01 [0.01, 0.04]	0.03±0.02 [0.00, 0.05]

Note: Data expressed as Mean ± SD [95% CI]. Pan 2023– Santiago Panamerican Games, Olympic 2024– Paris Olympic Games, LWC – Lower Weight Categories; IWC – Intermediate Weight Categories; HWC – Higher Weight Categories. * $p \leq 0.004$ vs. Round 2 and 3.

Table 4 presents the bout analysis across competitive phases. Likelihood-ratio tests comparing mixed-effects models with and without the interaction term indicated significant phase × competition interactions for displacement rate ($\chi^2(3) = 20.05$, $p \leq 0.001$), attack rate ($\chi^2(3) = 11.88$, $p = 0.008$), defense rate ($\chi^2(3) = 9.92$, $p = 0.019$), clinch rate ($\chi^2(3) = 15.1$, $p = 0.002$), and pause rate ($\chi^2(3) = 16.49$, $p \leq 0.001$). Post-hoc analyses showed a marked reduction in displacement rate during the Olympic Games Finals compared with the Round of 16 ($p \leq 0.001$), for both winners and losers. Attack rate decreased from the semi-finals to the finals across both competitions ($p = 0.029$), while defense rate was lower in the Olympic Games Finals than in the Round of 16 ($p = 0.016$). At the Olympic Games, pause rate increased from the Round of 16 to the quarter- and semi-finals ($p = 0.003$).

Table 4. Competitive phase analysis at the Pan American games 2023 and the Olympic games 2024.

Competition	Outcome	Round of 16	Quarter-finals	Semi-finals	Finals
Displacement					
Pan-2023	Winner	0.3±0.05 [0.26, 0.34]	0.29±0.08 [0.23, 0.36]	0.34±0.05 [0.31, 0.37]	0.32±0.08 [0.26, 0.38]
	Loser	0.33±0.07 [0.28, 0.39]	0.31±0.08 [0.24, 0.37]	0.35±0.04 [0.32, 0.37]	0.22±0.01 [0.19, 0.24]
Olympic-2024	Winner	0.32±0.06 [0.3, 0.34]	0.28±0.02 [0.23, 0.33]	0.24±0.03 [0.21, 0.28]	0.22±0.02 [a] [0.21, 0.24]
	Loser	0.32±0.05 [0.3, 0.34]	0.27±0.01 [0.23, 0.3]	0.27±0.04 [0.22, 0.32]	0.22±0.03 [a] [0.2, 0.24]
Attack					
Pan-2023	Winner	0.33±0.04 [0.29, 0.36]	0.41±0.13 [0.31, 0.52]	0.46±0.09 [0.41, 0.51] [b]	0.36±0.11 [0.28, 0.45]
	Loser	0.49±0.09 [0.42, 0.56]	0.37±0.11 [0.28, 0.46]	0.45±0.07 [0.41, 0.49] [b]	0.23±0.04 [0.13, 0.34]
Olympic-2024	Winner	0.39±0.11 [0.35, 0.43]	0.33±0.02 [0.27, 0.39]	0.32±0.06 [0.25, 0.38] [b]	0.24±0.04 [a] [0.21, 0.27]
	Loser	0.42±0.09 [0.38, 0.45]	0.43±0.04 [0.32, 0.55]	0.33±0.08 [0.24, 0.43] [b]	0.25±0.0 [a] [0.21, 0.28]
Defense					
Pan-2023	Winner	0.2±0.06 [b] [0.15, 0.25]	0.11±0.06 [0.06, 0.16]	0.16±0.04 [0.14, 0.19]	0.1±0.04 [0.07, 0.13]
	Loser	0.1±0.03 [b] [0.08, 0.12]	0.18±0.05 [0.14, 0.22]	0.16±0.06 [0.12, 0.19]	0.07±0.04 [0.01, 0.19]
Olympic-2024	Winner	0.13±0.05 [0.12, 0.15]	0.13±0.02 [0.06, 0.2]	0.08±0.03 [0.05, 0.11]	0.08±0.04 [a] [0.05, 0.11]
	Loser	0.13±0.06 [0.1, 0.15]	0.05±0.01 [0.03, 0.07]	0.09±0.04 [0.05, 0.14]	0.08±0.03 [a] [0.06, 0.1]
Clinch					
Pan-2023	Winner	0.02±0.01 [0.01, 0.03]	0.02±0.03 [c] [0.01, 0.05]	0.04±0.02 [0.03, 0.05]	0.04±0.03 [0.02, 0.07]
	Loser	0.02±0.01 [0.01, 0.04]	0.02±0.03 [c] [0.01, 0.04]	0.04±0.02 [0.02, 0.05]	0.06±0.02 [0.01, 0.12]
Olympic-2024	Winner	0.03±0.02 [0.03, 0.04]	0.05±0.01 [0.01, 0.09]	0.03±0.01 [0.02, 0.04]	0.02±0.01 [0.02, 0.03]
	Loser	0.03±0.02 [0.02, 0.04]	0.05±0.01 [0.01, 0.08]	0.03±0.01 [0.02, 0.03]	0.02±0.01 [0.02, 0.03]
Pause					
Pan-2023	Winner	0.01±0.01 [0.01, 0.02]	0.01±0.01 [0.01, 0.02]	0.02±0.01 [0.02, 0.03]	0.03±0.02 [0.01, 0.05]
	Loser	0.01±0.01 [0.01, 0.02]	0.01±0.01 [0.01, 0.02]	0.02±0.01 [0.01, 0.03]	0.05±0.02 [0.01, 0.11]
Olympic-2024	Winner	0.02±0.01 [0.01, 0.02] [c]	0.04±0.01 [0.01, 0.07]	0.03±0.01 [0.02, 0.04]	0.02±0.01 [0.01, 0.03]
	Loser	0.02±0.01 [0.01, 0.02] [c]	0.03±0.01 [0.01, 0.07]	0.03±0.01 [0.01, 0.04]	0.02±0.01 [0.01, 0.03]

Note: Data expressed as Mean ± SD [95% CI]. Pan 2023– Santiago Panamerican Games, Olympic 2024– Paris Olympic Games, LWC – Lower Weight Categories; IWC – Intermediate Weight Categories; HWC – Higher Weight Categories. [a] $p \leq 0.016$ vs. Round of 16; [b] $p = 0.029$ vs. Finals; [c] $p = 0.003$ vs. Quarter and Semi-finals.

Complementary bout-level analyses examined whether technical-tactical variables discriminated winners from losers (Table 5). Paired within-bout comparisons (winner vs. loser; n = 30 bouts) revealed no significant differences in any variable, although displacement (dz = −0.35, p = 0.065) and attack rate (dz = −0.32, p = 0.087) tended to be higher among losers, consistent with the significant outcome effect on attack rate observed in the mixed-effects model. Similarly, bout-stratified conditional logistic regression showed that none of the variables significantly predicted winning. For each 1-SD increase, the odds of winning were 0.49 (95% CI: 0.22–1.09; p = 0.081) for displacement, 0.52 (0.24–1.14; p = 0.101) for attack rate, 1.41 (0.67–2.99; p = 0.369) for defense rate, 1.40 (0.66–2.97; p = 0.377) for clinch rate, and 1.43 (0.62–3.28; p = 0.398) for pause rate. A multivariable conditional model including all five variables likewise found no significant predictors of bout outcome (all p ≥ 0.4).

Table 5. Within-bout determinants of victory: paired comparisons and conditional logistic regression.

Variable	Paired difference	Cohen's dz	p	OR per 1 SD [95% CI]	p
Displacement rate	−0.01	−0.35	0.065	0.49 [0.22, 1.09]	0.081
Attack rate	−0.029	−0.32	0.087	0.52 [0.24, 1.14]	0.101
Defense rate	0.01	0.17	0.371	1.41 [0.67, 2.99]	0.369
Clinch rate	0.002	0.16	0.378	1.40 [0.66, 2.97]	0.377
Pause rate	0.001	0.16	0.385	1.43 [0.62, 3.28]	0.398

Discussion

The present study is the first, to our knowledge, to compare the technical-tactical behavior of elite female boxers between the Santiago 2023 Pan American Games and the Paris 2024 Olympic Games while simultaneously considering the influence of weight category, round, and bout outcome. Previous investigations have predominantly examined isolated competitions, specific tournament stages, or individual weight categories, limiting the understanding of how technical-tactical demands evolve across major international events within the same Olympic cycle. Although the literature describing female boxing has expanded in recent years, most studies have focused on World Championship competitions or specific Olympic weight divisions rather than comparing distinct competitive levels (Deng et al., 2026; Martusciello et al., 2025a; Martusciello et al., 2025b). The present findings demonstrate that competition level and weight category were the primary factors influencing technical-tactical behavior, whereas

bout outcome influenced only attack rate. Specifically, Pan American bouts were characterised by higher displacement, attack, and defence rates than Olympic contests, while lower- and intermediate-weight categories consistently exhibited greater technical-tactical activity than heavier athletes. The lower attack and defense rates observed in Olympic bouts compared with Pan American contests may be explained, at least in part, by the distinct psychological and contextual demands of the Olympic Games. As the pinnacle of elite sport, the Olympic Games impose unique stressors, including restricted qualification pathways, heightened media exposure, and the exceptional salience of medal outcomes, that increase competitive pressure and anxiety even among highly experienced athletes (Olusoga et al., 2012). Under such pressure, physiological arousal and competitive stress can alter perceptual-motor behavior by narrowing attention and modifying decision-making and movement organization (Nieuwenhuys & Oudejans, 2017), which may favor more conservative strategies, with athletes prioritizing action effectiveness and error minimization over action volume. In addition, the Olympic competitive field comprises a more highly selected pool of opponents, so that stronger and more evenly matched athletes may mutually constrain the emergence of offensive and defensive opportunities, reducing the overall frequency of Exchange (Krabben et al., 2019). It should be noted, however, that psychological variables were not directly assessed in this study; therefore, this interpretation remains speculative and should be examined in future research combining performance analysis with psychophysiological measures.

Complementing these findings, the complementary bout-level analyses (paired winner–loser comparisons and bout-stratified conditional logistic regression) showed that no technical-tactical variable significantly discriminated winners from losers. Together, these results indicate that the competitive context and body-mass division influence technical-tactical demands to a greater extent than action frequency differences between winners and losers. Defense, attack, and displacement are recognized as the dimensions that constitute the core of competitive behavior in boxing, jointly characterizing athletes' offensive and defensive actions and ring mobility (Ashker, 2011; Davis et al., 2017). However, the inability of action frequencies to discriminate bout outcomes suggests that technical-tactical action frequencies alone capture only part of what determines competitive performance. This finding aligns with predictive modelling applications in striking combat sports, in which models based on technical-tactical indicators achieve only moderate predictive power for bout outcomes (İnce et al., 2026). In elite competition, where athletes present high and homogeneous skill levels, differences between winners and losers may reside more in the quality, timing, and effectiveness of actions than in their frequency, as suggested by analyses indicating that punching accuracy, rather than punch volume, distinguishes successful boxers (Wandee & Benjapalakorn, 2018). Moreover, from an ecological dynamics perspective, competitive performance emerges from the continuous interaction between athletes and the specific constraints of each event, so that contextual factors (such as competition level and weight category), may exert a stronger influence on behavioral organization than the relatively small performance margins separating winners from losers (Krabben et al., 2019). This interpretation is consistent with the present finding that, among all the variables analyzed, only attack rate differed between winners and losers.

The lower displacement, attack, and defence rates observed in Olympic bouts compared with Pan American contests may be explained, at least in part, by the distinct psychological and contextual demands of the Olympic Games. Previous studies have demonstrated that elite boxing performance depends on the continuous interaction between offensive and defensive actions performed under substantial physiological stress, requiring athletes to repeatedly adjust their tactical behavior according to the opponent and competitive context (Ruddock et al., 2021; Slimani et al., 2017). A recent investigations in elite female boxing further support this interpretation by showing that the current 3 × 3 min competition format imposes high cardiovascular and metabolic demands, with athletes sustaining heart rates above 90% of maximum values and blood lactate concentrations approaching 15 $mmol \cdot L^{-1}$ throughout competition (Hausen et al., 2024). Under these conditions, the ability to sustain high-intensity efforts despite lower action frequencies during the Olympic Games likely reflects tactical strategies oriented toward effectiveness at the highest level of international competition rather than differences in physical preparation alone.

Weight category also influenced technical-tactical behavior. Lower- and intermediate-weight athletes performed attack and defense actions (and, in the intermediate categories, actions) more frequently than heavyweights. Similar observations have recently been reported by Martusciello et al. (2025b) who

demonstrated that temporal structure and combat dynamics differ across female Olympic weight divisions, with heavier categories exhibiting longer clinching periods and lower displacement intensity. These findings agree with previous observations in Olympic boxing indicating that body mass influences combat tempo and tactical organization (Davis et al., 2017; Kruszewski et al., 2016), while extending this evidence to the current female Olympic competition format.

Among the technical-tactical variables, only attack rate differed between winners and losers, with losers exhibiting higher attack rates than winners. This pattern may indicate that athletes trailing in the score increase their offensive activity in an attempt to overcome the deficit, whereas winners may rely more on the effectiveness of their actions than on offensive volume. Previous notational analyses have consistently reported that successful boxers distinguish themselves through greater punching accuracy, defensive effectiveness, tactical precision, and decision-making rather than simply producing a greater number of actions (Ashker, 2011; Davis et al., 2017; Davis et al., 2018; Dunn et al., 2017). Recent investigations focused specifically on elite female boxing reinforce this concept. Martusciello et al. (2025a) reported that winners demonstrated greater offensive and defensive efficiency despite performing a similar or even lower number of offensive actions than their opponents, suggesting that the effectiveness of technical execution may be more important than action frequency alone. This finding is consistent with the higher attack rates observed among losers in the present study. Likewise, Deng et al. (2026) demonstrated that successful female boxers are characterized by distinct offensive patterns, greater technical diversity, and higher scoring efficiency, with different tactical styles leading to successful performances. Collectively, these findings support the interpretation that action frequency represents only one component of competitive performance and that qualitative characteristics of technical execution are likely more relevant for determining success.

Furthermore, individual factors not captured by notational analysis may contribute to the scarcity of differences in action frequency between winners and losers. Psychological characteristics, including mental toughness, pre-competitive anxiety regulation, and the ability to cope with the specific stressors of major international events, may substantially influence the execution and effectiveness of technical-tactical actions (Jones et al., 2002). Likewise, athletes' injury history, particularly cumulative exposure to head impacts and knockout losses, has been associated with impairments in cognitive processing, reaction time, and motor performance (Heilbronner et al., 2009; Ramada et al., 2026), which may affect competitive behavior in subsequent bouts. In multi-bout tournaments, the accumulated physiological and cognitive demands of successive contests may further modulate performance across competition stages. Since these variables were not directly assessed in the present study, future investigations should integrate notational analysis with psychological and injury-history data to better explain outcome differences in elite female boxing.

This interpretation is reinforced by the complementary bout-level analyses: although attack rate was higher in losers according to the mixed-effects model, neither the paired within-bout comparisons nor the bout-stratified conditional logistic regression identified any variable capable of significantly discriminating winners from losers, indicating limited discriminatory ability when action frequencies are considered in isolation. Rather than identifying a single technical-tactical determinant of

success, these results suggest that competitive performance in elite female boxing results from the interaction of multiple factors. Previous studies have similarly emphasized that scoring effectiveness, tactical timing, punch selection, and the integration of offensive and defensive behaviors are more closely associated with winning than isolated measures of activity volume (Davis et al., 2018; Martusciello et al., 2025a; Martusciello et al., 2025b; Puchol et al., 2023). Therefore, the present findings reinforce that technical-tactical actions should be interpreted together with qualitative indicators of performance instead of relying exclusively on action frequency.

The findings of the present study should be interpreted in light of some limitations. First, the observational protocol quantified the frequency of technical-tactical actions but did not evaluate qualitative performance indicators such as punch accuracy, scoring effectiveness, punch type, combination patterns, or tactical decision-making. These variables have been shown to discriminate successful performances in elite boxing and may provide greater explanatory power than action frequency alone (Deng et al., 2026; Martusciello et al., 2025a; Martusciello et al., 2025b). A further limitation relates to the grouping of individual Olympic weight classes into broader weight-category groups. Although this approach in-

creased statistical robustness, it may have masked technical-tactical characteristics specific to individual weight divisions. Future investigations should examine each Olympic weight class separately to determine whether more specific competitive profiles exist. In addition, individual characteristics that may influence fighting style, including age, previous fight record, and years of training, were not systematically available for all athlete-bout observations and therefore could not be included in the analyses. These factors may contribute to differences in technical-tactical behavior and represent potential sources of unmeasured variability. Finally, contextual variables known to influence boxing performance, including score progression, opponent ranking, competitive balance, judging decisions, and fighting style, were not incorporated into the analyses. Integrating these factors with observational, biomechanical, physiological, and predictive modelling approaches may provide a more comprehensive understanding of performance determinants in elite female boxing.

Practical applications

The present findings provide practical implications for coaches and performance analysts working with elite female boxers. The higher attack and defense rates observed in Pan American compared with Olympic bouts suggest that athletes should be prepared to adapt to different competitive demands, including the higher action frequency characteristic of continental competition and the more constrained rhythm observed at the Olympic level. Rather than emphasizing action volume alone, training should prioritize the effective execution of technical-tactical actions under different bout tempos and competitive constraints. The findings also indicate distinct technical-tactical profiles across weight categories that may be considered when designing sport-specific training tasks. Lower and intermediate weight categories, which showed higher attack and defense rates, may benefit from training that emphasizes continuous footwork, rapid offensive initiation, defensive transitions, and repeated exchanges under high-tempo conditions. In heavier weight categories, training may place greater emphasis on positioning, controlled displacement, defensive organization, and the quality of offensive actions during lower-frequency exchanges. These differences should not, however, be interpreted as evidence that higher action frequency reflects superior performance, as the present study did not assess the effectiveness or outcome of individual actions. The progressive increase in pause and clinch frequencies across competition phases further suggests the importance of maintaining technical-tactical efficiency as bout rhythm changes. Training tasks should therefore reproduce the temporal characteristics of competition, including the intermittent work-to-rest demands and changes in action frequency observed across rounds and competitive phases. Finally, although attack rate was the only variable that differed between winners and losers, with higher values among losers, none of the technical-tactical variables consistently discriminated bout outcome in the within-bout analyses. This finding further supports an emphasis on the quality, efficiency, and tactical appropriateness of actions rather than on increasing action frequency alone. Collectively, these findings may help practitioners develop more context-specific training strategies and establish technical-tactical benchmarks according to competition level, weight category, and bout demands.

Conclusions

Competition level and weight category influenced the technical-tactical behaviour of elite female boxers, whereas bout outcome was associated only with attack rate, which was higher in losers than in winners. Pan American bouts presented higher displacement, attack, and defence rates than Olympic contests, and lower- and intermediate-weight categories demonstrated greater technical-tactical activity than heavier athletes. Although attack rate differed according to bout outcome, neither the paired within-bout comparisons nor the bout-stratified conditional logistic regression identified any variable capable of discriminating winners from losers, indicating that action frequency alone shows limited ability to discriminate winners from losers. The present findings provide contemporary reference values for the technical-tactical demands of elite female boxing under the current Olympic competition format.

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