



## Technical-tactical and pacing profiles in European and Pan-American Pre-Olympic boxing qualification tournaments: influence of sex, weight category, and round dynamics

*Perfiles técnico-tácticos y de ritmo de combate en los torneos clasificatorios preolímpicos de boxeo de Europa y Panamérica: influencia del sexo, la categoría de peso y la dinámica de los asaltos*

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### Abstract

**Objective:** This study compared the technical-tactical profiles of male and female boxers competing in the European (2021) and Pan-American (2023) Pre-Olympic qualification tournaments, examining differences according to continent, bout outcome, grouped weight categories, and round dynamics.

**Methods:** A total of 138 bouts (414 rounds; 77 men's and 61 women's) were analyzed using a validated time-motion protocol (Frami®).

**Results:** Pan-American boxers of both sexes displayed significantly greater offensive and defensive activity than their European counterparts (all  $p \leq 0.001$ ), whereas European men spent more time in clinch situations ( $p = 0.012$ ). Winning male boxers exhibited greater attacking activity than losing athletes ( $p = 0.034$ ). Analyses by grouped weight categories revealed continent-specific competitive patterns, with Pan-American middle- and heavyweight boxers demonstrating higher offensive and defensive outputs, while European heavyweights engaged in longer clinch durations ( $p \leq 0.05$ ). Across rounds, athletes adjusted their pacing strategy, characterized by reduced attacking activity and increased pause and clinch durations in the final round ( $p \leq 0.05$ ).

**Conclusion:** Technical-tactical performance varied according to continent, sex, weight category, bout outcome, and round progression, highlighting distinct competitive profiles in Olympic qualification events. These findings provide practical evidence to support the development of sex- and weight-specific conditioning and tactical strategies for high-level boxing.

### Keywords

Combat sports; martial arts; sports performance, Olympic Games.

### Resumen

**Objetivo:** Este estudio comparó los perfiles técnico-tácticos de boxeadores y boxeadoras que compitieron en los torneos Preolímpicos de Clasificación de Europa (2021) y Panamérica (2023), examinando las diferencias según el continente, el resultado del combate, las categorías de peso agrupadas y la dinámica de los asaltos.

**Métodos:** Se analizaron un total de 138 combates (414 asaltos; 77 masculinos y 61 femeninos) mediante un protocolo validado de análisis tiempo-movimiento (Frami®).

**Resultados:** Los boxeadores panamericanos de ambos sexos mostraron una actividad ofensiva y defensiva significativamente mayor que sus homólogos europeos (todos  $p \leq 0.001$ ), mientras que los hombres europeos permanecieron más tiempo en situaciones de clinch ( $p = 0.012$ ). Los boxeadores masculinos vencedores exhibieron una mayor actividad ofensiva que los derrotados ( $p = 0.034$ ). El análisis por categorías de peso agrupadas reveló patrones competitivos específicos según el continente, con los boxeadores panamericanos de peso medio y pesado presentando mayores niveles de actividad ofensiva y defensiva, mientras que los pesos pesados europeos registraron una mayor duración del clinch ( $p \leq 0.05$ ). A lo largo de los asaltos, los atletas ajustaron su estrategia de ritmo de combate, caracterizada por una reducción de la actividad ofensiva y un incremento de las pausas y del tiempo en clinch en el último asalto ( $p \leq 0.05$ ).

**Conclusiones:** El rendimiento técnico-táctico varió en función del continente, el sexo, la categoría de peso, el resultado del combate y la progresión de los asaltos, poniendo de manifiesto perfiles competitivos diferenciados en eventos clasificatorios para los Juegos Olímpicos. Estos hallazgos aportan evidencia práctica para apoyar el desarrollo de estrategias de preparación física y táctica específicas según el sexo y la categoría de peso en el boxeo de alto nivel.

### Palabras clave

Deportes de combate; artes marciales; rendimiento deportivo; Juegos Olímpicos



## Introduction

Olympic boxing is one of the most established combat sports on the Olympic program and represents the highest competitive level for amateur athletes worldwide (Slimani et al., 2017). Securing qualification for the Olympic Games is therefore a major objective for elite boxers, making Pre-Olympic qualification tournaments among the most demanding events of the competitive cycle. These tournaments are characterized by high competitive density, limited qualification opportunities, and considerable physical, technical, and psychological demands, requiring athletes and coaches to optimize preparation according to the specific characteristics of each qualification pathway (Mitchell J Finlay, Greig, Page, & Bridge, 2023; Martusciello, Perazzetti, Kaçurri, Consolati, & Tessitore, 2025). As women's participation has expanded and qualification systems have evolved, understanding the technical-tactical demands of these competitions has become increasingly relevant for evidence-based coaching and athlete development (Slimani et al., 2017; Tjønndal, Haudenhuyse, De Geus, & Buyse, 2021).

In this high-stakes context, Time-motion analysis has become one of the most widely used approaches to quantify the temporal organization of technical-tactical actions during boxing bouts. Time-motion and notational studies in Olympic-style boxing quantify specific combat actions, such as punching volume and accuracy, defensive actions, and movement patterns, to provide objective indicators that can be directly translated into training design and tactical preparation (Davis, Connorton, Driver, Anderson, & Waldock, 2017; Wandee & Benjapalakorn, 2018). Research consistently shows that winning boxers tend to exhibit higher offensive output, greater technical effectiveness (more punches landed, especially straight and well-selected punches), and more efficient defensive actions than their losing counterparts in both men's and women's elite competitions (Kapo, El-Ashker, Kapo, Colakhodzic, & Kajmovic, 2021; Martusciello et al., 2025). These technical-tactical profiles form performance benchmarks for elite activity rates (i.e.  $\sim 1.4\text{--}1.6$  actions $\cdot\text{s}^{-1}$  with 20–25 punches and 2.5–3.6 defensive actions per minute) and demonstrate that success is closely tied to the volume, accuracy, and strategic deployment of actions across rounds (Davis et al., 2017; Slimani et al., 2017; Thomson & Lamb, 2016). Although detailed notational analyses may quantify punch types, defensive techniques and action effectiveness, validated time-motion protocols provide complementary information regarding the temporal organization and volume of technical-tactical behaviors, allowing comparisons across different competitive contexts.

Previous research in boxing has predominantly focused on Olympic competitions or national championships (A. Gutiérrez-Santiago, Vázquez-Estévez, Muñoz-Rodrigo, & Prieto-Lage, 2023; Kapo et al., 2021; Kruszewski et al., 2016). For instance, studies have analyzed the technical aspects of Olympic finals, often under regulations preceding the removal of headgear in men's Olympic boxing, such as the London 2012 Games (Kruszewski et al., 2016). More recent investigations have described the temporal structure of bouts in contemporary Olympic editions like Tokyo 2020 (Alfonso Gutiérrez-Santiago et al., 2024). Other works have explored technical-tactical differences between winners and losers in specific national contexts or identified performance indicators associated with competitive success in elite tournaments (Ashker, 2011; Kapo et al., 2021). However, a significant gap remains concerning the analysis of the Pre-Olympic qualification stage, particularly when comparing different continental contexts and considering the integrated influence of weight categories and round-by-round pacing. This phase is critical for Olympic qualification, being characterized by high competitive density, immense pressure, and unique strategic demands. Given that Pre-Olympic tournaments may exhibit distinct technical-tactical patterns compared to Olympic or national competitions, it becomes crucial to identify which performance indicators are associated with securing an Olympic berth.

In view of these gaps, the present study provides a comprehensive time-motion analysis of technical-tactical behaviours performed by male and female boxers during the European (2021) and Pan-American (2023) Pre-Olympic qualification tournaments. Specifically, we compared continental competitions according to bout outcome, grouped weight categories, sex, and round-by-round dynamics, aiming to identify technical-tactical profiles associated with Olympic qualification contexts. We hypothesized that technical-tactical activity patterns would differ according to the competitive continent, sex, grouped weight category, bout outcome, and round progression, reflecting the distinct demands and tactical characteristics of Olympic qualification tournaments.



## Method

### Experimental approach

This observational, comparative study analyzed the technical–tactical activity patterns of male and female boxing bouts from two Olympic qualification events: the European Olympic Qualification Tournament (London, United Kingdom, 2021) and the boxing competition of the Pan-American Games (Santiago, Chile, 2023), which served as the continental qualification pathway for the Paris 2024 Olympic Games. All bout videos were obtained from the official Olympics YouTube channel and analyzed using the validated Frami® time-motion protocol (Brito et al., 2022).

### Data acquisition

Only complete boxing bouts were included in the analysis. Data acquisition was performed using high-quality official video recordings in which the entire bout was continuously visible, ensuring accurate identification of all technical–tactical actions. Bouts with incomplete footage or compromised image quality (e.g., obstruction by the referee or camera limitations) were excluded from the analysis. None of the analyzed bouts ended by knockout. A minimum sample size calculation was performed to ensure adequate statistical power for all comparisons. Because the European Olympic Qualification Tournament (2021) and the Pan-American Games (2023) belonged to different Olympic qualification cycles (Tokyo 2020 and Paris 2024, respectively), the official Olympic weight divisions differed between competitions. To maximize comparability while maintaining adequate statistical power, equivalent Olympic weight divisions from each qualification cycle were harmonized into comparable grouped categories for the statistical analyses.

For female boxers, the grouped categories corresponded to Flyweight/Bantamweight (50–54 kg), Featherweight/Lightweight (57–60 kg), and Welterweight/Middleweight (66–75 kg). For male boxers, equivalent Olympic divisions from the two qualification cycles were harmonized as follows: Flyweight (51/52 kg) + Featherweight (57 kg); Lightweight (63/63.5 kg) + Welterweight (69/71 kg); and Middleweight to Heavyweight divisions (75/80 kg, 81/92 kg, and +91/+92 kg). This approach preserved the competitive equivalence between the two qualification systems while ensuring sufficient observations within each analytical group. The final sample comprised 138 bouts (414 rounds), including 77 male bouts (231 rounds) and 61 female bouts (183 rounds). The European tournament included athletes representing 18 countries (Azerbaijan, Belarus, Belgium, Bulgaria, Croatia, France, Georgia, Germany, Great Britain, Ireland, Italy, Poland, Russia, Slovakia, Spain, Sweden, Turkey, and Ukraine), whereas the Pan-American tournament included athletes from 14 countries (Argentina, Brazil, Canada, Chile, Colombia, Cuba, Dominican Republic, Ecuador, El Salvador, Haiti, Mexico, Panama, Trinidad and Tobago, and the United States). The distribution of bouts and rounds according to sex, harmonized Olympic weight groups, and competition is presented in Table 1.

Table 1. Distribution of bouts and rounds according to sex, grouped Olympic weight categories, and qualification tournament.

| Sex             | Weight group                                       | European | Pan American | Total     |
|-----------------|----------------------------------------------------|----------|--------------|-----------|
| Female          | Flyweight (50 kg) + Bantamweight (54 kg)           | 10 (30)  | 4 (12)       | 14 (42)   |
|                 | Featherweight (57 kg) + Lightweight (60 kg)        | 12 (35)  | 18 (54)      | 30 (90)   |
|                 | Welterweight (66 kg) + Middleweight (75 kg)        | 13 (42)  | 4 (12)       | 17 (52)   |
| Female subtotal |                                                    | 35 (105) | 26 (78)      | 61 (183)  |
| Male            | Flyweight (52/51 kg) + Featherweight (57 kg)       | 5 (15)   | 4 (12)       | 9 (27)    |
|                 | Lightweight (63/63.5 kg) + Welterweight (69/71 kg) | 20 (60)  | 4 (12)       | 24 (72)   |
|                 | Middleweight (75/80 kg) + Heavyweight (91/92 kg)   | 22 (66)  | 22 (66)      | 44 (132)  |
| Male subtotal   |                                                    | 47 (141) | 30 (90)      | 77 (231)  |
| Total           |                                                    | 82 (246) | 56 (168)     | 138 (414) |

Note: The data in parentheses is the number of rounds.

### Technical-tactical analysis protocol

All technical-tactical actions were analyzed using the Frami® software, following a validated time-motion protocol developed by Brito et al. (2022). This protocol categorizes actions into five main groups, with each variable quantified by the time dedicated to its execution. The analysis was performed by a



single experienced boxing coach with over 10 years of experience in this combat sport. Intra-rater reliability was assessed using test-retest procedures to ensure the reliability of the data, which is consistent with the original protocol, demonstrating high consistency in the coding of actions. The definitions for each technical-tactical action are as follows: (a) Attack: Defined as an offensive gesture against the opponent, which can be a punch or an arm extension. It starts when the athlete initiates the arm extension and ends when the athlete completes it; (b) Defense: Characterized as a defensive gesture, such as an evasion, pendulum movement, guard defense, etc. It begins when the athlete performs a movement to avoid the opponent's attack and ends after absorbing the blow or at the end of the identified defensive movement; (c) Displacement: Refers to the athlete's movement gesture within the ring, either approaching or moving away from the opponent. It starts when the athlete begins a movement task and ends when the athlete completes the step, whether simple, quick, or prolonged; (d) Clinch: Involves the complete immobilization of the opponent's arms, preventing their actions. It starts with the complete immobilization of the opponent's arms and ends when the referee intervenes to restart the combat; (e) Pause: Represents moments when the combat is stopped due to a foul (punishment), a restart of the combat, or an unspecific stop. It begins with the referee's hand signal, a gesture identified as a stop, or when the combat is identified as paused, and ends when the combat restarts.

## Data analysis

All statistical analyses were performed using Python (version 3.11) with the pandas, numpy, and statsmodels libraries. Descriptive statistics are presented as mean  $\pm$  standard deviation, accompanied by 95% confidence intervals for all technical-tactical variables. Three separate two-way analyses of variance (ANOVA) were performed for each technical-tactical variable. The first model examined the effects of bout outcome (Winner vs. Loser) and competition (European vs. Pan-American). The second evaluated the effects of the harmonized Olympic weight groups and competition, whereas the third investigated the effects of round (Rounds 1, 2, and 3) and competition. For each model, the main effects of both factors and their interaction were examined. When significant main effects or interactions were identified, Tukey's post hoc tests or Bonferroni-adjusted pairwise comparisons were performed, as appropriate, to identify specific between-group differences. Effect sizes were quantified using partial eta-squared ( $\eta^2$ ) and interpreted as small (0.01), medium (0.06), and large (0.14). Statistical significance was established at  $p < 0.05$ .

## Results

Our bout comparison revealed significant competition effects for Attack (male:  $F = 33.346$ ,  $p \leq 0.001$ ,  $\eta^2 = 0.128$ ; female:  $F = 136.191$ ,  $p \leq 0.001$ ,  $\eta^2 = 0.432$ ), Defense (male:  $F = 54.547$ ,  $p \leq 0.001$ ,  $\eta^2 = 0.194$ ; female:  $F = 78.388$ ,  $p \leq 0.001$ ,  $\eta^2 = 0.305$ ), and Clinch (male:  $F = 6.798$ ,  $p = 0.009$ ,  $\eta^2 = 0.029$ ). Compared with European athletes, Pan-American boxers of both sexes exhibited greater attack and defense volumes. In contrast, European male boxers spent significantly more time in clinch situations. A significant main effect of bout result was observed only for Attack in male boxers ( $F = 4.315$ ,  $p = 0.039$ ), with winners spending more time performing attacking actions than losers. Table 1 summarizes the comparisons between winners and losers across the European and Pan-American qualification tournaments for both male and female athletes.

Table 2. Comparison between Winners and Losers in the Pan-American and European Olympic qualifying tournaments.

| Sex    | Action       | European                          |                                   | Pan-American                      |                                   | F (Res) | F (Comp) | $\eta^2$ (Comp) |
|--------|--------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|---------|----------|-----------------|
|        |              | Winners                           | Losers                            | Winners                           | Losers                            |         |          |                 |
| Male   | Attack *     | 25.3 $\pm$ 10.6 a<br>[22.8-27.9]  | 22.9 $\pm$ 8.4<br>[20.9-24.9]     | 32.0 $\pm$ 8.1 a<br>[29.6-34.5]   | 29.7 $\pm$ 6.0<br>[28.0-31.5]     | 4.315   | 33.346   | 0.128           |
|        | Defense *    | 8.2 $\pm$ 5.3<br>[7.0-9.5]        | 9.8 $\pm$ 6.0<br>[8.3-11.2]       | 14.6 $\pm$ 5.3<br>[13.0-16.2]     | 14.9 $\pm$ 6.4<br>[13.0-16.8]     | 1.847   | 54.547   | 0.194           |
|        | Displacement | 112.2 $\pm$ 20.4<br>[107.3-117.1] | 112.3 $\pm$ 20.2<br>[107.5-117.0] | 106.0 $\pm$ 16.6<br>[101.0-111.0] | 108.0 $\pm$ 17.2<br>[102.8-113.1] | 0.108   | 4.089    | 0.018           |
|        | Clinch *     | 18.6 $\pm$ 15.7<br>[14.8-22.3]    | 18.5 $\pm$ 15.7<br>[14.8-22.2]    | 13.2 $\pm$ 12.4<br>[9.5-17.0]     | 13.5 $\pm$ 13.4<br>[9.5-17.6]     | 0.002   | 6.798    | 0.029           |
|        | Pause        | 15.7 $\pm$ 12.4<br>[12.7-18.7]    | 16.6 $\pm$ 13.0<br>[13.6-19.7]    | 14.4 $\pm$ 9.2<br>[11.7-17.2]     | 14.2 $\pm$ 9.2<br>[11.4-16.9]     | 0.097   | 1.441    | 0.006           |
| Female | Attack *     | 22.4 $\pm$ 8.9<br>[20.0-24.9]     | 21.4 $\pm$ 6.3<br>[19.6-23.1]     | 35.9 $\pm$ 8.4<br>[33.3-38.5]     | 37.1 $\pm$ 9.7<br>[33.8-40.4]     | 0.006   | 136.191  | 0.432           |



|              |                               |                               |                              |                              |       |        |       |
|--------------|-------------------------------|-------------------------------|------------------------------|------------------------------|-------|--------|-------|
| Defense *    | 5.4 ± 3.4<br>[4.5-6.4]        | 6.2 ± 5.8<br>[4.6-7.9]        | 13.1 ± 6.2<br>[11.2-15.1]    | 11.9 ± 4.7<br>[10.4-13.5]    | 0.003 | 78.388 | 0.305 |
| Displacement | 121.0 ± 17.3<br>[116.3-125.7] | 117.8 ± 17.9<br>[112.7-122.8] | 102.2 ± 17.5<br>[96.7-107.6] | 102.2 ± 17.6<br>[96.3-108.1] | 0.507 | 43.295 | 0.195 |
| Clinch       | 16.4 ± 11.8<br>[13.2-19.7]    | 17.4 ± 13.6<br>[13.6-21.2]    | 14.7 ± 11.7<br>[11.1-18.4]   | 15.0 ± 12.8<br>[10.7-19.3]   | 0.118 | 1.179  | 0.007 |
| Pause        | 15.0 ± 10.7<br>[12.1-17.9]    | 17.6 ± 12.4<br>[14.1-21.1]    | 14.3 ± 11.9<br>[10.6-18.0]   | 14.2 ± 13.2<br>[9.7-18.7]    | 0.663 | 1.223  | 0.007 |

Note: Data present by Mean ± Standard deviation and 95% Confidence Interval. <sup>a</sup> p=0.039 vs. Losers. <sup>\*</sup> p≤0.009 vs Pan-American. Res – result, Comp – competition.

Regarding Weight groups, the analysis revealed significant main effects of Competition for both sexes. For male boxers, effects were found for Attack ( $F=26.944$ ;  $p\leq 0.001$ ;  $\eta^2=0.107$ ), Defense ( $F=47.542$ ;  $p\leq 0.001$ ;  $\eta^2=0.174$ ), and Clinch ( $F=10.238$ ;  $p=0.002$ ;  $\eta^2=0.044$ ). Female boxers showed even stronger competition effects for Attack ( $F=114.563$ ;  $p\leq 0.001$ ;  $\eta^2=0.393$ ), Defense ( $F=70.634$ ;  $p\leq 0.001$ ;  $\eta^2=0.285$ ), and Displacement ( $F=40.092$ ;  $p\leq 0.001$ ;  $\eta^2=0.185$ ). Significant interactions (Weight x Competition) were observed across most metrics. In the male category, interactions were found for Attack ( $F=7.048$ ;  $p=0.001$ ), Defense ( $F=13.246$ ;  $p\leq 0.001$ ), and Clinch ( $F=19.887$ ;  $p\leq 0.001$ ). Post-hoc analysis for European males showed that Lightweights performed significantly more attacks and defenses than Middleweights and Heavyweights ( $p<0.003$ ), while Heavyweights utilized the clinch more than Lightweights ( $p\leq 0.001$ ). In the Pan-American tournament, male Heavyweights performed more defensive actions than other groups ( $p\leq 0.001$ ).

For female boxers, significant interactions occurred for Attack ( $F=8.496$ ;  $p<0.001$ ), Defense ( $F=10.146$ ;  $p<0.001$ ), and Pause duration ( $F=8.166$ ;  $p<0.001$ ). Post-hoc analysis in the European tournament showed that Heavyweight females performed fewer defenses than Lightweights ( $p=0.006$ ) and Middleweights ( $p=0.031$ ). In the Pan-American tournament, Lightweights ( $p=0.001$ ) and Middleweights ( $p=0.002$ ) performed significantly more attacks than Heavyweights, while Middleweights also performed more defensive actions than Heavyweights ( $p=0.003$ ) and had significantly shorter pause durations than Heavyweights ( $p=0.002$ ). Continental comparisons revealed that Pan-American athletes (both sexes) generally exhibited higher attack and defense volumes in Light and Middleweight categories ( $p\leq 0.001$ ), whereas European athletes showed greater displacement (Female,  $p<0.003$ ) and higher clinch usage (Male Heavyweights,  $p\leq 0.001$ ). Table 2 presents the detailed comparison between weight groups in the two pre-Olympic competitions.

Table 3. Comparison Between Weight groups by Sex and Competition.

| Action       | Competition  | Light                      | Middle                     | Heavy                       | F (W) | F (Comp) | F (W x Comp) | $\eta^2$ (Comp) |
|--------------|--------------|----------------------------|----------------------------|-----------------------------|-------|----------|--------------|-----------------|
| Male         |              |                            |                            |                             |       |          |              |                 |
| Attack       | European     | 32.9±16.87 a *             | 21.9±6.7 *                 | 24.1±8.6                    | 4.093 | 26.944   | 7.048        | 0.107           |
|              | Pan-American | 28.5±7.7<br>[23.6-33.4]    | 32.9±6.9<br>[20.2-23.7]    | 31.0±7.1<br>[22.0-26.2]     |       |          |              |                 |
| Defense      | European     | 14.1±10.0 a *              | 8.5±4.8 *                  | 8.4±4.6                     | 1.343 | 47.542   | 13.246       | 0.174           |
|              | Pan-American | 10.0±3.8<br>[8.6-19.7]     | 12.6±2.9<br>[7.2-9.7]      | 16.0±6.0<br>[7.2-9.5]       |       |          |              |                 |
| Displacement | European     | 114.6±12.0 *               | 116.7±22.4                 | 107.6±18.8                  | 5.996 | 0.916    | 3.639        | 0.004           |
|              | Pan-American | 94.6±19.9<br>[107.9-121.2] | 119.9±6.9<br>[110.9-122.5] | 106.9±16.0<br>[103.0-112.2] |       |          |              |                 |
| Clinch       | European     | 2.2±3.0<br>[0.5-3.9]       | 18.4±16.8<br>[14.1-22.7]   | 22.4±13.9 b *               | 2.562 | 10.238   | 19.887       | 0.044           |
|              | Pan-American | 26.2±14.9<br>[16.7-35.7]   | 3.5±3.3<br>[1.4-5.6]       | 12.8±11.8<br>[9.9-15.7]     |       |          |              |                 |
| Pause        | European     | 15.0±18.4<br>[4.8-25.2]    | 14.7±11.9<br>[11.7-17.8]   | 17.8±11.8<br>[14.8-20.7]    | 1.545 | 2.601    | 2.285        | 0.011           |
|              | Pan-American | 21.1±6.7<br>[16.8-25.3]    | 11.6±6.7<br>[7.3-15.8]     | 13.6±9.4<br>[11.3-15.9]     |       |          |              |                 |
| Female       |              |                            |                            |                             |       |          |              |                 |
| Attack       | European     | 19.4±6.7 *                 | 23.3±6.9 *                 | 22.5±8.8                    | 2.245 | 114.563  | 8.496        | 0.393           |
|              | Pan-American | 40.4±8.4<br>[35.0-45.7]    | 37.4±8.2<br>[35.2-39.6]    | 28.1±8.7 c<br>[22.6-33.6]   |       |          |              |                 |
| Defense      | European     | 4.2±2.0 *<br>[3.5-5.0]     | 5.0±2.5 *<br>[4.1-5.9]     | 7.7±6.7 c<br>[5.6-9.9]      | 2.018 | 70.634   | 10.146       | 0.285           |



|              |              |                             |                             |                             |       |        |       |       |
|--------------|--------------|-----------------------------|-----------------------------|-----------------------------|-------|--------|-------|-------|
| Displacement | Pan-American | 12.0±3.1<br>[10.0-13.9]     | 13.7±5.8 d<br>[12.2-15.3]   | 8.0±4.0<br>[5.5-10.5]       | 0.568 | 40.092 | 4.942 | 0.185 |
|              | European     | 121.5±21.2<br>[113.6-129.4] | 116.0±17.8<br>[109.9-122.1] | 120.8±14.1<br>[116.3-125.3] |       |        |       |       |
|              | Pan-American | 88.6±13.2<br>[80.3-97.0]    | 105.0±15.6<br>[100.7-109.2] | 103.2±23.2<br>[88.4-117.9]  |       |        |       |       |
| Clinch       | European     | 19.8±14.3<br>[14.5-25.2]    | 17.0±13.1<br>[12.5-21.5]    | 14.7±10.6<br>[11.3-18.1]    | 2.592 | 0.525  | 0.835 | 0.003 |
|              | Pan-American | 20.7±8.2<br>[15.5-25.9]     | 13.2±11.9<br>[10.0-16.5]    | 16.4±15.2<br>[6.8-26.1]     |       |        |       |       |
|              | European     | 15.3±12.8<br>[10.5-20.1]    | 18.9±11.0<br>[15.1-22.7]    | 14.7±10.9<br>[11.2-18.2]    | 0.623 | 0.485  | 8.166 | 0.003 |
| Pause        | Pan-American | 18.5±9.1<br>[12.7-24.3]     | 11.1±9.0 d<br>[8.6-13.6]    | 24.3±20.8<br>[11.1-37.5]    |       |        |       |       |
|              | European     | 15.3±12.8<br>[10.5-20.1]    | 18.9±11.0<br>[15.1-22.7]    | 14.7±10.9<br>[11.2-18.2]    |       |        |       |       |

Note: Data present by Mean ± Standard deviation and 95% Confidence Interval. <sup>a</sup> p≤0.003 vs. Middle and Heavy; <sup>b</sup> p≤0.001 vs. Light; <sup>c</sup> p=0.031 vs. Light and Middle; <sup>d</sup> p=0.003 vs. Heavy; \* p≤0.003 vs Pan-American.

About pacing strategy, significant main effects of Round were observed for both sexes across multiple actions. For male boxers, effects were found for Attack ( $F=6.647$ ;  $p=0.001$ ), Displacement ( $F=8.492$ ;  $p\leq 0.001$ ), Clinch ( $F=6.208$ ;  $p=0.002$ ), and Pause ( $F=13.983$ ;  $p\leq 0.001$ ). Female boxers also exhibited significant round effects for Attack ( $F=3.107$ ;  $p=0.046$ ), Displacement ( $F=14.592$ ;  $p\leq 0.001$ ), Clinch ( $F=9.660$ ;  $p\leq 0.001$ ), and Pause ( $F=16.671$ ;  $p\leq 0.001$ ).

Post-hoc analysis for male boxers showed that Attack volume in the Pan-American tournament was significantly lower in Round 3 compared to Round 1 ( $p=0.005$ ) and Round 2 ( $p=0.028$ ). Displacement decreased significantly from Round 1 to Round 2 in both European ( $p=0.040$ ) and Pan-American ( $p=0.038$ ) events. Clinch usage increased significantly in Round 3 compared to Round 1 in the European tournament ( $p=0.028$ ) and in Round 2 compared to Round 1 in the Pan-American event ( $p=0.033$ ). Pause duration increased significantly from Round 1 to Round 3 in both competitions ( $p<0.022$ ).

For female boxers, Attack volume in the Pan-American event was significantly lower in Round 3 compared to Round 1 ( $p=0.024$ ). Displacement was significantly higher in Round 1 compared to both subsequent rounds in both tournaments ( $p\leq 0.016$ ). Clinch usage and Pause duration increased significantly from Round 1 to Round 3 in both European and Pan-American competitions ( $p\leq 0.03$ ).

Furthermore, Pan-American boxers (both sexes) exhibited significantly higher attack and defense volumes across all rounds ( $p<0.001$ ) compared to European boxers. European boxers, however, showed greater displacement in Round 1 (Male:  $p=0.003$ ; Female:  $p<0.001$ ) and higher clinch usage specifically in the third round of the male bouts ( $p=0.031$ ). Table 3 presents the detailed round-by-round comparison for the two competitions.

Table 4. Round-by-Round Comparison by Sex and Competition.

| Action        | Competition  | Round 1                       | Round 2                                  | Round 3                                | F (Round) | F (Comp) | F (Round x Comp) | $\eta^2$ (Comp) |
|---------------|--------------|-------------------------------|------------------------------------------|----------------------------------------|-----------|----------|------------------|-----------------|
| Male          |              |                               |                                          |                                        |           |          |                  |                 |
| Attack        | European     | 25.7±10.2 *<br>[22.8-28.6]    | 25.0±9.9 *<br>[22.2-27.8]                | 21.6±8.2 *<br>[19.3-24.0]              | 6.647     | 34.662   | 0.171            | 0.133           |
|               | Pan-American | 33.1±7.6<br>[30.4-35.9]       | 32.1±7.2<br>[29.5-34.6]                  | 27.5±5.3 <sup>a</sup><br>[25.6-29.4]   |           |          |                  |                 |
| Defense       | European     | 9.4±6.6<br>[7.5-11.3]         | 9.3±5.8<br>[7.6-11.0]                    | 8.4±4.6<br>[7.1-9.7]                   | 0.655     | 53.66    | 0.157            | 0.193           |
|               | Pan-American | 15.5±5.8<br>[13.4-17.6]       | 14.4±5.9<br>[12.3-16.5]                  | 14.3±5.9<br>[12.2-16.4]                |           |          |                  |                 |
| Displacement  | European     | 120.4±19.9 *<br>[114.7-126.1] | 110.5±20.3 <sup>b</sup><br>[104.7-116.3] | 105.8±18.0<br>[100.6-110.9]            | 8.492     | 4.433    | 1.77             | 0.019           |
|               | Pan-American | 112.3±15.8<br>[106.6-117.9]   | 101.6±15.7 <sup>b</sup><br>[96.0-107.3]  | 107.1±17.8<br>[100.8-113.5]            |           |          |                  |                 |
| Clinch        | European     | 13.8±13.0<br>[10.1-17.5]      | 19.8±16.6<br>[15.1-24.6]                 | 22.0±16.1 <sup>a</sup><br>[17.4-26.6]  | 6.208     | 7.145    | 0.529            | 0.031           |
|               | Pan-American | 8.8±11.8<br>[4.5-13.0]        | 17.0±13.2<br>[12.3-21.7]                 | 14.4±12.6 <sup>a</sup><br>[9.9-18.9]   |           |          |                  |                 |
| Pause         | European     | 10.9±9.5<br>[8.2-13.7]        | 15.5±11.1<br>[12.3-18.7]                 | 22.1±14.5 <sup>b*</sup><br>[17.9-26.2] | 13.983    | 1.628    | 1.244            | 0.007           |
|               | Pan-American | 10.7±9.9<br>[7.2-14.3]        | 15.2±8.4<br>[12.2-18.2]                  | 17.0±8.2 <sup>b</sup><br>[14.0-19.9]   |           |          |                  |                 |
| Female Attack | European     | 22.7±8.5 *                    | 21.7±8.2 *                               | 21.3±6.5 *                             | 3.107     | 141.768  | 1.6              | 0.445           |



|              |              | [19.9-25.5]<br>40.2±10.6<br>[36.2-44.3]   | [19.0-24.5]<br>35.3±7.6<br>[32.4-38.2] | [19.1-23.4]<br>33.8±7.4 <sup>b</sup><br>[30.9-36.6] |        |        |       |       |
|--------------|--------------|-------------------------------------------|----------------------------------------|-----------------------------------------------------|--------|--------|-------|-------|
|              | Pan-American |                                           |                                        |                                                     |        |        |       |       |
| Defense      | European     | 5.9±4.4<br>[4.5-7.4]                      | 5.7±5.2<br>[3.9-7.4]                   | 5.8±4.8<br>[4.2-7.4]                                | 0.878  | 78.579 | 0.944 | 0.307 |
|              | Pan-American | 14.0±4.9<br>[12.1-15.8]                   | 12.5±5.9<br>[10.2-14.8]                | 11.3±5.8<br>[9.1-13.5]                              |        |        |       |       |
| Displacement | European     | 128.6±16.1 <sup>c*</sup><br>[123.3-133.8] | 116.8±16.5<br>[111.2-122.3]            | 112.5±16.3<br>[107.1-117.9]                         | 14.592 | 48.818 | 0.211 | 0.216 |
|              | Pan-American | 111.0±14.0 <sup>c</sup><br>[105.6-116.4]  | 98.0±17.4<br>[91.3-104.7]              | 97.6±17.8<br>[90.7-104.4]                           |        |        |       |       |
| Clinch       | European     | 11.9±10.1<br>[8.6-15.2]                   | 19.5±13.2<br>[15.1-24.0]               | 19.5±13.2<br>[15.2-23.9]                            | 9.660  | 1.412  | 0.091 | 0.008 |
|              | Pan-American | 8.9±9.9<br>[5.1-12.7]                     | 17.2±12.5<br>[12.4-22.0]               | 18.4±12.0<br>[13.8-23.0]                            |        |        |       |       |
| Pause        | European     | 11.3±8.4<br>[8.6-14.1]                    | 16.5±10.6<br>[13.0-20.1]               | 21.1±13.3<br>[16.7-25.5]                            | 16.671 | 1.606  | 1.099 | 0.009 |
|              | Pan-American | 6.1±5.8<br>[3.9-8.4]                      | 17.3±9.9<br>[13.5-21.1]                | 19.3±15.6<br>[13.3-25.3]                            |        |        |       |       |

Note: Data present by Mean ± Standard deviation and 95% Confidence Interval. <sup>a</sup> p≤0.033 vs. Round 1 and 2; <sup>b</sup> p≤0.04 vs. Round 1; <sup>c</sup> p≤0.03 vs. Round 2 and 3; \* p≤0.031 vs Pan-American.

## Discussion

This study provides a comprehensive technical-tactical analysis of male and female boxing bouts from the European and Pan-American Pre-Olympic qualification tournaments, examining performance differences according to bout outcome, grouped weight categories, and round-by-round dynamics. The findings offer novel insights into the competitive demands of elite amateur boxing. Overall, Pan-American boxers, irrespective of sex, consistently exhibited greater offensive and defensive activity than their European counterparts across most performance indicators and grouped weight categories. These results suggest a higher-output competitive profile among Pan-American athletes, extending previous evidence derived primarily from Olympic and national-level competitions (Alfonso Gutiérrez-Santiago et al., 2024; A. Gutiérrez-Santiago et al., 2023). The present findings also reinforce the influence of weight category on technical-tactical performance, as distinct patterns of attacking, defensive, and clinch actions were observed among Light-, Middle-, and Heavyweight boxers. Importantly, these performance profiles differed according to the competitive continent, indicating that weight-related tactical demands are influenced by regional competitive characteristics. Furthermore, the round-by-round analysis revealed consistent pacing adjustments, characterized by increased pause duration and greater clinch engagement during the later stages of the bout. These temporal changes likely reflect the combined effects of accumulated fatigue and tactical decision-making, as commonly reported in combat sports (Manzini, Burini, Manda, Caiado, & Burini, 2024). From an applied perspective, these findings provide coaches and practitioners with evidence-based information to optimize training prescription and tactical preparation according to continental competitive profiles, grouped weight categories, and the specific demands of male and female boxing. Such sport-specific strategies may contribute to improving competitive performance and enhancing preparedness for the highly demanding Olympic qualification process.

Our analysis revealed that winners in the Pre-Olympic tournaments performed significantly more attacks, which aligns with previous research suggesting that offensive volume and accuracy are critical determinants of success in elite amateur boxing (Davis et al., 2017; Kapo et al., 2021; Wandee & Benjapalakorn, 2018). Specifically, our results showed that male winners performed significantly more attacking actions than losers, particularly in the Pan-American tournament. In contrast, female bouts showed a more balanced offensive profile between winners and losers, suggesting that in women's elite boxing, success may be more heavily influenced by tactical precision or defensive efficiency rather than sheer volume. This differentiation is supported by previous studies involving technical-tactical analyses which reveal that successful boxers use selective offensive actions combined with superior defensive efficiency, such as pivoting and counterattacks (Dunn, Humberstone, Iredale, Martin, & Blazevich, 2017; Martusciello et al., 2025). The high-pressure environment of Olympic qualifiers underscores the importance of these performance indicators for coaches aiming to develop high-volume offensive strategies and defensive skills (Slimani et al., 2017). Identifying these sex-specific technical-tactical profiles helps athletes prepare for the intense competitive density of qualification bouts (Deng et al., 2026; Martusciello et al., 2025).



We identified weight-class-specific patterns in attack, defense, and movement for both male and female categories, reinforcing the need for contextualized training. This aligns with evidence that lighter categories present higher work rates and faster movements, whereas heavier divisions rely more on force production and tactical strategies such as greater clinch use to manage fatigue (A. Gutiérrez-Santiago et al., 2023; Slimani et al., 2017). Notably, our findings highlighted that Pan-American female boxers in the light and middleweight categories exhibited exceptionally high offensive and defensive volumes compared to their European counterparts. Treating all categories as a single group would obscure these distinctions and lead to overly generalized training prescriptions (Alfonso Gutiérrez-Santiago et al., 2024). Further examination of the temporal structure of bouts across weight divisions may refine conditioning and tactical adjustments (Davis et al., 2017; Alfonso Gutiérrez-Santiago et al., 2024; Martusciello et al., 2025). Studies of Olympic boxing categories demonstrate how pacing strategies differ at the elite level (A. Gutiérrez-Santiago et al., 2023; Kapo et al., 2021). Incorporating effort-pause relationships into periodization can enhance identification of high-intensity phases and recovery demands (Ashker, 2011; Deng et al., 2026), supporting the development of targeted conditioning protocols according to division-specific physiological traits (Kapo et al., 2021; Ruddock et al., 2021).

The importance of pacing strategy for combat success was evident in our round-by-round analysis for both men and women. Pause duration and clinch activity increased significantly towards the third round, reflecting the onset of physiological fatigue and the subsequent strategic shift to manage energy expenditure (Mitchell J Finlay et al., 2023). Effective pacing is a hallmark of elite boxers (Dunn et al., 2017; Mitchell J Finlay et al., 2023; Mitchell James Finlay, Page, Greig, & Bridge, 2021). Interestingly, our data showed that European male boxers utilized the clinch significantly more in the third round compared to Pan-American boxers, likely as a tactical maneuver to control the final minutes of the bout. Mastering pacing strategies ensures athletes remain competitive during the decisive final minutes, a factor which is often the difference between winning and losing (Martusciello et al., 2025). This strategic regulation of exercise intensity is critical for achieving desired outcomes and mitigating early exhaustion (Dunn et al., 2017). Such pacing strategies are notably influenced by individual physiological capacities and gender-specific considerations (Davis et al., 2017; Deng et al., 2026; Alfonso Gutiérrez-Santiago et al., 2024). Previous research on male Olympic boxing also emphasizes the necessity of adjusting training to meet these competitive demands (Alfonso Gutiérrez-Santiago et al., 2024; A. Gutiérrez-Santiago et al., 2023).

The differences between the two Olympic qualifying tournaments can be explained by the influence of distinct boxing schools that predominate in each continent. In the Pan-American context, the Cuban school is central, characterized by high offensive volume combined with active defense (Viciedo-Domínguez & Álvarez-Berta, 2019). This school emphasizes distance control and constant mobility, "hitting without being hit" through rapid counterattacks (Flores, Santana, Iglesias, & Hernández, 2020; Viciedo-Domínguez & Álvarez-Berta, 2019). Cuba's international success has driven the diffusion of this model throughout the Americas (Gastón González, Sotolongo Herrera, & Villegas Rodríguez, 2024). In contrast, European boxing often emphasizes strategic control, technical efficiency, and management of fighting pace (Dunn et al., 2017; Shtanagei & Saveniuk, 2025). Our results confirm this, showing that European boxers exhibited more displacement in the early rounds and higher clinch usage in the final round of male bouts, reflecting a more calculated style associated with the tactical use of the clinch to control time and fatigue (Shtanagei & Saveniuk, 2025).

Despite its novel contributions, this study is not without limitations. The observational nature of video analysis restricts the ability to infer causality (Barreira, Casal, Losada, & Maneiro, 2020). While we achieved a robust sample size by including both male and female bouts, the necessary grouping of individual weight categories into broader Light, Middle, and Heavy categories limits the granularity of findings for specific classes. Furthermore, while we compared two distinct Pre-Olympic tournaments (European 2021 and Pan-American 2023), the findings represent specific continental contexts. Future research should incorporate physiological data (i.e., heart rate, lactate levels) to better understand the metabolic demands underlying the observed technical-tactical patterns. Longitudinal studies tracking athletes across multiple competitive stages would also provide valuable insights into adaptation. While this study successfully extended the analysis to female boxing, future investigations should continue to explore the distinct tactical profiles that may exist across genders and weight categories in different competitive cycles.



From a practical standpoint, the findings offer actionable insights for coaches. The identified continental and sex-specific differences in offensive and defensive volumes underscore the importance of tailoring training to the specific competitive environment (Mitchell J Finlay et al., 2023). Coaches can use this data to develop region-specific game plans and optimize conditioning programs which support the unique demands of each weight category and gender. The emphasis on high offensive output in Pan-American boxing suggests a need for robust anaerobic capacity, while the European focus on strategic control and clinching might require specific tactical endurance training. Understanding these nuances can significantly enhance an athlete's readiness for the high-stakes Olympic qualification process. Finally, comparative analyses across different Olympic cycles could reveal trends in technical-tactical evolution influenced by rule changes or coaching philosophies. Future studies should employ more detailed notational analysis protocols capable of identifying punch types, defensive techniques, action variability, and technical effectiveness (e.g., punch accuracy and successful defensive actions). Such analyses would complement the time-motion approach adopted in the present study and provide a more comprehensive understanding of elite boxing performance.

## Conclusions

This study examined the technical-tactical profiles of male and female boxers in European and Pan-American Pre-Olympic tournaments, identifying clear differences across continents, weight categories, and rounds. Pan-American athletes, regardless of sex, showed higher offensive and defensive volumes, whereas European boxers demonstrated distinct tactical patterns, including greater clinch use specifically in the final rounds of male bouts. These effects were significantly influenced by the interaction between competitive context, weight-class demands, and sex. Winners generally presented higher offensive output in the male category, while female bouts exhibited more balanced profiles between winners and losers. Round-by-round changes, such as increased pauses and clinch actions for both sexes, suggest fatigue management strategies. Overall, the findings support the development of targeted, context-specific, and sex-sensitive training and tactical preparation for Olympic-level competition.

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