

Article

Twenty Years in the Octagon: An Analysis of the Strategic Evolution and Distributional Concentration of Knockouts and Submissions in Mixed Martial Arts

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Abstract

This study examined differences in finishing techniques and positional contexts across three temporal windows in the Ultimate Fighting Championship (2003–2004, 2013–2014, and 2023–2024), revealing differences consistent with a shift from greater diversity to a specialized and systematized model. Analysis of 906 finalized bouts demonstrated a marked concentration of submission finishes, with rear naked choke increasing from 15.8% to 46.8% ($p \leq 0.001$), while back control was the dominant positional context (45.5%, $p \leq 0.001$). In striking-based finishes, punches maintained prevalence, evolving from 77.4% (2003–2004) to 86.1% (2023–2024, $p \leq 0.001$), whereas kicks declined from 20.5% to 11.3% ($p \leq 0.001$). Submissions increased from 37.0% to 52.0% of all finalized bouts ($p \leq 0.001$). These findings indicate a growing emphasis on specific finishing techniques, with modern mixed martial arts demonstrating increased distributional concentration in the methods used to finalize bouts. The increased frequency of certain techniques (e.g., rear naked choke and punches) among finalized fights may reflect strategic preferences, training priorities, or rule-driven changes in technique effectiveness, but cannot be interpreted as evidence of inherent technical superiority without additional data on success rates or efficiency metrics. Our data suggest that contemporary fighters have developed more direct and systematized approaches to finishing fights, reflecting the evolution of training methodologies and competitive strategies.

Keywords: martial arts; performance analysis; athletic performance; time motion analysis; competitive behavior



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1. Introduction

The professionalization of mixed martial arts (MMA) has been shaped by the establishment of standardized rules, weight categories, and fight-stopping criteria, which have contributed to its transformation from a marginal activity to a regulated sport [1,2]. This process involved legal and political contestations, such as in Canada, where MMA evolved from being viewed as a criminal activity to a legalized and widely accepted sport through lobbying and regulatory changes [3]. The sport's development reflects a balance between informalization and formalization, with phases of regulatory tightening and "cosmetic" rule changes designed to maintain excitement while ensuring safety, thus influencing fight dynamics and competition outcomes [2,4]. The legalization and sportivization of MMA, as seen in France, further professionalized the practice by reassuring participants and organizers, which has impacted training and competition structures [1,5]. The hybridization of various martial arts styles and the rise of professionalism over amateurism have also been key factors in MMA's evolution into a global sport with standardized organizational frameworks [6,7]. Overall, these structural, technical, and organizational transformations have directly influenced how fights are conducted and judged, contributing to the sport's ongoing professionalization and competitive dynamics [2,8,9].

Studies analyzing the temporal and motor behavior of MMA athletes have documented changes in fight structure, including variations in combat pace, technical action volume, and offensive and defensive behavior distributions over time [10,11]. Research on regulatory changes shows that rules modifications correlate with shifts in technical-tactical actions and injury rates, highlighting how the competitive environment influences the evolution of sport [4]. Previous studies have examined the pace and motor patterns of fights ending in knockouts/technical knockouts (KOs/TKOs) across different rounds, providing insights into how fight dynamics vary with bout progression [8,9,12,13]. Longitudinal analyses of MMA fights, such as those in the UFC, have revealed evolving tactical strategies and diverse combat styles over the years, reflecting adaptations to rule changes and competitive demands [11,14,15]. These studies underscore the importance of examining historical intervals to understand the transformations in submission strategies and technical specializations in MMA [4,7].

Existing MMA research has largely examined the frequency of KO/TKO and submission outcomes, comparisons across weight categories and sex, temporal fight characteristics, and the effects of rule changes on technical-tactical actions and injury incidence [1,12,16]. More recent studies have explored the pacing and motor patterns in KO/TKO outcomes, underscoring the dynamic nature of MMA competitions [12]. Although a limited number of longitudinal investigations have examined historical trends in fight outcomes over extended times, these analyses have primarily focused on the distribution of results (e.g., KO/TKO, submission, unanimous, and split decisions) without detailing the technical or positional mechanisms underlying these outcomes [13,14,17]. However, there are still significant gaps. Most studies rely on cross-sectional designs, limiting insights into long-term evolutionary trends, and few systematically analyze the positional context of submissions, focusing only on the outcomes [18,19]. This omission is critical because the positional context underpins technical specialization and strategic development. Consequently, the literature has struggled to capture and quantify long-term strategic and technical evolution in MMA, particularly the increasing distributional concentration of finishing techniques. In contrast to previous longitudinal approaches [13,14], this study integrates outcomes, techniques, and positional contexts within the same analytical framework, allowing for a more granular assessment of how finishing strategies have evolved and systematized over time. To address these limitations, the present study conducted a comparative analysis across three historical windows (2003–2004, 2013–2014, and 2023–2024) to examine the

differences in finishing techniques and positional contexts in MMA. We hypothesized that technical and positional distributional concentration in KOs/TKOs and submission finishes would differ significantly across windows, with progressive increases in distributional concentration from the Early (2003–2004) through the Mid (2013–2014) to the Modern window (2023–2024), characterized by more position-specific patterns in the most recent window.

2. Materials and Methods

2.1. Study Design and Data Source

This was a retrospective comparative analysis of MMA fight data from the UFC. The study examined 1735 UFC bouts conducted across three distinct temporal windows: 2003–2004 (Early window, $n = 78$), 2013–2014 (Mid window, $n = 813$), and 2023–2024 (Modern window, $n = 844$). The selection of three discrete two-year periods was based on the following theoretical and practical rationale: (1) 2003–2004 represents the Early temporal window, before major organizational changes and weight class standardization, when the sport was still establishing standardized rules and competition formats; (2) 2013–2014 represents a Mid temporal window following significant rule modifications (including restrictions on certain techniques), the expansion of women's divisions, and increased professionalization of training; and (3) 2023–2024 represents a recent temporal window characterized by established training methodologies, global athlete participation, and mature competition structures. This approach captures distinct competitive windows while maintaining sufficient sample sizes within each window to enable robust statistical analysis.

Video quality and resolution were standardized across all three temporal windows using UFC's official broadcast footage, which maintains consistent technical specifications across all events. Data collection followed a mixed pipeline: (1) Database extraction: Fight outcomes (KO/TKO, submission, decision), fighter names, dates, and weight classes were extracted from the official UFC database (www.ufc.com) and supplemented with detailed fight information from FightMetric (now part of the UFC Stats). (2) Video coding: All finishing techniques (specific choke type, strike type, etc.) and positional contexts (back control, guard, mount, etc.) were independently coded by four experienced evaluators (three Judo black belts and one Taekwondo black belt) based on video analysis of UFC fight footage. (3) Coder training and independence: Before coding, all four evaluators underwent standardized training on technique and position classification using a detailed coding guide. The evaluators coded independently without access to each other's classifications. (4) Disagreement resolution: Disagreements between evaluators were resolved through consensus discussions facilitated by the lead researcher, with the final classification determined by majority agreement (three of four evaluators). (5) Verification: Action frequency data were extracted from the official UFC database and verified against video analysis of a random sample of 50 fights to assess the consistency between database records and video-based observations. This mixed approach ensured data completeness from the official database and independent verification through video analysis.

2.2. Sample Selection Criteria

For inclusion, the analysis considered completed UFC fights from the specified temporal windows (2003–2004, 2013–2014, and 2023–2024) that resulted in a finalization by knockout/technical knockout or submission and had complete data on finishing techniques and action frequency, encompassing all weight classes and fighter experience levels. Fights were excluded if they were incomplete (e.g., no-contests or medical stoppages without a clear victor), ended by decision (unanimous, split, or majority), disqualification, or other non-finalization outcomes; presented missing or ambiguous classification of finishing techniques; lacked complete action frequency data across measured categories; or corresponded

to exhibition or non-sanctioned events. This selection focused exclusively on finishing methods and their associated positional contexts. The final analytical sample comprised 906 finalized fights, distributed as follows: Early ($n = 54$; 70.1% of window fights), Mid ($n = 418$; 51.4% of window fights), and Modern window ($n = 437$; 52.0% of window fights), with a detailed flowchart of the selection process presented in Figure 1.

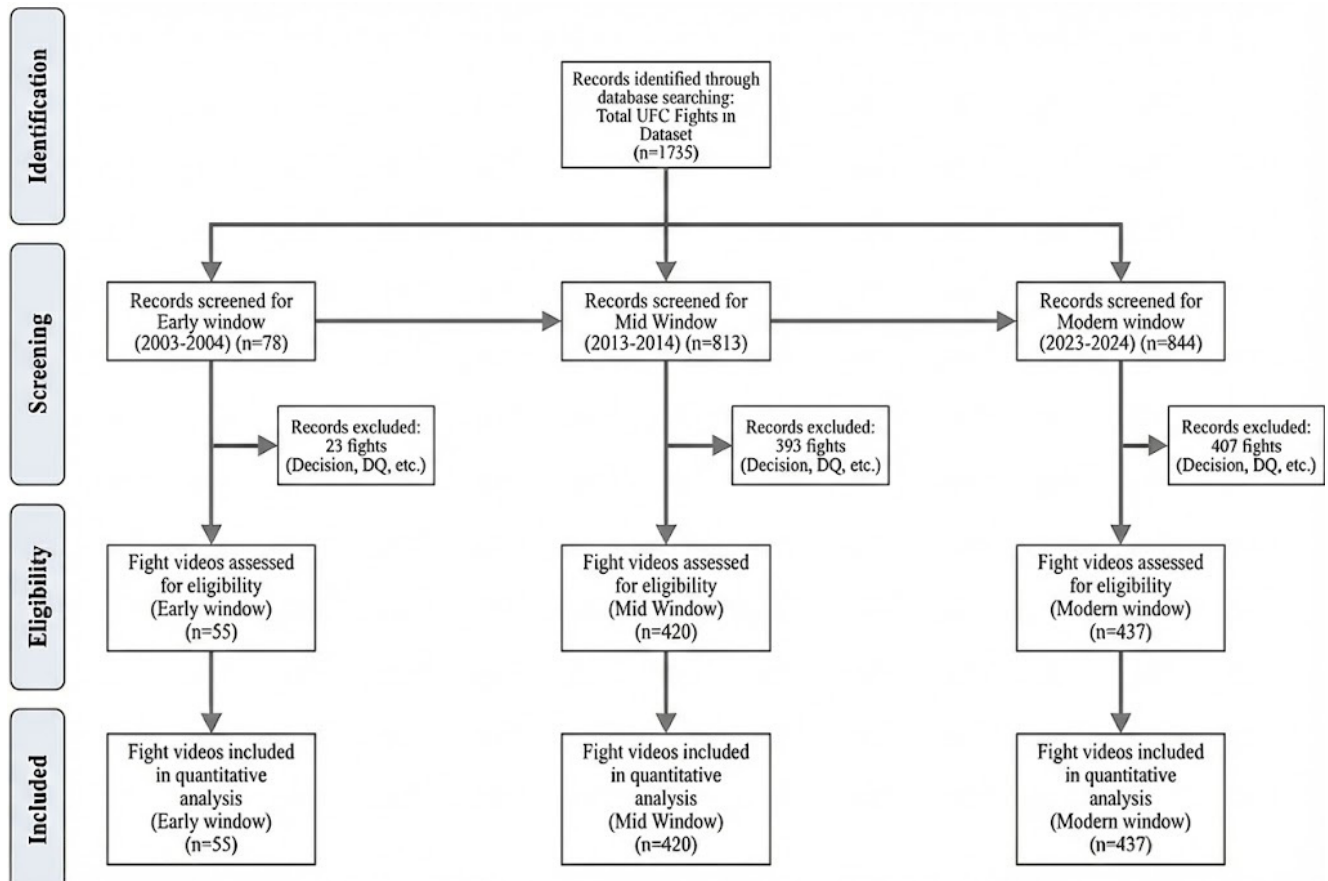


Figure 1. The flowchart illustrates the identification, screening, and inclusion of UFC fights across three distinct windows (2003–2004, 2013–2014, and 2023–2024). Data were extracted from the official UFC database and supplemented with video analysis for finishing technique and positional context coding.

2.3. Data Collection and Variables

The primary variables of interest were as follows: (1) Finishing Technique, categorized as KO/TKO techniques (punches, kick, knee, elbows, and other strikes) or Submission techniques (rear naked choke, guillotine choke, arm triangle, katagatame, armbar, triangle choke, and other locks and chokes); (2) Finishing Position, categorized as standing positions (at distance, in clinch and other distances), ground positions (from back control, from guard, from side control, and from mount), and other positions; and (3) Temporal window, coded as Early, Mid, and Modern window. Data consolidation was performed to address low-frequency categories (frequency < 5) by grouping similar techniques into broader categories. Consolidation rules were applied consistently across all windows using the following criteria: (1) techniques with absolute frequency < 5 in a given window were consolidated into broader “Other” categories based on functional similarity (e.g., “Other Chokes”, “Other Locks”, and “Other Strikes”); (2) the same consolidation rule was applied identically to all three windows. (3) For the Early window (2003–2004), where the overall sample size was substantially smaller ($n = 54$), an additional consolidation threshold of < 3 was applied only to categories that would otherwise remain empty or contain single cases.

All raw frequency counts before consolidation are provided in Supplementary Table S1 to allow readers to assess the impact of consolidation on the reported percentages.

2.4. Inter- and Intra-Reliability Analysis

Inter- and intra-evaluator reliability was assessed using intraclass correlation coefficients (ICCs). Inter-reliability was evaluated with ICCs (2,k) based on independent coding of a random sample of 120 UFC bouts by four experienced evaluators (three judo black belts and one taekwondo black belt). Intra-reliability was assessed using a test–retest design, in which each evaluator re-coded the same subset of bouts after a 2-week interval (ICC 2,1). This two-stage approach ensured agreement among evaluators and the temporal stability of individual classifications. The evaluators were selected based on their extensive expertise in combat sports, as judo and taekwondo share key grappling and striking principles with MMA. Specifically, judo expertise is particularly relevant for assessing submission techniques and positional control, whereas taekwondo expertise contributes to the evaluation of striking mechanics and distance management. All variables demonstrated excellent inter-rater reliability ($ICC > 0.90$), with values ranging from 0.95 to 1.0 (Table 1).

Table 1. Inter-reliability (ICC 2,k).

Variable	ICC (2,k)	CI Lower	CI Upper	Interpretation
Punches KO/TKO %	0.98	0.98	0.98	Excellent
Kicks KO/TKO %	1.0	1.0	1.0	Excellent
Submissions %	0.98	0.98	0.98	Excellent
Rear Naked Choke %	0.96	0.94	0.98	Excellent
Guillotine Choke %	0.97	0.95	0.98	Excellent
Armlock %	1.0	1.0	1.0	Excellent
Leg Lock %	1.0	1.0	1.0	Excellent
Other Submissions %	0.95	0.89	0.99	Excellent

ICC values represent inter-rater reliability for both finishing techniques (e.g., punch types and submission types) and positional variables (e.g., back control, guard, mount, and side control).

Intra-reliability was assessed through test–retest analysis, with each evaluator independently re-evaluating a subset of 120 cases at a 2-week interval. The ICC (2,1) values represented a single agreement between the test and retest occasions (Table 2).

Table 2. Intra-reliability (Test–retest).

Variable	Evaluator 1	Evaluator 2	Evaluator 3	Evaluator 4	Mean
Punches KO/TKO %	0.96	0.97	0.96	0.97	0.97
Kicks KO/TKO %	0.98	0.97	0.98	0.97	0.98
Submissions %	1.0	1.0	1.0	1.0	1.0
Rear Naked Choke %	0.97	0.96	0.97	0.95	0.96
Guillotine Choke %	0.98	0.95	0.97	0.99	0.97
Armlock %	1.0	0.98	1.0	0.98	0.99
Leg Lock %	1.0	1.0	0.98	1.0	0.99
Other Submissions %	0.97	0.95	0.95	0.96	0.95

Intra-reliability was excellent for all variables and evaluators, with ICC values ranging from 0.95–1.0.

2.5. Statistical Analysis

All statistical analyses were conducted using the Python programming language (version 3.11), with the aid of the Pandas library for data manipulation, SciPy for statistical testing, and Matplotlib 3.11 for visualization. Categorical variables, such as final strike and

final position, were initially assessed using descriptive statistics, including absolute frequencies and percentage proportions for each analyzed window (2003–2004, 2013–2014, and 2023–2024). Raw frequency data for all techniques are provided in Supplementary Table S1 to maintain transparency regarding the consolidation process. To optimize trend analysis and statistical power, techniques and positions with an absolute frequency of less than five in each window were grouped into broader categories based on functional similarity (e.g., “Other Chokes”, “Other Locks”). Consolidation rules were applied consistently across all windows, except the Early window (2003–2004), where a lower overall sample size necessitated additional grouping.

To test the association between finishing techniques/positions and time windows, chi-square tests of independence (χ^2) were employed. This test determined whether the frequency distributions of finishes by KO/TKO and submission differed significantly among the three windows. To identify which specific technique categories drive the overall significant associations, standardized residuals were calculated for each cell in the contingency tables. Standardized residuals with absolute values $> |2|$ indicate cells contributing substantially to the overall χ^2 statistic. Given the multiple comparisons conducted across different technique categories, a Bonferroni correction was applied to maintain the family-wise error rate at $\alpha = 0.05$. The per-comparison alpha was adjusted to 0.0083 for KO/TKO techniques and 0.0033 for submission techniques. To quantify the magnitude of the observed associations, Cramér’s V was calculated as a measure of the effect size. The interpretation of the strength of the association followed established conventions: $V \approx 0.1$ (small effect), $V \approx 0.3$ (medium effect), and $V \geq 0.5$ (large effect). Cramér’s V provides a standardized measure of association strength independent of sample size, complementing the chi-square p -values and providing practical significance alongside statistical significance.

To empirically validate the temporal segmentation, hierarchical cluster analysis was conducted on finishing technique frequency distributions across the entire 20-year dataset (2003–2024) using Ward’s linkage method. The resulting dendrogram revealed natural clustering patterns with inflection points occurring around 2012–2013 and 2022–2023, closely aligning with our theoretically selected windows. This analysis confirms that years within each selected window cluster together with high similarity, while years from different windows show greater dissimilarity, validating the use of these temporal windows as distinct analytical units (Supplementary Figure S1).

To characterize temporal trends in technique specialization across the three windows, linear trend analysis was conducted using the Cochran-Armitage test for trend in proportions. This test evaluates whether the proportion of a specific technique shows a significant linear trend across the ordered time windows. Trend statistics (Z -score) and associated p -values are reported for techniques showing significant temporal patterns. The significance level (alpha) was set at $p \leq 0.05$ for all analyses, with Bonferroni-corrected thresholds applied to multiple comparisons as described above.

3. Results

Our comparison revealed a significant evolution in MMA finishing strategies over the three studied windows, with submission techniques showing statistically significant differences across the windows ($p < 0.05$). The most significant shift was identified in submission finishes ($\chi^2 = 72.37$; $df = 12$; Cramér’s $V = 0.332$, medium effect). Standardized residuals (Supplementary Tables S2 and S4) revealed that the rear-naked choke (standardized residual = +3.2, $p < 0.001$) and katagatame (standardized residual = +2.1, $p < 0.05$) showed significant increases across windows, while the armbar (standardized residual = −2.8, $p < 0.001$), guillotine choke (standardized residual = −1.9, $p < 0.05$), and arm triangle (stan-

standardized residual = -1.7 , $p < 0.05$) showed significant decreases. These distributions are presented in Figure 2.

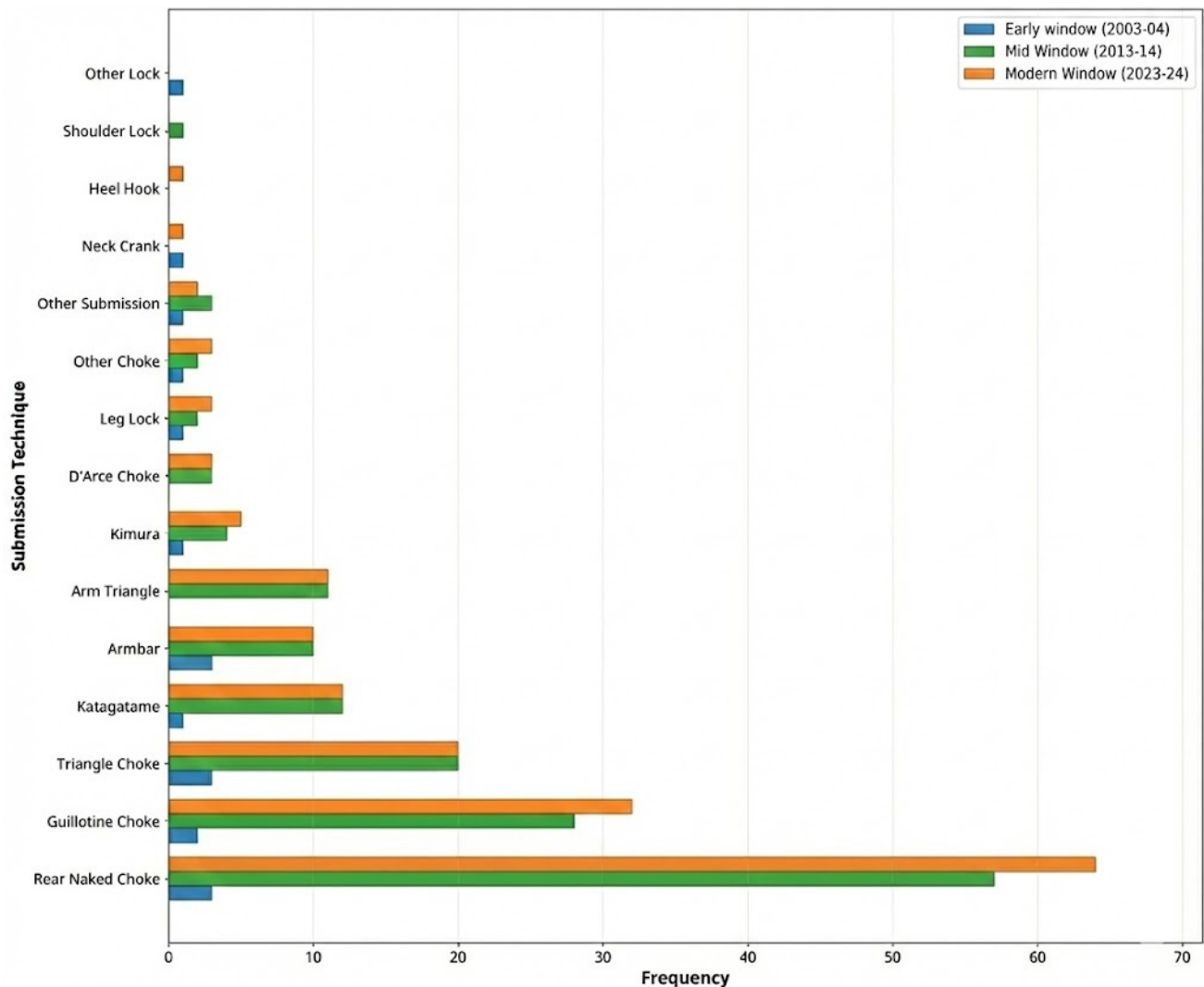


Figure 2. Evolution of Submission Finishing Techniques in Mixed Martial Arts over Three Decades. Horizontal bar charts display the frequency distribution of submission finishing techniques across the three temporal windows.

The strategic evolution of submission positions was statistically significant ($\chi^2 = 93.88$; $df = 12$; Cramér's $V = 0.378$, detailed in Supplementary Table S3), with the temporal window accounting for approximately 14% of the variance in positional selection. Early-era submission attempts were characterized by guard dominance (42.11%), whereas the modern era showed consolidation of back control (45.45%) and the emergence of side control submissions (20.78%). This distribution of submission finishing positions across windows is presented in Figure 3.

The evolution of KO/TKO finishing techniques demonstrated a statistically significant trend ($\chi^2 = 53.61$; $df = 8$; Cramér's $V = 0.218$, detailed in Supplementary Table S3), with the temporal window accounting for approximately 4.8% of the variance in technique selection. Punching remained the dominant finishing method across all windows. Heterogeneity in technique selection persisted within each temporal window, as presented in Figure 4.

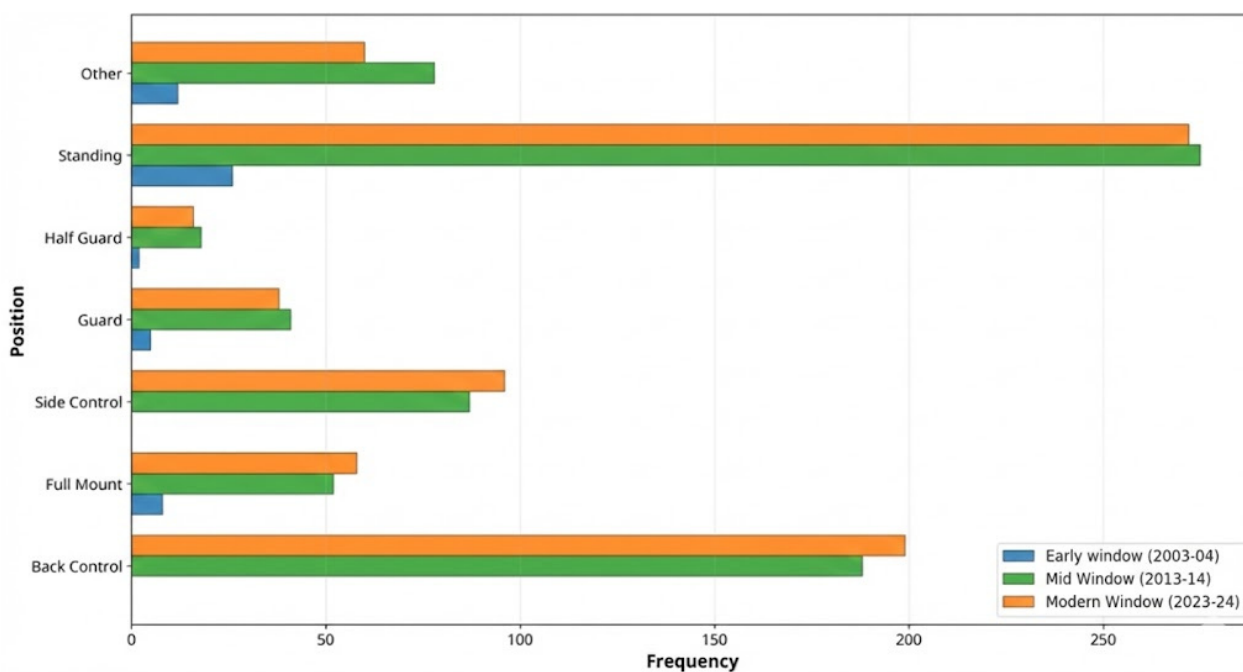


Figure 3. Evolution of Submission Finishing Positions in MMA over Three Decades. Horizontal bar charts display the frequency distribution of submission finishing positions across three temporal windows, and the color scheme distinguishes each position.

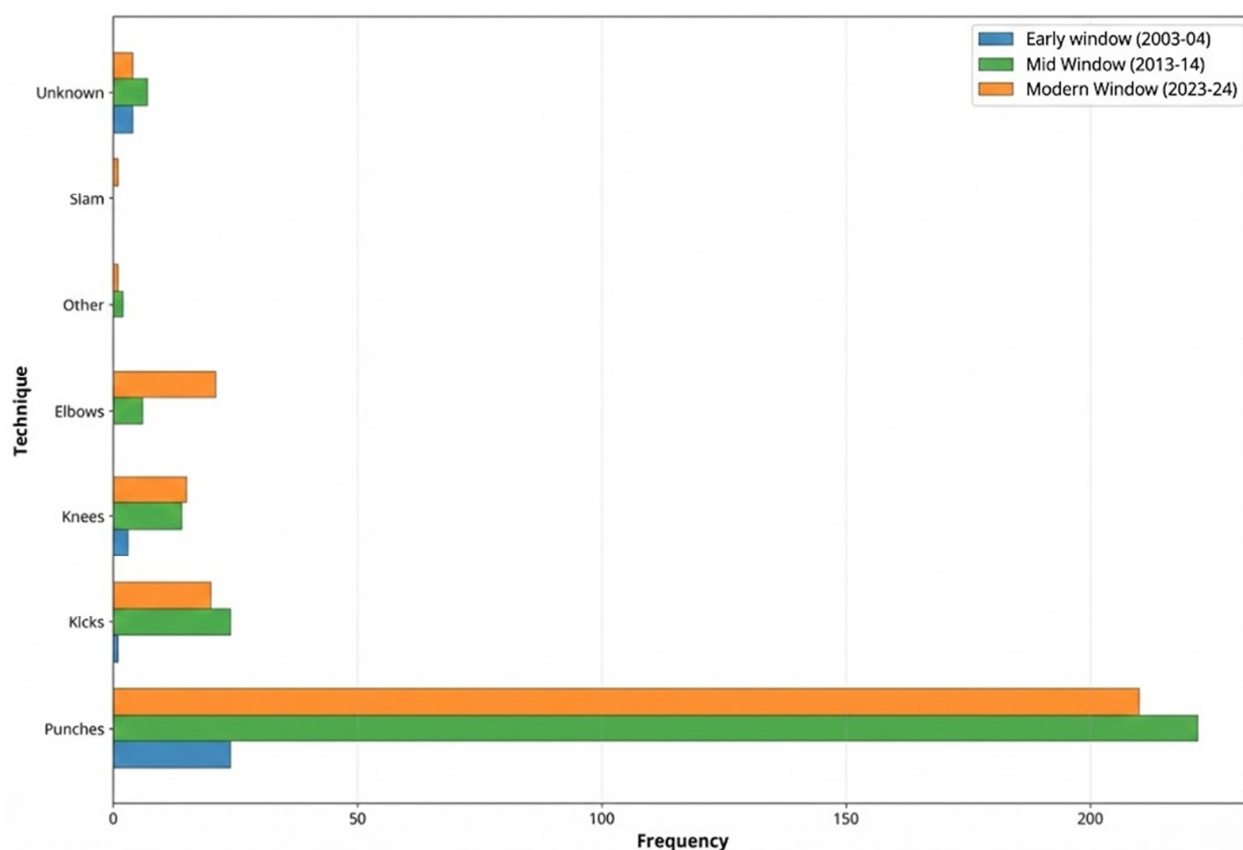


Figure 4. Evolution of most effective KO/TKO finishing techniques across three decades of MMA. Horizontal bar charts display the frequency distribution of KO/TKO finishing techniques across the three temporal windows.

Regarding KO/TKO finishing positions, a strong temporal trend was observed ($\chi^2 = 454.14$; $df = 14$; Cramér's $V = 0.633$, detailed in Supplementary Table S3), with the temporal window accounting for approximately 40% of the variance in positional selection. Early-era positional distribution was relatively even, followed by a mid window dominance of finishes At Distance and, a modern window distribution characterized by finishes at distance (46.57%) and from side control (22.02%). This distribution of finishing positions across windows is presented in Figure 5.

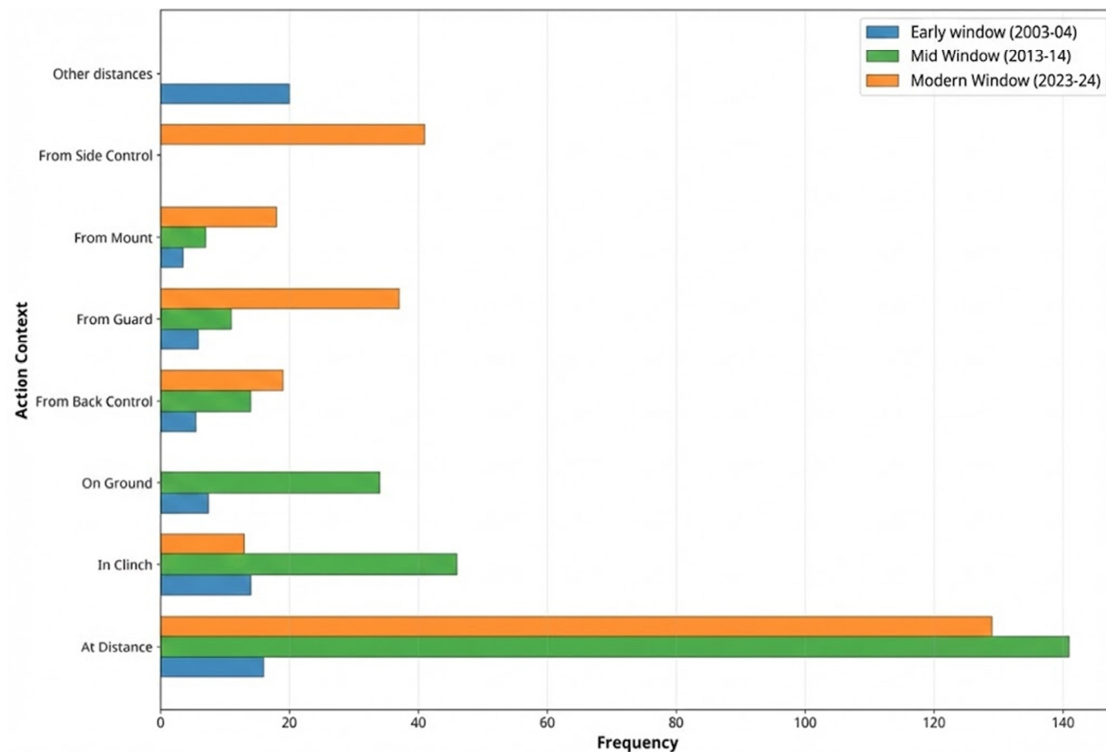


Figure 5. Evolution of the most effective KO/TKO Finishing Positions Across Three Decades of MMA. Horizontal bar charts display the frequency distribution of KO/TKO finish positions across the three temporal windows.

4. Discussion

The findings of this study provide a quantitative portrait of temporal patterns in the strategic approaches to MMA over two decades, revealing a sport that demonstrates characteristics consistent with a window of technical diversity transitioning toward one of deep distributional concentration. Statistical evidence shows that the methods used to finish fights, both by submission and KO/TKO, have not remained static; instead, the frequency distribution of finishing techniques has shifted substantially across the three windows. These shifts in frequency patterns may reflect changes in fighter training priorities, strategic preferences, or the relative effectiveness of techniques under evolving rule sets, but the present analysis cannot directly measure efficiency or effectiveness without additional data on success rates or attempt-to-success ratios. The most significant trends documented in this analysis are the dramatic rise of the rear naked choke from 15.8% to 46.8% in submission finishes, the consolidation of back control as the dominant submission position (from 0% to 45.5%), which is very similar to the results obtained by Stellpflug et al. [20], where they found that the frequency of this same position was widely used in UFC (49.1%), the increased prevalence of punches for knockouts, and the recent emergence of side control as a key platform for ground-and-pound (rising from 0% to 22.0%). These patterns of increased frequency may be consistent with the importance of grappling and accuracy

identified by James et al. [21], though direct comparison requires caution because our analysis measures technique frequency in finalized bouts, whereas that study examined performance indicators across all fight outcomes. The increased prevalence of specific techniques in our data does not directly measure accuracy or performance indicators.

Several potential mechanisms may explain the observed temporal patterns in finishing technique prevalence. The regulatory environment of the UFC has evolved substantially over the study windows, with multiple rule modifications that may have directly influenced technical distributional concentration. Specifically, the 2012 rule changes introduced restrictions on certain striking techniques and modified ground-fighting regulations, while the comprehensive 2016 rule modifications, particularly regarding grounded opponent striking regulations and the introduction of new weight classes, fundamentally altered the relative effectiveness of striking-based versus grappling-based victory strategies [22]. Additionally, changes in referee stoppage criteria and the standardization of officiating across events may have influenced the prevalence of specific finishing techniques by affecting the threshold at which fights are stopped and the opportunities available for different finishing methods [10,23]. Safety regulations, including restrictions on certain submission types and modifications to protective equipment requirements, may also have contributed to shifts in finishing technique prevalence [4,9,24].

Improvements in athlete conditioning, professionalization of training camps, and increased distributional concentration in striking coaching may have enhanced the overall athlete population's technical proficiency [7]. The evolution of the competitive athlete pool, potentially attracting more athletes from striking-based martial arts backgrounds, may have naturally selected fighters with superior striking abilities [15,25,26]. Increased access to fight footage and technical knowledge through digital media may have accelerated the standardization and optimization of effective finishing techniques [13,25]. The commercialization of the UFC and associated economic incentives, including higher purses for knockout finishes, increased media rights revenue, and sponsorship opportunities, may have influenced training priorities and fighter specialization toward finishing-oriented strategies [27,28]. These potential mechanisms are not mutually exclusive and likely interact to produce the observed temporal patterns. The relative contribution of regulatory changes, athlete development factors, and commercialization pressures to the observed technical distributional concentration cannot be definitively determined from this descriptive analysis, highlighting the need for future research that specifically examines the temporal relationship between regulatory changes and technical-tactical evolution.

The temporal patterns reveal bifurcation in modern MMA competitive approaches rather than simple convergence toward a single dominant strategy. This bifurcation reflects the emergence of two distinct finishing pathways: a grappling-dominant pathway and a striking-dominant pathway. The strategic advantage of the rear position as an efficient finishing platform in modern MMA [20,29] underscores the importance of foundational grappling competencies, particularly systematic progression from standing control through positional transitions to back control establishment [8,21]. The emergence of new submission techniques alongside the decline of historically dominant ones reflects a dynamic process of technique adoption, adaptation, and abandonment based on evolving competitive pressures, defensive innovations, and fighter-specific tactical preferences [4,9,20]. The large effect sizes for positional variables indicate that the temporal window is a strong predictor of positional strategy. This bifurcation, characterized by grappling- and striking-dominant pathways, may reflect multiple mechanisms: professionalization of training camps, rule-driven incentives for ground control, defensive adaptations to previously dominant techniques, or fighter demographic shifts [26,28]. However, the substantial within-window heterogeneity suggests that fighters continue to employ diverse finish-

ing strategies, reflecting tactical flexibility and fighter-specific specialization rather than sport-wide convergence [9,26,28,30].

The increased concentration in striking techniques reflects broader changes in how modern fighters approach knockout finishes. Punches operate at specific distance ranges and with particular temporal dynamics compared with kicks [19,31]. The increased prevalence of punches may be associated with their biomechanical characteristics, including distance requirements and the ability to execute rapid successive strikes [4,26,32]. Training innovations that emphasize distance management and biomechanical precision may underlie these patterns [6,7]. The technical complexity of effective striking suggests that modern fighters have invested substantially in developing the competencies necessary for consistent finishing opportunities.

The emergence of ground-and-pound as a secondary finishing approach alongside standing striking suggests that modern MMA has developed multiple viable pathways to knockout finishes rather than converging on a single method. This bifurcation between standing and ground-based striking may reflect changes in training methodologies, rule interpretations, fighter selection, or competitive incentives [28]. The modest effect size indicates that substantial heterogeneity in striking technique selection persists within each temporal window, reflecting the continued use of diverse striking approaches by different fighters [11,15,33]. This heterogeneity indicates that punching specialization at the population level coexists with tactical diversity at the individual level, suggesting that alternative striking techniques remain viable within modern competitive contexts [4,20]. Modern MMA striking success requires not only technical punching proficiency but also sophisticated spatial and tactical control to consistently capitalize on finishing opportunities [18,34]. This pattern suggests that combat sport rewards versatility and adaptability alongside technical specialization. Future research employing efficiency metrics, success rate analysis, and qualitative interviews with fighters and coaches would clarify whether these distributional changes reflect genuine shifts in training philosophy or other mechanisms.

This study has some limitations that should be acknowledged. As a retrospective analysis, it relies on historical UFC records with variable documentation standards across windows. Although finishing technique data were complete for all 906 finalized fights analyzed, data collection required cross-referencing archival sources and video analysis, resulting in the exclusion of bouts with incomplete or ambiguous information. Moreover, the analysis was limited to finalized bouts (knockout/technical knockout or submission), representing approximately 52% of all UFC fights, which introduces selection bias toward finishing-oriented strategies and may limit generalizability to decision-based outcomes; consequently, the findings should be interpreted as describing patterns in finishing strategies rather than comprehensive technical-tactical evolution of the sport. A key methodological limitation is that the study assesses the frequency of techniques rather than their effectiveness or efficiency, as higher frequency does not necessarily indicate superior performance and may reflect changes in training priorities, strategic preferences, rule modifications, fighter demographics or backgrounds, or referee stoppage criteria. Direct assessment of effectiveness would require measures such as success rates, time to completion, or contextual factors (e.g., opponent characteristics and fight stage); therefore, the findings should be interpreted as descriptive patterns of fight finalization rather than evidence of inherent technical superiority. Additionally, the use of three discrete two-year windows provides window-specific snapshots rather than a continuous temporal perspective and may obscure gradual transitions or introduce sampling bias, particularly given the smaller sample size in the Early window. Finally, several potential confounders, including rule changes, weight class evolution and standardization, fighter nationality and training background, competition structure, and differences in athlete experience across windows, were not

directly controlled and may have influenced the observed trends. Despite these limitations, the large sample size, consistency of results across multiple statistical approaches, and meaningful effect sizes support the robustness of the main findings regarding temporal shifts in finishing techniques and positional contexts.

Despite these limitations, this study has clear practical implications for MMA coaching, athlete development, and training design. The findings provide evidence-based guidance for strength and conditioning specialists and technical coaches regarding which finishing techniques should be prioritized in training. In submission-oriented preparation, the dominance of the rear naked choke and the consolidation of back control indicate that grappling programs should emphasize a structured progression from standing control through positional transitions to back control, with particular attention to choke application mechanics. In striking-oriented preparation, the distributional concentration in punches—especially rear straight punches, front hooks, and rear hooks—in combination, with the central role of foot positioning and distance management suggests, that training should focus on stance-specific footwork, punch-type specialization, and distance-management drills as core components. These insights can inform periodized training cycles, talent identification processes, and competitive preparation across weight classes and levels of competition. Future research should address remaining gaps through longitudinal designs that examine continuous temporal trends, enabling a more refined understanding of strategic evolution and the identification of potential inflection points, while also incorporating decision-based outcomes alongside knockouts and submissions to determine whether technical distributional concentration extends beyond stoppages. Additional investigations into the influence of rule changes and fighter-level variables, such as experience, training background, weight class, and coaching methodology, would help clarify the mechanisms underlying the observed trends, and comparative analyses across MMA organizations and competitions, together with biomechanical studies of prevalent finishing techniques focusing on force production, injury risk, and technical efficiency, would determine whether these patterns reflect a broader evolution of the sport and support evidence-based injury prevention strategies.

5. Conclusions

This study documents differences in MMA finishing strategies across three temporal windows spanning two decades, demonstrating differences consistent with a shift from technical diversity toward distributional concentration and systematization. However, these patterns are based on three discrete time windows and do not characterize continuous evolution; longitudinal analyses with more frequent sampling would be needed to confirm whether this represents a gradual, continuous process or distinct shifts between windows. The findings provide quantitative support for patterns suggesting that modern MMA finishing strategies have become increasingly specialized and position-dependent. While these patterns are consistent with multiple potential explanations, including the maturation of the sport, changes in training methodologies, rule modifications, improvements in athlete conditioning, and evolution of the competitive athlete pool, the specific mechanisms driving these changes cannot be definitively established from descriptive analysis alone. These results contribute to the growing body of evidence documenting that elite MMA competitions demonstrate increasingly specialized and systematic characteristics, with potential implications for coaching methodology, athlete development, and competitive preparation across all levels of the sport. Future research employing mixed-methods approaches (combining quantitative analysis with qualitative interviews of coaches and athletes) or quasi-experimental designs would be valuable for establishing causal relationships and identifying the specific factors driving the observed temporal changes.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/app16042034/s1>.

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Abbreviations

The following abbreviations are used in this manuscript:

MMA	Mixed Martial Arts
UFC	Ultimate Fighting Championship
KO	Knockout
TKO	Technical Knockout
ICC	Intraclass Correlation Coefficient
CI	Confidence Interval
DF	Degrees of Freedom
χ^2	Chi-Square Statistic

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