DIFFERENCES BY ENDING-ROUNDS AND OTHER ROUNDS IN TIME-MOTION ANALYSIS OF MIXED MARTIAL ARTS: IMPLICATIONS FOR ASSESSMENT AND TRAINING

Running head: Performance analysis and Mixed Martial Arts

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ABSTRACT

This study aimed to support training program development through the comparison of performance analysis of professionals mixed martial arts (MMA) athletes in the bouts that were not finished by points. Using digital recordings of each bout, we analyzed 1,564 rounds (678 bouts) which were separated by Ending and other Rounds. Our results indicated that KO/TKO is the main outcome that defines the ending round (≈60%), however, there is a higher frequency of ending by submission on the 1st and 2nd round (>30%). Bouts ending during the 1st or 2nd rounds had shorter total time and standing combat with low-intensity than ending in the 3rd round (91.5±71.4, 93.4±67.5 and 143.2±87.4; for low-intensity in the 1st, 2nd and 3rd round respectively; p<0.05), while standing combat time with high intensity was longer in the last round in comparison to bouts that finished in the 1st or 2nd rounds (7.4±9.2, 9.7±18.0 and 17.7±29.1 for high intensity in the 1st, 2nd and 3rd round respectively; p<0.05). The lower time dedicated to low-intensity stand up combat actions, regardless of round, and forcefulness of the actions in groundwork in the 1st and 2nd rounds appear to be elements that increase the probability of success in professional MMA bouts, these factors have essential implications related to training program design.

Keywords: Time and Motion Studies, Training Program, Task Performance and Analysis, Martial Arts.
INTRODUCTION

Mixed Martial Arts (MMA) has grown immensely, particularly after 1993, with the beginning of the Ultimate Fighting Championship® (UFC) (12). This combat sport consists of five minute rounds with open tasks, involving full contact striking skills (punches, kicks, knees and elbow attacks), grappling actions (throws and takedowns) as well as submissions techniques during grappling, including chokes/strangles and joint locking (17, 33). The athletes aim to obtain a full knockout, which is considered any legal strike or combination thereof that renders an opponent unable to continue fighting (6, 12). However, it is not clear whether the technical-tactical aspects for applied sport scientists and strength and conditioning coaches would change when a knockout (TKO/KO) occurs in order to assist in the development of combat-specific conditioning programs (28, 42, 43). Performance analyses of MMA competition may offer useful information for athletes and coaches who are interested in physic-physiological demands (2, 18, 42), to create sport-specific assessments (8, 19), comparable training sessions (14, 29, 35), preventing injury (20, 35) and improving performance (7, 23, 33).

Time-motion analysis has been used extensively to investigate the movement patterns and activity profiles of sports combat competitions (6, 7, 33, 40, 48), research into the physical demands and movements patterns of MMA rounds is limited. Previous reports have displayed specific and circumstantial observations, which affect MMA performance and determine competitive success, such as the effort: pause ratio (10, 26, 33), stand up and groundwork phase (10, 17, 26, 33), strike attacks (26, 33), takedowns (26, 33), and submission attempts (26, 33). Despite the important contributions of these studies, neither discriminates the ending-combat situation in the first, second or third round.
MMA instructors use traditional conditioning (i.e., high-intensity strike combinations), repeated high-intensity effort training, skill ‘drills’, and MMA combat-based training to prepare for competition without essential requirement of bouts and round demands of combat tasks (9, 11). Therefore, strength and conditioning databases based in time-motion ending rounds patterns could be actively altered in order to increase the possibility of KO and TKO during a specific round (32, 33, 40). This information has essential consequences, with regard to the needs analyses required in the development of both general and specific training programs for MMA fighters.

Obtaining accurate performance analysis of MMA ending rounds is of interest to coaches and high-level support athletes because the potential to relate intensities of different combat phase characteristics, and to assist in the design of better training programs (12). Due to complications in conducting physiological measurements during MMA combat, numerous investigations interested in match demands of MMA have focused on injuries, valuations of time-motion, heart rate and gas analysis in training and fight simulations (4, 7, 8, 20, 22, 26, 33).

Time-motion analysis in Mixed Martial Arts reveals a variety of efforts during actions and constant interruptions during bouts which clearly define the intermittent nature of the combat sport (26, 33). Lately, findings which compared outcome results in bouts in the 3rd round showed differences between combat phase time between rounds, when comparing winners and losers by round (33). However, authors did not make distinctions between bouts ending in KO/TKO in different rounds. This new data could allow coaches, practitioners and researchers to make inferences about functional movements of MMA(4), and to improve training programs with appropriate demands(2). Schematic models of time-motion analysis for MMA may help to observe competitive condition, as showed in other combat sports (5, 27, 34, 36, 41, 42). Further,
time-motion comparisons of ending rounds can offer essential information to improve contextualized training plans with potentially unknown key factors (1).

Therefore, this study aimed to compare time-motion and technical-tactical behaviors of professional mixed martial arts (MMA) athletes in the bouts that were not finished by points. The study considered two situations: a) bouts when the combat is finished (i.e. 1st vs. 2nd vs. 3rd round); b) bouts of ending combats vs. other bouts (i.e. compare ending bouts with 1st when the combat finished on the 2nd round and, 1st and 2nd bouts when the combat was finished on 3rd round). The present research concludes with the introduction of a novel hypothesis inspired by an ecological approach on the integration of bouts when the combat is finished (i.e. 1st vs. 2nd vs. 3rd round) and bouts of ending combats vs. other bouts information about differences between groups to discover the mechanisms to achieve the TKO/KO situation. The information gained from this research has the potential to assist strength and conditioning specialists, coaches and trainers to devise appropriate efficient and effective training schedules.

**METHODS**

**Experimental approach to the problem**

This comparative and descriptive applied research study, using time-motion analysis, allowed us to determine specific physical demands by arrangements used at a specific time by elite level athletes participating in professional MMA bouts. This information brings new conceptions of physical evaluations and training programs with specific situations and intensity levels relative to ending rounds (TKO/KO rounds), Figure 1.

***Please, insert Figure 1 near here***
The study was divided into three stages. First, the indicators were identified in preceding reports and in time-motion and technical-tactical actions (9, 24, 34), as dependent variables, and Ending Rounds (in which a KO/TKO occurred) and other Rounds, as independent essential variables in MMA bouts, which were incorporated in a conceptual model. These factors could show how coaches and researchers can use the most determinant variables of MMA bouts associated with the strategic profile of MMA athletes for further physical conditioning, strength and technical-tactical training based on the pacing strategy found in fights with different Ending Rounds. Second, validated protocols were identified in previous studies addressing time-motion analysis (3, 6, 7, 10, 17, 26, 29, 33, 37) and professional bouts were recorded and analyzed according to the time-motion model. All bouts occurred during UFC events in air-conditioned arenas, except Ibirapuera's Gym, between 18:30 and 24:00 at a range temperature between 24.5 and 27.0 C. Afterward, in the last stage, an inferential analysis between rounds was conducted, comparing time-motion demands by Ending Rounds (in which a KO/TKO occurred) and other Rounds.

Subjects

The sample was composed of 364 professional male MMA athletes (age range from 20 to 48 years old) comprised of all weight division: a) strawweight (52.2 kg; n = 25); b) flyweight (56.7 kg; n = 22); c) bantamweight (61.2 kg; n = 23); d) featherweight (65.8 kg; n = 47); e) lightweight (70.3 kg; n = 61); f) welterweight (77.1 kg; n = 77); g) middleweight (83.9 kg; n = 41); h) light heavyweight (93 kg; n = 42); i) heavy weight (120.2 kg; n = 26). The present research analyzed 1,564 rounds of 678 UFC bouts, the sample was separated by Ending Rounds (Round in which a KO/TKO occurred) and other Rounds (Ending 1st Round, n = 192 vs. Ending 2nd Round and 1st Round, n = 86 vs. Ending 3rd Round and 1st Round, n = 400 vs. Ending 2nd Round, n = 86 vs. Ending
3\textsuperscript{rd} Round and 2\textsuperscript{nd} Round, \( n = 400 \) vs. Ending 3\textsuperscript{rd} Round, \( n = 400 \) from 2014 UFC™ events (TUF 19, TUF Brazil, TUF China, TUF Nations: Canada vs. Australia, UFC-169, UFC-170, UFC-171, UFC-172, UFC-173, UFC-174, UFC-175, UFC-177, Fight Night 34, Fight Night 35, Fight Night 36, Fight Night 37, Fight Night 38, Fight Night 39, Fight Night 40, Fight Night 41, Fight Night 42 and Fight Night 43. A minimum of six weeks of rest was observed between bouts to prevent stress interference between different combats (14). All participants had previous experience with professional UFC events, rules and procedures used during the championship. No interferences were made in the training, nutritional or hydration status of participants and they maintained the weight loss recovery time pattern of 24 hours between Official weigh-in and the bout, following UFC rules (15, 21). The criteria of inclusion was to consider only bouts which were not decided by points, while exclusion criteria were concerning bouts with less or more than three rounds and/or with characteristics that disqualified prospective outcomes comparisons – bouts which finished in “draw” or “no contest”. Table 1 presents the percentage of ending bouts separated by rounds.

***Please, insert Table 1 near here***

In order to guarantee ecological validity and facility to acquire high level performances, the combats were documented by different cameras with sufficient quality (standard definition 480/60i) and taken from a landscape view of the entire combat area, following preceding research protocols (3, 10, 26, 29, 33). This study was submitted to and approved by the Superior School of Physical Education, Federal University of Pelotas Committee of Ethics in Research, following the rules of resolution 196/96 of the Brazilian National Health Council. All data was established by FightMetric®, the official statistics provider of the UFC®, which had all informed consent term signed for unlimited use of collected images from athletes. In addition, the
The present study was approved and ensured anonymity and confidentiality by replacing the athletes’ personal identification and there are no ethical issues in analyzing or interpreting data obtained at public events, as established by previous protocols (26, 29, 33).

**Procedures**

*Protocol of time-motion analysis, intra and inter-expert validation*

Time-motion and technical-tactical actions were observed by five researchers, according to frequency of actions and time of the Standing and Groundwork situations, separated by low (i.e. displacements or stable positions and movements without opposition) or high intensity (i.e. offensive and defensive techniques, exchanges between opponents), following a previously established protocol (10, 26, 33). Table 2 presented the criteria applied to conduct the analysis by time-motion variable.

***Please, insert Table 2 near here***

In order to guarantee ecological validity and to verify the elite status of the sample, the bouts were analyzed by FightMetric Team using UFC records with professional quality and recorded by performance analysts (40). All available videos of sufficient quality (standard definition 480/60i) and taken from a landscape view of the entire competition area were included in the analysis (40). When appropriate, considering the inclusion criteria, both athletes were evaluated in a single match, and individual athletes were evaluated more than once when videos of multiple matches were available, following previously published protocol (40).

The reliability measures were assessed through intra-observer and inter-observer testing procedures on time-motion and technical-tactical variables provided by two experts, with more than ten years of combat sports experience and university degrees in Physical Education(6, 38), who analyzed MMA bouts with Frami software.
Comparisons of ten bouts were conducted to determine possible differences between the intra and inter-expert measurement of the combat phases using the Wilcoxon Mann-Whitney test and no differences were observed among intra and inter-expert (31). The correlation between measurements obtained for each time-motion variable was verified by intraclass correlation coefficient (ICC), two-way random single measures (absolute agreement) (24, 30), with an agreement classified as ‘Strong’ for all time-motion variables, with an agreement by bouts analyzed of 0.99 ($P<0.001$; 95% CI= -199.45 to 197.45) for total effort time, 0.96 ($P<0.001$; 95% CI= -131.16 to 201.6) for standing up with low intensity, 0.98 ($P<0.001$; 95% CI= -28.53 to 26.53) for standing up with high intensity, of 0.98 ($P<0.001$; 95% CI= -7.73 to 5.73) for groundwork with low intensity, of 0.99 ($P<0.001$; 95% CI= -87.12 to 85.12) for groundwork with high intensity. The correlation between measurements obtained for each technical variable was verified with Cohen's Kappa(41), with an agreement of 0.54 ($P<0.001$; 95% CI= -11.99 to 12.99) for strike attempts, 0.85 ($P<0.001$; 95% CI= -0.06 to 0.06) for takedowns attempts, 1.0 ($P<0.001$; 95% CI= 0.0 to 0.0) for chokes, 1.0 ($P<0.001$; 95% CI= 0.0 to 0.0) for locks and 0.85 ($P<0.001$; 95% CI= -0.45 to 0.45) for submissions. The following values and strength of agreement classifications were used: 0.0 to <0.2, poor; 0.2 to <0.4, fair; 0.4 to <0.6, moderate; 0.6 to <0.8, substantial; 0.8 to <1.00, almost perfect and 1: perfect (6, 31). These statistical tests were processed using SPSS software (version 20.0; SPSS, Inc., Chicago, IL, USA).
Statistical Analysis

All statistical tests were processed using SPSS software (version 20.0; SPSS, Inc., Chicago, IL, USA). Kolmogorov-Smirnov test (K-S) was used to determine data’s normal distribution. Descriptive data of continuous dependent variables (i.e. total effort time, standing up with low intensity time, standing up with high intensity time, groundwork with low intensity time and groundwork with high intensity time) are presented as mean and standard deviation (SD). Descriptive data of frequency of dependent variables (i.e. strikes landed, strikes attempted, takedowns landed, takedowns attempted, submissions, chokes and locks) are presented as percentage or mean, standard deviation (SD) and confidence intervals. Two-way [Ending Round (1st round, 2nd round and 3rd round) × Round (1st round, 2nd round and 3rd round)] (ANOVA) with Bonferroni post-hoc tests were used to compare the time-motion variables. For non-parametric data, Kruskal Wallis ($X^2$) was used to conduct repeated measures analysis of variance by ranks, followed by Bonferroni post-hoc tests. The Eta squared ($\eta^2$) was calculated. The 95% confidence intervals were calculated and a significance level of $P \leq 0.05$ was used for all analysis.

RESULTS

Of the total bouts analyzed, 28.3% were finished during the 1st Round, 13% during the 2nd Round and 59% during the 3rd Round. Table 3 shows descriptive analysis of time-motion analysis in stand up combat phase separated by Ending Round and other Rounds.

***Please, insert Table 3 near here***

Variance analysis showed a significant main effect of Ending Rounds in Standing combat with low intensity ($F_{5, 1564}= 28.674; P<0.001; \eta^2=0.084$), where bouts ending in the 1st round had shorter standing combat time with low intensity than bouts
with ending in the 2nd round ($P<0.001$; 95% CI=-57.59 to -15.09) and bouts ending in the 3rd round ($P<0.001$; 95% CI=-79.58 to -48.12), while the bouts ending in the 2nd round had shorter standing combat time with low intensity than the bouts which finished in the 3rd round ($P<0.001$; 95% CI=-44.01 to -11.01). Comparisons of standing combat time with low intensity showed significant differences between rounds ($F_{5, 240} = 2.889; P<0.001; \eta^2=0.35$), where the bouts ending in the 1st round showed shorter standing combat time with low intensity than the bouts ending in the ending 2nd round ($P<0.001$; 95% CI=-97.930 to -37.095) and, shorter than the 2nd round of the ending 3rd round ($P<0.001$; 95% CI=-95.803 to -27.136), while the 1st round of the ending 2nd round had longer standing combat time with low intensity than the 2nd round of the ending 2nd round ($P<0.001$; 95% CI=37.539 to 108.311) and the 3rd round of the ending 3rd round ($P<0.001$; 95% CI=28.580 to 106.188), the 1st round of the 3rd ending round had longer standing combat time with low intensity than the 3rd round of the ending 3rd round ($P<0.001$; 95% CI=39.606 to 123.494) and the 2nd round of the ending 3rd round group had longer standing combat time with low intensity than the 3rd round of the ending 3rd round ($P<0.001$; 95% CI=19.397 to 103.285). No other effect in standing combat time with low intensity was observed between comparisons ($P>0.05$ for all comparisons).

In relation the standing combat with high intensity, a significant main effect of Ending Rounds was observed ($F_{5, 1564} = 7.519; P<0.001; \eta^2=0.024$), where bouts with 1st Round as the ending round had shorter standing combat time with high intensity than the 3rd round ($P<0.001$; 95% CI=-17.738 to -6.705). In addition, post hoc comparisons showed that the 1st round of the ending 1st round showed shorter time on this combat phase than the 1st round of the ending 2nd round ($P=0.41$; 95% CI=-24.092 to -0.252) and from the 2nd round of the ending 3rd round ($P=0.022$; 95% CI=-28.044 to -1.135).
No other effect standing combat time with high intensity was observed between groups (\(P>0.05\) for all comparisons).

For the groundwork combat with low intensity, a significant main effect of Ending Rounds and Rounds was observed (\(F_{5, 1564}= 6.078; P<0.001; \eta^2=0.019\)), where bouts finished on the 1\(^{st}\) round and 2\(^{nd}\) round had a shorter time with high intensity than the 3\(^{rd}\) round (\(P<0.001; 95\% \text{ CI}=-35.999 \text{ to } -11.200\) and \(P=0.012; 95\% \text{ CI}=-27.268 \text{ to } -2.489\)). No other effect in groundwork combat time with low or high intensity was observed between groups (\(P>0.05\) for all comparisons).

In the total combat time with low intensity, a significant main effect of Ending Rounds and Rounds was observed (\(F_{5, 1564}= 28.483; P<0.001; \eta^2=0.084\)), where bouts finished on the 1\(^{st}\) Round had shorter standing lower intensity than the 2\(^{nd}\) round (\(P<0.001; 95\% \text{ CI}=-57.261 \text{ to } -14.859\)) and the 3\(^{rd}\) round (\(P<0.001; 95\% \text{ CI}=-79.388 \text{ to } -47.995\)) and the 2\(^{nd}\) round was shorter than the 3\(^{rd}\) round (\(P<0.001; 95\% \text{ CI}=-44.095 \text{ to } -11.167\)). The post-hoc comparisons showed significant differences between rounds (\(F_{5, 240}= 2.901; P<0.001; \eta^2=0.35\)), where the finish on the 1\(^{st}\) round showed a longer time than the 1\(^{st}\) round of the ending 2\(^{nd}\) round (\(P<0.001; 95\% \text{ CI}=-96.983 \text{ to } -36.346\)) and the 3\(^{rd}\) round (\(P<0.001; 95\% \text{ CI}=-115.143 \text{ to } -46.698\)) and from the 2\(^{nd}\) round of the ending 3\(^{rd}\) round (\(P<0.001; 95\% \text{ CI}=-94.855 \text{ to } -26.411\)), while the 1\(^{st}\) round of the ending 3\(^{rd}\) round had shorter time than 2\(^{nd}\) round of the ending 2\(^{nd}\) round (\(P<0.001; 95\% \text{ CI}=-107.321 \text{ to } -36.779\)) and from 2\(^{nd}\) round of the ending 3\(^{rd}\) round (\(P<0.001; 95\% \text{ CI}=-124.984 \text{ to } -47.629\)), also, the 2\(^{nd}\) round of the ending 3\(^{rd}\) round had shorter time than the 3\(^{rd}\) round of the ending 3\(^{rd}\) round (\(P<0.001; 95\% \text{ CI}=-103.020 \text{ to } -19.404\)).
A significant main effect of Ending Rounds and Rounds was observed in Total combat time with high intensity ($F_{5, 1564}= 10.503; P<0.001; \eta^2=0.033$), where bouts finished on the 1st Round had shorter standing high intensity than the 3rd round ($P<0.001; 95\% CI=-49.588$ to $-22.053$). Lastly, a significant main effect of Ending Rounds and Rounds was observed in total combat time ($F_{5, 1564}= 424.374; P<0.001; \eta^2=0.58$), where bouts finished on the 1st Round had shorter standing lower intensity than the 2nd round ($P<0.001; 95\% CI=-83.515$ to $-61.168$) and the 3rd round ($P<0.001; 95\% CI=-143.331$ to $-126.787$) and the 2nd round was shorter than the 3rd round ($P<0.001; 95\% CI=-71.395$ to $-54.041$). Comparisons in total time showed significant differences between each round ($F_{5, 240}= 37354.427; P<0.001; \eta^2=1.00$), where 1st round of the 1st ending round was shorter than 1st round of the ending 2nd round ($P<0.001; 95\% CI=-137.132$ to $137.838$), 2nd round of the ending 2nd round ($P<0.001; 95\% CI=0.000$ to $0.705$), 1st round of the ending 3rd round ($P<0.001; 95\% CI=-138.305$ to $-137.508$), 2nd round of the ending 3rd round ($P<0.001; 95\% CI=-138.034$ to $-137.237$) and from 3rd round of the ending 3rd round ($P<0.001; 95\% CI=-22.788$ to $-21.991$).

Figure 2 shows descriptive analysis of technical analysis in stand up combat phase realized by fighters in UFC™ separated by Ending Round and other Rounds.

***Please, insert Figure 2 near here***

The principal results presented in Figure 2 indicated a significant main effect of Ending Rounds and Rounds was observed in the total of Strikes Landed by round ($X^2=129.388, P<0.001$), where the combat finished in the 1st round had lower values than 1st round of the ending 2nd round ($P=0.002; 95\% CI=-12.84$ to $-1.79$), 1st round of the ending 3rd round ($P<0.001; 95\% CI=-11.67$ to $-4.20$), 2nd round of the ending 3rd round ($P<0.001; 95\% CI=-13.30$ to $-5.82$) and from 3rd round of the ending 3rd round ($P<0.001; 95\% CI=-13.70$ to $-6.23$), also, the 2nd round of bouts with ending 2nd round
had lower values than 1\textsuperscript{st} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-12.16 to -2.04), 2\textsuperscript{nd} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-13.79 to -3.66) and the 3\textsuperscript{rd} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-14.19 to -4.07). No other effect in the Strikes Landed variable was observed between groups ($P>0.05$ for all comparisons).

For total of Strike Attempted, a significant main effect of Ending Rounds and Rounds was observed ($X^2=178.530$, $P<0.001$), where the combat finished on the 1\textsuperscript{st} round had lower values than 1\textsuperscript{st} round of the ending 2\textsuperscript{nd} round ($P=0.002$; 95\% CI=-24.58 to -8.06), 1\textsuperscript{st} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-22.95 to -11.78), 2\textsuperscript{nd} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-25.55 to -14.38) and from 3\textsuperscript{rd} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-25.76 to -14.59), also, the 2\textsuperscript{nd} round of bouts with ending 2\textsuperscript{nd} round had lower values than 1\textsuperscript{st} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-23.05 to -7.92), 2\textsuperscript{nd} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-25.65 to -10.52) and the 3\textsuperscript{rd} round of the ending 3\textsuperscript{rd} round ($P<0.001$; 95\% CI=-25.65 to -10.73). No other effect in the Strikes Attempted variable was observed between groups ($P>0.05$ for all comparisons). No effects in Takedowns Landed and Attempted comparisons were observed between groups ($P>0.05$ in all comparisons).

Table 4 shows frequencies of arrangements in groundwork phase.

***Please, insert Table 4 near here***

When analyzed the total of Submission Attempted, we observed a significant main effect of Ending Rounds and Rounds ($X^2=35.026$, $P<0.001$), where the combat finished on the 1\textsuperscript{st} round had higher values than 1\textsuperscript{st} round of the ending round 3\textsuperscript{rd} group ($P<0.001$; 95\% CI=0.06 to 0.31), 2\textsuperscript{nd} round of the ending 3\textsuperscript{rd} round ($P=0.06$; 95\% CI=0.03 to 0.28) and from 3\textsuperscript{rd} round of the ending 3\textsuperscript{rd} round ($P=0.038$; 95\% CI=0.0 to
0.25). No other effect in Submission Attempted variable was observed between groups 
\((P > 0.05 \text{ for all comparisons})\).

Lastly, a significant main effect was observed in the total of Chokes Attempted 
\((X^2 = 39.258, P < 0.001)\), where the combat finished on the 1\(^{st}\) round had higher values 
than 1\(^{st}\) round of the ending 3\(^{rd}\) round group \((P < 0.001; 95\% \text{ CI}=0.05 \text{ to } 0.25)\), 2\(^{nd}\) round 
of the ending 3\(^{rd}\) round \((P=0.03; 95\% \text{ CI}=0.01 \text{ to } 0.21)\) and lower values from 3\(^{rd}\) round 
of the ending 3\(^{rd}\) round \((P=0.037; 95\% \text{ CI}=0.0 \text{ to } 0.21)\), while the 2\(^{nd}\) round of the 
ending 2\(^{nd}\) round group presented higher values than 1\(^{st}\) round of the ending 3\(^{rd}\) round 
group \((P=0.043; 95\% \text{ CI}=0.00 \text{ to } 0.28)\). No other effect in Chokes Attempted variable 
was observed between groups \((P > 0.05 \text{ for all comparisons})\). No effects in Locks 
Attempted comparisons were observed between groups \((P > 0.05 \text{ in all comparisons})\).

**DISCUSSION**

Strength and conditioning training for MMA requires a great breadth of 
attributes to achieve a TKO/KO, and the primary aim of the present study was to 
describe performance analysis and to compare how bouts ended. This information 
serves to update practical applications of physical evaluations and training programs 
with particular situations and intensity regarding rounds and ending rounds, especially 
for combat styles with TKO/KO during the 1\(^{st}\) round versus ending rounds during the 
2\(^{nd}\) and 3\(^{rd}\) rounds. The main results showed that bouts ending during the 1\(^{st}\) round had 
shorter total time and standing combat with low intensity than all other rounds. Standing 
combat time with high intensity had similar results, with shorter time in ending during 
the 1\(^{st}\) round than all other rounds. Despite the greater number of strikes attempted and 
landed in bouts ending during the 2\(^{nd}\) and 3\(^{rd}\) rounds, bouts ending in the 1\(^{st}\) round had a 
higher ratio of strike attempts: landed attacks with 88\% of effectiveness, while TKO/KO 
rounds during the 2\(^{nd}\) and 3\(^{rd}\) rounds showed 54\% and 63\% of effectiveness attacks,
respectively. The current analyses allowed the changes in training activities associated with both long-term trends and the introduction of proficiency to be estimated while taking into account the effect of MMA bout environmental conditions.

Specific training programs with real parameters of intensity for TKO/KO situations are critical for reaching an end point in the shortest possible time of the bout. For instance, practical application of present data for conditioning and strength training allows a particular pattern of strike pacing actions during bouts ending in the 1st round, with ~9 strike attempts applied in 7 seconds, while the ending 2nd round and the ending 3rd round showed a ratio of ~11 strike attempts per 10 seconds and ~11 strike attempts per 18 seconds of high intensity time, other rounds maintained ~12 strike attempts per 20 seconds. In winners, the objective was also to outscore the bout (34); in those athletes attack pacing is often used tactically to score at the right time, when chances of success are most likely (14, 34). Therefore, in virtually every type of MMA athletic conditioning training, pacing is a prerequisite for success. Athletes must maintain enough metabolic capacity to avoid fatiguing before the end of the bout, and so a pacing strategy is required (11). Similar studies in combat sports (6, 24, 26, 28, 32, 39, 43) suggest that not only technical-tactical actions, but the time of effort-pause should be analyzed to establish training strategies.

Present ratios between higher intensity and lower intensity were similar between all rounds, about 1:3. Previous time-motion studies on UFC indicated an 1:2-1:3 (26) and 1:4 (32) of effort: pause ratio. These data support an original hypothesis encouraged by our ecological approach about strategic consideration to use mechanisms to achieve the TKO/KO situation discovered, considering the distribution of strike actions during high intensity time and the recovery ability of athlete, which could be the
difference for high power strikes when necessary, as higher volume of punches was applied by winners in UFC combats without TKO/KO (32).

In the present study, there has a higher prevalence of ending by submission in the 1st and 2nd round vs. 3rd (30.2%, 37.2% and 0.5% for the 1st, 2nd and 3rd round respectively). Although not observe significant differences, there is less time devoted to high intensity ground fight when the combat ends in the 1st and 2nd round when compared to the 3rd (26.1±48.3, 25.0±41.8 and 52.1±73.7 for groundwork with high-intensity in the 1st, 2nd and 3rd respectively). These results possibly indicate a higher vigor applied by winners to achieve a victory by submission in the 1st and 2nd rounds.

In fact to the groundwork, there was more time dedicated the lower intensity activities when the match is finished in the 3rd round. We believe that low-intensity developed by an athlete can allow the domain by the opponent. Previously, Miarka, Vecchio, Camey and Amtmann (32) observed that the factors that differentiate winners in the 3rd round are advancing the half guard, side mounted and back. These data suggest that the ground combat area in more advanced stages of combat (3rd round) can define the winner. In fact, another study in the form (10) already indicated the 3rd round as the moment where the high intensity ground fighting occur long dedicated.

A decisive nature of MMA (KO:TKO and submission) was observed during the groundwork phase, particularly in strike attempts linked with actions focused in dominate the opponent movements, as advances to half guard, advances to side, and advance to mount (24). Previous authors (10) determined that approximately 50% of fights ended during ground fighting action. Thus, the development of this characteristic can contribute to the performance enhancement of a decisive MMA skill. Particularly, submissions and chokes are associated with bouts with ending 1st and 2nd round, as shown in the present results. Preceding report (14), suggests differences in athletic
profiles between grappling and striking successful MMA fighters. In present study, grappling actions had smallest frequency, these results are associated with the high-force demands of bouts and training programs, causing an upwards shift of the entire force–velocity relationship driven by an increase in maximal strength (14).

In comparison, bouts with three rounds demonstrated mechanisms involved time-motion and technical-tactical self-regulation over the course of the bout, maintaining the time-motion ratio and the number of strike actions, these findings are in agreement with preceding reports (32). Practical applications suggest that smaller increases in maximal force development with more distinguished enhancements in lighter load, higher velocity actions may better identify superior performance in striking actions (11). Time-motion strategies and physical capabilities largely distinguished higher- from lower-level combat sport athletes (11) and outcomes (14, 32). In particular, longer-term anaerobic efforts in groundwork combat with high intensity appear to define successful grappling-based MMA athletes, while winning athletes in striking style tend to display dominance in shorter-term strike arrangements (14). Present comparisons by ending rounds and other rounds highlight how the time-motion process changes amongst TKO/KO and submission in continuous analyses during the combat phases (32). A comprehensive understanding of the time structure of MMA bouts may positively influence success rate and may also improve training efficiency (14).

Regarding total time, low intensity activity time is used by the athlete to control the distance by opponent and apply power strikes that could define the win. Our results indicate that the total time devoted to stand low-intensity activities seems to be lower in ending rounds while stand total time high-intensity appears to increase when the combat is finished in the 2nd and 3rd round. Possibly the athlete who makes better reading on the technical performance of the opponent during low intensity activities will have a higher
chance to win (24). These data are similar with those observed in the female UFC, where the combats ended in KO/TKO have lower volume strikes applied during the standing combat (24). Another analysis should be performed on the lower standing in ending rounds. When the combat finished in the 1st and 2nd round there a lower time dedicated when comparing with the 3rd round (91.5±71.4, 93.4±67.5 and 143.2±87.4; for low-intensity in the 1st, 2nd and 3rd round respectively, 7.4±9.16, 9.7±18.0 and 17.7±29.1 for high intensity in the 1st, 2nd and 3rd round respectively).

It is important, however, that time-motion studies has limitations associated to the investigator’s ability to video observer and your decision on the technical-tactical and intensity analyze to be recorded as score (30). To minimize the bias associated with data collection, our study used experienced evaluators in the knowledge associated with combat sports and time-motion. Our results indicated homogeneity among intra and inter-expert (31), high correlation between measurements (24, 30), with a ‘Strong’ agreement for all time-motion variables. From technical-tactical variable, we observed 0.54 to 0.85 (index Kappa) for strikes attempts and takedowns attempts and 0.80 to 0.90 for submissions, locks and chocks attempts.

Therefore, based on the aims of this study and the methodology applied, we can be concluded that technical-tactical and effort differs in the ending rounds and other rounds. In addition, there are differences in the decisions of the athletes when the combat is finished in 1st, 2nd and 3rd round. Generally, ending rounds have a lower time dedicated to stand combat in low-intensity. Furthermore, the ending rounds present a lower time of high-intensity stand combat, especially in the 1st and 2nd, where there a higher percentage of ending by submission. Therefore, the lower time dedicated to low-intensity actions on stand combat, regardless of round, and forcefulness of the actions in
the groundwork in the 1st and 2nd rounds appear as factors that increase the possibility of win in professional MMA.

**PRACTICAL APPLICATIONS**

Present outcomes permit scientist and coaches to establish assessment and training plans which consider specific contextual differences by ending-rounds and other rounds in time-motion analysis of MMA bouts. These differences by ending-rounds are essential to create high-intensity interval training (HIIT), alternating short periods of intense strike or grappling actions with low intensity or recovery periods following present data about each specific ending round result. These short, intense workouts provide improved athletic capacity and condition as well as improved tactical plans based in physical and mental capabilities (39).

Current study allows coaches and athletes to recognize when pacing action strategy is not working during stand and groundwork combat phases in different intensities by ending rounds and rounds. Results about time-motion analysis give referential to adjust actions combat simulations and take a special MMA athlete to execute an optimal pacing strategy during the very highest levels of competition, such as UFC, when emotions are hard to control. For instance, the time dedicated to the standing combat showed as a relevant factor for the ending combat, on our evidence and other time-motion studies in professional MMA (26, 32), we recommend that coaches organize the focusing sessions in two ways: complete round or ending round. Ex: a) 5 minute series (full round) focused on the standing combat respecting the effort: pause ratio for MMA i.e. 10 sec. High and 20, 30 or 40 Low; b) series also focused on maximum round length but running 5 sec. of high standing, making the transition more and 5 sec on the high groundwork intensity and 20, 30 or 40 Low (alternating to stand and groundwork actions); c) specific groundwork training on metabolic fatigue

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conditions (ex. In the end of session) aimed to increase the intensity of the actions on the groundwork in the 3rd round.

These examples proposed are generally and indicative for possible models aimed to minimal fitness required by professional MMA, furthermore, coach and athlete know the opponent's in advance, this allow to establish a specific strategy for fast or late ending depending on the degree of difficulty that can be imposed by the next combat.

Recovery and low intensity moments during bouts in MMA are critical components of any successful training program and to avoid injuries. In rounds without ending we observed ≈80% more low-intensity standing combat, so the trainer and athlete can establish training strategies aiming to weary the opponent until the last round. These results should benefit the debate among scientists and coaches, in order to increase the quality of the MMA training and promote an effective athletic development related with expert MMA performers’ models.

Present study suggest specific contextual training according rounds outcomes, as if the athlete intends to conduce the combat for the next rounds, the average values of strikes are near 50 per round. So, the coach can establish a competitive strategy to punctuate on the 1st and 2nd round, but to achieve a minimum ability to defend of strikes and takedown attempts, because there is a higher percentage of ending by submission in the 1st and 2nd rounds and punch and kick at least 50 attempts, depending on the volume and forcefulness the athlete achieved the win by points in the round.

If the goal is to ending, should develop the ability to quickly read on the technical-tactical strategies by the opponent and try to apply powerful strikes or conduced to the groundwork in the 1st or 2nd round, preferably. As the 3rd round there is more time dedicated to the groundwork, we recommend a specific strategy for this
round due to possible metabolic fatigue (17, 32) can be the difference for the ending of combat.

REFERENCES


Table 1. Percentage of ending combat separated by rounds.

<table>
<thead>
<tr>
<th>Ending Factor</th>
<th>1st round</th>
<th>2nd round</th>
<th>3rd round</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could Not Continue</td>
<td>1.0%</td>
<td>-</td>
<td>1.0%</td>
</tr>
<tr>
<td>Disqualified</td>
<td>1.0%</td>
<td>-</td>
<td>20.5%</td>
</tr>
<tr>
<td>KO/TKO</td>
<td>63.5%</td>
<td>58.1%</td>
<td>64.0%</td>
</tr>
<tr>
<td>Overturned</td>
<td>2.1%</td>
<td>-</td>
<td>8.0%</td>
</tr>
<tr>
<td>Submission</td>
<td>30.2%</td>
<td>37.2%</td>
<td>0.5%</td>
</tr>
<tr>
<td>TKO – Doctor’s Stoppage</td>
<td>2.1%</td>
<td>4.7%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Table 2. Criteria of technical-tactical analysis.

<table>
<thead>
<tr>
<th>Time-motion variables</th>
<th>Criteria of analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total effort time</strong></td>
<td>Effort temporal time. which includes low and high intensity moments in standing up and groundwork and combat.</td>
</tr>
<tr>
<td><strong>Standing up with low intensity</strong></td>
<td>Standing up combat. which includes displacements or stable positions and movements without opposition or with isolated attack.</td>
</tr>
<tr>
<td><strong>Standing up with high intensity</strong></td>
<td>Standing up combat. which includes multiple offensive and defensive techniques. exchanges between opponents.</td>
</tr>
<tr>
<td><strong>Groundwork with low intensity</strong></td>
<td>Groundwork combat. which includes stable positions and movements without opposition or with isolated attack.</td>
</tr>
<tr>
<td><strong>Groundwork with high intensity</strong></td>
<td>Groundwork combat. which includes multiple offensive and defensive techniques. exchanges between opponents.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical Variables</th>
<th>Criteria of analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strikes Attempts</strong></td>
<td>Any attempt to carry out an attack with striking techniques (punches. kicks. elbows and knees) at the opponent.</td>
</tr>
<tr>
<td><strong>Takedowns Attempts</strong></td>
<td>A technique that involves off-balancing an opponent trying to bring him to the ground. typically with the attacker landing on top.</td>
</tr>
<tr>
<td><strong>Submission Attempts</strong></td>
<td>Occurs when one of the fighters tries to dominate the opponent on the ground. keeping him with one or both shoulders on the ground.</td>
</tr>
<tr>
<td><strong>Locks Attempts</strong></td>
<td>Single or double joint lock involving manipulation of an opponent’s joints in such a way that the joints reach their maximal degree of motion.</td>
</tr>
<tr>
<td><strong>Chokes Attempts</strong></td>
<td>Any attempt to do a mechanical obstruction of the flow of air towards the lungs of the opponent.</td>
</tr>
</tbody>
</table>
Table 3. Descriptive and inferential time-motion analysis in stand up and groundwork combat phases separated by Ending Round and other Rounds, in seconds.

<table>
<thead>
<tr>
<th>Combat Phase</th>
<th>Standing combat</th>
<th>Groundwork</th>
<th>Total combat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intensity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low X ±SD</td>
<td>High X ±SD</td>
<td>Low X ±SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X ±SD</td>
<td>High X ±SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X ±SD</td>
<td>Low X ±SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X ±SD</td>
<td>High X ±SD</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>X ±SD</td>
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<tr>
<td></td>
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<td>X ±SD</td>
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<td></td>
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<td>X ±SD</td>
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<tr>
<td></td>
<td></td>
<td>X ±SD</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>X ±SD</td>
<td></td>
</tr>
<tr>
<td>Ending Round</td>
<td></td>
<td>X ±SD</td>
<td>X ±SD</td>
</tr>
<tr>
<td>1st Ending Round</td>
<td>91.5±71.4*</td>
<td>7.4±16.9a</td>
<td>0.7±5.8</td>
</tr>
<tr>
<td>2nd Ending Round</td>
<td>162.3±89.4</td>
<td>19.6±27.7</td>
<td>–</td>
</tr>
<tr>
<td>3rd Ending Round</td>
<td>160.4±86.8ab</td>
<td>20.3±32.6a</td>
<td>0.3±2.3</td>
</tr>
</tbody>
</table>

Data presented by mean±standard deviation. * significant different from all other ending round groups (P<0.05); a significant difference from 1st round vs. the ending 1st round (P<0.05); b significant difference from bouts with ending 1st round; c significant difference from 1st round vs. the ending 2nd round (P<0.05); d significant difference from ending 2nd round vs. the ending 3rd round (P<0.05); e significant difference from 1st round vs. the ending 3rd round (P<0.05); f significant different from 3rd round vs. the ending 3rd round (P<0.05).
Table 4. Descriptive and inferential data of technical analysis in groundwork combat by Ending Round and other Rounds.

<table>
<thead>
<tr>
<th>Ending Round</th>
<th>Round</th>
<th>Submissions</th>
<th>95% CI</th>
<th>Chokes</th>
<th>95% CI</th>
<th>Locks</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>X ±SD</td>
<td>Lower</td>
<td>Upper</td>
<td>X ±SD</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>1st Ending Round</td>
<td></td>
<td>0.3±0.04</td>
<td>0.2</td>
<td>0.4</td>
<td>0.2±0.03</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>2nd Ending Round</td>
<td></td>
<td>0.2±0.1</td>
<td>0.1</td>
<td>0.3</td>
<td>0.2±0.04</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>3rd Ending Round</td>
<td></td>
<td>0.1±0.1</td>
<td>0.2</td>
<td>0.4</td>
<td>0.1±0.1</td>
<td>-0.04</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Data presented by mean±standard deviation and 95% CI. * significant different from all other ending round groups (P<0.05); a significant difference from 1st round vs. the ending 1st round (P<0.05); b significant difference from bouts with ending 1st round; b significant difference from 1st round vs. the ending 2nd round (P<0.05); c significant difference from 1st round vs. the ending 3rd round (P<0.05); d significant different from 3rd round vs. the ending 3rd round (P<0.05).
Figure 1. Study design of time-motion demands by MMA Ending Rounds and other Rounds.
Data presented by Min, Q1, median, Q3, Max, and outliers are presented as:

- Significant difference from 1st round vs. the ending 1st round ($P < 0.05$);
- Significant difference from bouts vs. ending 1st round;
- Significant difference from 2nd round vs. the ending 2nd round ($P < 0.05$);
- Significant difference from 1st round vs. the ending 3rd round ($P < 0.05$);
- Significant difference from 3rd round vs. the ending 3rd round ($P < 0.05$).
Figure 2. Descriptive and inferential data of technical analysis in stand up combat by Ending Round and other Rounds.