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Optimizing Physical Training Planning for Boxing Athletes Based On Match Content Analysis of The PON XXI Aceh-North Sumatra Finals

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ABSTRACT

This study aimed to characterize the technical demands of competitive boxing and explore their implications for physical training planning across weight categories. A quantitative descriptive design employing match content analysis was used to examine video recordings of 20 final bouts from the 2024 Indonesian National Sports Week (PON XXI Aceh–North Sumatra). Structured observations quantified punching techniques (jab, straight, hook, and uppercut) and clinching actions, while a proposed workload calculation framework was used to estimate endurance, strength-related, and speed, agility, and quickness (SAQ) training volumes. The results revealed substantial variation in technical activity across weight categories. The men's 48 kg category recorded the highest overall activity (310 actions), while the women's 66 kg category exhibited 282 actions. These findings suggest that competition-derived technical profiles may inform individualized conditioning priorities. However, the proposed training volumes require physiological validation before implementation as standardized training prescriptions.

Keywords: boxing, match content analysis, physical training planning, technical performance, training load

INTRODUCTION

Boxing is a high-intensity intermittent combat sport that requires the integration of technical proficiency, tactical awareness, muscular strength, explosive power, and aerobic and anaerobic capacities to maintain competitive performance. During competition, athletes repeatedly execute offensive and defensive actions, including punching combinations, evasive movements, and rapid changes in body position. These activities impose substantial physiological and neuromuscular demands, particularly when athletes must sustain technical effectiveness across successive rounds. Previous investigations have demonstrated that competitive boxing involves repeated high-intensity efforts supported by well-developed cardiorespiratory fitness, muscular endurance, and explosive strength (Chaabène et al., 2015; Davis et al., 2015; Slimani et al., 2017). Furthermore, the metabolic demands of boxing highlight the importance of maintaining energy availability and recovery capacity during repeated offensive exchanges (Halperin et al., 2016; Bruzas et al., 2023). Therefore, physical training programs should be developed according to the specific physiological and technical demands encountered during competition rather than relying exclusively on generalized conditioning approaches.

Performance analysis has become an important methodological approach for identifying the technical and tactical characteristics of competitive boxing. Systematic observation of match recordings enables researchers to quantify punching frequency, offensive combinations, defensive actions, and movement patterns that reflect athletes' competitive behavior. Davis et al. (2013) demonstrated that technical activity profiles differ between winning and losing amateur boxers, while Davis et al. (2018) reported variations in competitive activity following modifications to international boxing

regulations. Similarly, Thomson and Lamb (2016) identified differences in technical demands associated with competitive outcomes, weight categories, and performance levels. The integration of video-based analysis with sport-specific physiological assessment may provide additional information about the relationship between observable technical actions and physical demands (Thomson & Lamb, 2017; Venckunas et al., 2022). These findings indicate that systematic competition analysis can provide objective information for identifying performance characteristics and supporting the development of evidence-informed training programs.

The relationship between technical execution and physical conditioning represents an important consideration in boxing performance development. Punching effectiveness depends on coordinated force production involving the lower extremities, trunk, and upper limbs, while repeated offensive actions require sufficient muscular endurance and neuromuscular efficiency. Biomechanical investigations have demonstrated that punching techniques involve distinct movement characteristics and force-generation mechanisms, emphasizing the importance of technique-specific physical preparation (Dinu & Louis, 2020; Beattie & Ruddock, 2022). Furthermore, sport-specific repeated-sprint training and high-intensity interval training have been investigated as strategies for improving physiological capacity and repeated high-intensity performance in combat-sport athletes (Kamandulis et al., 2018; Franchini et al., 2019). Nevertheless, training adaptations depend on appropriate exercise selection, intensity regulation, and progressive workload management. Consequently, training prescriptions should integrate competition-specific technical demands with individualized physical assessments and established strength-and-conditioning principles (Ruddock et al., 2016; Franchini, 2020).

Despite substantial progress in boxing performance analysis and conditioning research, the translation of competition-derived technical indicators into structured physical training plans remains insufficiently established. Previous studies have primarily examined competitive activity profiles, physiological characteristics, punching biomechanics, and conditioning interventions as separate research domains (Davis et al., 2015; Thomson & Lamb, 2016; Slimani et al., 2017). Although these investigations provide valuable information about boxing performance, limited evidence is available regarding how observed punching frequencies and movement characteristics can be systematically incorporated into preliminary training-volume planning across male and female weight categories. Moreover, training-load research emphasizes that external workload indicators must be interpreted alongside individual physiological responses, recovery capacity, and injury risk (Bourdon et al., 2017; Gabbett et al., 2017; Soligard et al., 2016). Emerging conditioning approaches further highlight the potential benefits of individualized training strategies for improving sport-specific physical performance (Xu et al., 2025). Therefore, an important research gap concerns the development of transparent frameworks that connect descriptive competition analysis with practical conditioning considerations while acknowledging the limitations of estimating physiological demands from technical frequency alone.

To address this gap, the present study aimed to analyze the technical activity profiles of boxing athletes competing in 20 final matches at the 2024 Indonesian National Sports Week (PON XXI Aceh–North Sumatra) and explore their implications for physical training planning. Specifically, the study examined the frequency of jabs, straight punches, hooks, uppercuts, and clinching actions across male and female weight categories, alongside movement-related considerations for speed, agility, and quickness training. The novelty of this research lies in the proposed integration of competition-

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derived technical observations with a preliminary framework for estimating training-volume requirements related to endurance, strength-oriented exercises, and movement preparation. Rather than establishing experimentally validated training prescriptions, the study provides descriptive evidence and an initial planning approach that may assist coaches in identifying competition-specific conditioning priorities. The findings are expected to contribute to evidence-informed boxing preparation while providing a foundation for future research examining the validity and effectiveness of individualized training programs.

METHODS

This study used a quantitative descriptive design with a *content analysis* approach. The choice of this method is supported by the view of Wildan et al. (2024), who stated that content analysis of match recordings is a highly useful observation instrument for identifying technique variations across different competition weight classes. The study was conducted by analyzing video recordings of the final round of PON XXI Aceh-North Sumatra 2024 across 20 match classes.

Population and Sample

The population in this study included all boxing athletes who competed at PON XXI 2024. The sampling technique used was *purposive sampling*, namely a sampling technique based on certain considerations (Sugiyono, 2018). The selected sample consisted of the gold medalists from the 20 match classes, on the assumption that final-round athletes reflect the physical demands at the highest performance level.

Data Measurement

Primary data were obtained through structured observation using video recordings of at least 720p quality to maintain the accuracy of technique identification. The researchers used the *slow motion* feature (0.5x speed) to perform *direct counting* of technique variables (*Jab, Straight, Hook, Uppercut* punches) and physical activity variables (*Clinch* and *footwork*).

Data Analysis

The data were processed through digital reduction and tabulation stages to calculate the accumulated demands during the tournament (a projection of 4 matches). The determination of training portion standards referred to the principle of *overload* (excess load). As stated by Bompa & Buzzichelli (2019), the application of a load exceeding competition demands (in this case using a multiplier factor of 2x or 100% excess load) aims to trigger physiological adaptation or supercompensation in the athlete's body. The physical parameters were calculated using the following formulas:

- Total Actions = Technique Frequency (1 Match) x 4.
- *Endurance* = Duration of 1 match x 4 x 2.
- *Strength* = Total number of technique repetitions x 4 x 2.
- SAQ = Total value of footsteps x 0.5 meters x 4 x 2.

The results of this analysis are then presented in the form of a narrative and summary tables to provide an objective overview of the specific physical demands of each weight category.

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RESULTS AND DISCUSSION

Results

1.Distribution of Technical Actions Across Boxing Weight Categories

The content analysis of 20 final matches at PON XXI Aceh–North Sumatra 2024 revealed considerable variation in the frequency and distribution of technical actions across male and female weight categories. The observed variables included four punching techniques (jab, straight, hook, and uppercut) and clinching actions. Table 1 presents the frequency of each technique and the total number of recorded actions across the 20 competition categories.

Table 1. Distribution of Technical Actions Across 20 Boxing Weight Categories

Weight Category	Jab	Straight	Hook	Uppercut	Clinch	Total Punches	Total Actions
Men 48 kg	61	60	108	78	3	307	310
Men 51 kg	11	35	88	34	26	168	194
Men 54 kg	51	52	46	21	6	170	176
Men 57 kg	87	80	54	18	2	239	241
Men 60 kg	36	30	36	18	0	120	120
Men 63.5 kg	57	42	82	15	9	196	205
Men 67 kg	123	25	28	5	0	181	181
Men 71 kg	102	21	54	69	0	246	246
Men 75 kg	62	45	57	4	16	168	184
Men 80 kg	117	43	38	29	1	227	228
Men 86 kg	78	12	41	32	5	163	168
Women 48 kg	25	50	51	3	28	129	157
Women 50 kg	71	72	41	0	3	184	187
Women 52 kg	11	29	49	0	16	89	105
Women 54 kg	60	51	41	5	24	157	181
Women 57 kg	103	38	14	5	14	160	174
Women 60 kg	72	34	66	38	24	210	234
Women 63 kg	24	11	31	5	8	71	79
Women 66 kg	117	102	42	8	13	269	282
Women 70 kg	47	54	72	55	9	228	237

The men's 48 kg category recorded the highest number of technical actions (310), consisting of 307 punches and three clinches. Hooks were the most frequently observed punching technique (108), followed by uppercuts (78), jabs (61), and straight punches (60). In contrast, the men's 60 kg category exhibited the lowest total action frequency among male categories (120). Among female categories, the 66 kg division demonstrated the highest recorded activity (282 actions), comprising 269 punches and 13 clinches. Jabs (117) and straight punches (102) accounted for the largest proportion of offensive actions. Conversely, the women's 63 kg category recorded the lowest activity frequency (79 actions), including 71 punches and eight clinches. These results demonstrate substantial descriptive differences in technical activity between the observed matches, indicating that the frequency and composition of offensive actions varied across competition categories.

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2.Dominant Punching Techniques and Competition-Specific Activity Profiles

The distribution of punching techniques differed considerably across the observed weight categories. In the men's divisions, hooks were the most frequently recorded technique in the 48 kg, 51 kg, and 63.5 kg categories, whereas jabs predominated in the 57 kg, 67 kg, 71 kg, 75 kg, 80 kg, and 86 kg categories. The men's 54 kg division demonstrated a relatively balanced distribution of jabs and straight punches, while the 60 kg division recorded equal frequencies of jabs and hooks. In the women's divisions, hooks were the most frequently recorded technique in the 48 kg, 52 kg, 63 kg, and 70 kg categories. Straight punches predominated in the 50 kg division, whereas jabs were the most frequent technique in the 54 kg, 57 kg, 60 kg, and 66 kg divisions.

The highest individual jab frequency was observed in the men's 67 kg category (123), followed by the men's 80 kg and women's 66 kg categories (117 each). The highest hook frequency occurred in the men's 48 kg category (108), while the highest uppercut frequency was also recorded in this category (78). Clinch activity showed additional variation across competition categories. The women's 48 kg division recorded the highest clinch frequency (28), followed by the men's 51 kg division (26). No clinching actions were recorded in the men's 60 kg, 67 kg, and 71 kg categories. Overall, the observed technical profiles indicate that individual bouts differed in their predominant punching techniques and clinching frequencies. These differences provide descriptive information regarding the technical characteristics of each final match.

3.Competition-Derived Training Volume Estimates

To explore the practical application of match content analysis, the observed technical frequencies were incorporated into a preliminary training-volume calculation framework. The proposed model estimated training requirements using a projection of four matches and a twofold workload multiplier. The calculations were intended to provide illustrative planning values for endurance, strength-related activities, and speed, agility, and quickness (SAQ) training rather than experimentally validated training prescriptions. The men's 48 kg category was selected as an example because it exhibited the highest recorded activity frequency among the observed categories. Based on the original calculation framework, the proposed training-volume targets were 72 minutes for endurance, 2,480 repetitions for strength-related activities, and 2,028 meters for SAQ training.

Table 2. Proposed Training-Volume Estimates for the Men's 48 kg Category

Training Component	Proposed Volume	Measurement Unit
Endurance	72	Minutes
Strength-related activities	2,480	Repetitions
SAQ	2,028	Meters

The estimated training volumes illustrate how observed competition activity may be translated into preliminary conditioning considerations. However, the calculations rely on predetermined assumptions regarding tournament participation and workload multiplication. Accordingly, these values should be interpreted as exploratory planning estimates requiring further empirical validation.

Discussion

The present study revealed considerable variation in technical activity across the 20 boxing finals at PON XXI Aceh–North Sumatra 2024, indicating that competitive

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demands differ between individual bouts and weight categories. The men's 48 kg category recorded the highest overall activity, comprising 307 punches and three clinching actions, while the women's 66 kg category exhibited 269 punches and 13 clinches. These findings demonstrate that boxing activity profiles are heterogeneous and may reflect differences in offensive strategies, technical preferences, and competitive interactions. Previous investigations have similarly identified variations in punching activity and movement characteristics across competitive boxing contests (Davis et al., 2013; Davis et al., 2015; Davis et al., 2018). Thomson and Lamb (2016) further demonstrated that technical performance is influenced by contest outcomes, competitive ability, and weight-related characteristics. Nevertheless, the present findings should not be interpreted as evidence of consistent physiological differences between weight divisions because each category was represented by a single final match. Instead, the observed variation highlights the potential value of competition-specific performance analysis for identifying technical demands relevant to physical preparation.

The distribution of punching techniques provides additional insight into the tactical characteristics of the observed matches. In the men's 48 kg category, hooks and uppercuts represented a substantial proportion of offensive actions, whereas the men's 67 kg category demonstrated a greater reliance on jabs. Similarly, the women's 66 kg category exhibited relatively high frequencies of jabs and straight punches, suggesting an emphasis on linear offensive techniques during the observed contest. These variations may reflect differences in fighting distance, tactical preferences, and individual technical characteristics rather than body mass alone. Thomson and Lamb (2016) emphasized the importance of competitive context when interpreting technical performance, while Dinu and Louis (2020) demonstrated that different punching techniques involve distinct biomechanical characteristics. Furthermore, Beattie and Ruddock (2022) highlighted the relationship between strength-related qualities and punch impact force. Accordingly, the observed technical profiles may provide useful information for selecting boxing-specific conditioning exercises. However, punching frequency alone cannot establish the effectiveness, accuracy, or mechanical intensity of offensive actions.

From a physiological perspective, the repeated execution of punching combinations and defensive movements places substantial demands on aerobic and anaerobic energy systems. Competitive boxing requires athletes to sustain repeated high-intensity efforts while maintaining technical coordination and recovering between successive exchanges. Chaabène et al. (2015) identified cardiorespiratory endurance, muscular strength, and explosive power as important characteristics of amateur boxers, while Slimani et al. (2017) emphasized the physiological demands associated with competitive boxing. Similarly, Halperin et al. (2016) and Bruzas et al. (2023) provided further evidence regarding the physiological and metabolic characteristics of boxing performance. These findings support the incorporation of sport-specific endurance development and repeated high-intensity exercise into boxing conditioning programs. Nevertheless, the present study quantified technical actions without directly measuring oxygen consumption, heart rate, blood lactate concentration, or mechanical power. Therefore, the recorded punching frequencies should be interpreted as descriptive indicators of external activity rather than direct measurements of physiological workload.

The implications of these findings extend to the development of strength, power, and muscular endurance training. Boxing performance depends on coordinated force generation involving the lower extremities, trunk, and upper limbs, particularly during explosive punching combinations and rapid defensive transitions. Dinu and Louis (2020)

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demonstrated that punching techniques involve specific biomechanical characteristics, supporting the importance of integrated neuromuscular preparation. Ruddock et al. (2016) also emphasized the need for structured strength-and-conditioning programs that reflect the physical requirements of competitive boxing. Furthermore, Kamandulis et al. (2018) demonstrated the potential benefits of sport-specific repeated-sprint training for punching-related performance, while Franchini et al. (2019) reviewed the physiological adaptations associated with high-intensity interval training in Olympic combat sports. These findings suggest that competition-derived technical profiles may help coaches prioritize relevant conditioning components. However, resistance-training repetitions, exercise intensity, and recovery periods should be prescribed according to individual physical capacities rather than directly equating the number of observed punches with the required number of strength-training repetitions.

Another important consideration is the contribution of lower-body movement, agility, and coordination to boxing performance. Effective footwork allows athletes to maintain appropriate fighting distances, create attacking opportunities, and respond to opponents' movements while preserving defensive positioning. Davis et al. (2015) demonstrated that competitive boxing involves repeated movement and technical activity, while Thomson and Lamb (2017) highlighted the value of boxing-specific simulation protocols for examining physical and physiological demands. Venckunas et al. (2022) further investigated cardiorespiratory responses to sport-specific and nonspecific exercise in trained boxers, reinforcing the importance of exercise specificity in conditioning assessment. These findings provide a rationale for incorporating multidirectional footwork, reactive movement drills, and speed-agility-quickness exercises into boxing preparation. However, the present study did not provide complete validated measurements of movement distance, acceleration, or directional changes across all weight categories. Consequently, the proposed SAQ training distances should be regarded as preliminary planning estimates rather than empirically established competition requirements.

The proposed training-planning framework represents a practical attempt to translate observed competition activity into structured conditioning considerations. In the original calculation model, technical activity was projected across four matches and multiplied by a factor of two to estimate preliminary endurance, strength-related, and SAQ training volumes. Although this approach offers a transparent illustration of how competition observations might inform training planning, the selected multiplier has not been experimentally validated as an optimal overload threshold. Bourdon et al. (2017) emphasized that athlete monitoring should incorporate multiple indicators of external and internal training load, while Gabbett et al. (2017) highlighted the importance of systematically interpreting monitoring information to guide training decisions. Similarly, Soligard et al. (2016) demonstrated that inappropriate workload progression may contribute to increased injury risk. Therefore, the proposed training quantities should not be interpreted as universal prescriptions. Instead, they should be adjusted according to individual fitness assessments, training history, recovery status, and progressive adaptation.

The practical application of competition-informed conditioning should also consider the effectiveness of different training modalities and the individual responses of athletes. Franchini (2020) emphasized the importance of appropriately prescribing high-intensity interval training according to the physiological and technical characteristics of combat sports. Similarly, Kamandulis et al. (2018) demonstrated that sport-specific

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conditioning can contribute to improvements in selected performance-related outcomes among amateur boxers. More recent investigations have explored alternative conditioning strategies, including blood-flow-restriction-based repeated-sprint training, as potential approaches for developing upper-limb performance and punching-related capacities (Xu et al., 2025). These findings indicate that training effectiveness depends not only on the quantity of exercise performed but also on the interaction between exercise intensity, movement specificity, recovery, and individual adaptation. Accordingly, the present framework should be considered an initial decision-support approach that requires further validation through longitudinal training interventions.

Several methodological limitations should be acknowledged when interpreting the findings. First, the analysis was restricted to 20 final matches from a single national competition, limiting the generalizability of the results to other competitive levels and tournaments. Second, the purposive selection of gold medalists may have introduced selection bias and prevented direct comparisons between successful and unsuccessful athletes. Third, the study primarily quantified technical frequency without systematically evaluating punching accuracy, defensive effectiveness, movement intensity, or tactical context. Fourth, the absence of reported interobserver and intraobserver reliability limits the assessment of coding consistency. Fifth, the proposed training volumes were derived from assumed workload multipliers rather than direct physiological measurements or experimentally validated training responses. These limitations are particularly relevant because previous investigations have demonstrated the importance of comprehensive activity analysis, physiological assessment, and individualized workload monitoring in boxing and other combat sports (Thomson & Lamb, 2016; Bourdon et al., 2017; Franchini, 2020). Future studies should therefore incorporate larger match samples, validated observational procedures, objective workload monitoring, and controlled training interventions to determine whether competition-informed planning improves physical fitness and competitive performance.

Overall, the findings suggest that systematic match content analysis can provide valuable descriptive information for identifying the technical characteristics of competitive boxing and supporting preliminary physical training planning. The substantial variation in punching patterns across the observed finals highlights the importance of considering individual technical demands rather than applying identical conditioning priorities to all athletes. Nevertheless, the relationship between competition-derived technical activity and optimal training prescription remains exploratory. Integrating reliable performance analysis with physiological testing, individualized workload monitoring, and longitudinal evaluation may provide a stronger scientific foundation for developing evidence-informed boxing conditioning programs..

CONCLUSION

This study concludes that the content analysis of the final matches of PON XXI Aceh-North Sumatra 2024 produces a highly specific technical profile for the 20 competition classes, in which the middle to heavy classes are dominated by *hook* and *uppercut* techniques at close range, while the light classes prioritize *jab, straight*, and a high volume of *footwork*. The physical standards developed include a cumulative *endurance* of 72 minutes of effective work through the application of a double *overload* principle to ensure energy supercompensation during the tournament. The resulting *strength* volume reaches more than 2,000 repetitions in aggressive classes, while the *speed, agility, and quickness* (SAQ) parameters show that agility is a crucial part of the

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strategy of finding attack angles and defending. Overall, these standard figures are ideal peak load targets whose effectiveness depends heavily on integration with athletes' initial physical test results to ensure a safe and objective training program.

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