

## A REVIEW OF TIME-MOTION ANALYSIS AND COMBAT DEVELOPMENT IN MIXED MARTIAL ARTS MATCHES AT REGIONAL LEVEL TOURNAMENTS<sup>1</sup>

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*Summary.*—Mixed martial arts (MMA) have become a fast-growing worldwide expansion of martial arts competition, requiring high level of skill, physical conditioning, and strategy, and involving a synthesis of combat while standing or on the ground. This study quantified the effort-pause ratio (EP), and classified effort segments of stand-up or groundwork development to identify the number of actions performed per round in MMA matches. 52 MMA athletes participated in the study ( $M$  age = 24 yr.,  $SD = 5$ ; average experience in MMA = 5 yr.,  $SD = 3$ ). A one-way analysis of variance with repeated measurements was conducted to compare the type of action across the rounds. A chi-squared test was applied across the percentages to compare proportions of different events. Only one significant difference ( $p < .05$ ) was observed among rounds: time in groundwork of low intensity was longer in the second compared to the third round. When the interval between rounds was not considered, the EP ratio (between high-intensity effort to low-intensity effort plus pauses) was 1:2 to 1:4. This ratio is between ratios typical for judo, wrestling, karate, and taekwondo and reflects the combination of ground and standup techniques. Most of the matches ended in the third round, involving high-intensity actions, predominantly executed during groundwork combat.

Mixed martial arts is a competitive combat sport in which both striking and grappling techniques are allowed (Amtmann & Berry, 2003). Although mixed martial arts has increased substantially in media exposure and worldwide popularity, relatively few studies have investigated its technical aspects and their implications for skill learning, strength, and conditioning (Amtmann, Amtmann, & Spath, 2008; Braswell, Szymanski, Szymanski, Dixon, Gilliam, & Wood, 2010; McGill, Chaimberg, Frost, & Fenwick, 2010). Amtmann (2010) developed a specific circuit training protocol based on the time structure of mixed martial arts matches and also reported high values of blood lactate ( $M = 15.21$  mmol  $\cdot$  L<sup>-1</sup>,  $SD = 4.75$ ) and rate of perceived exertion ( $M = 16.5$  on the 6–20 Borg scale,  $SD = 2.5$ ) during mixed martial arts training and bouts.

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As it is difficult to conduct physiological measurement during competition in combat sports, an important way to obtain information for a training prescription is to understand the time structure of these sports. To do this, the effort-pause ratio has been studied in many combat sports. In judo, wrestling, and karate, the typical effort-pause ratio is 2:1 (Nilsson, Csergo, Gullstrand, Tveit, & Refsnes, 2002; Beneke, Beyer, Jachner, Erasmus, & Hutler, 2004; Van Malderen, Zinzen, Watthy, & Luyten, 2006), while in taekwondo the ratio is between 1:3 to 1:4 (Heller, Peric, Dlouha, Kohlikova, Melichna, & Novakova, 1998) or 1:6 (Matsushigue, Hartmann, & Franchini, 2009), and during Brazilian jiu-jitsu matches the ratio is near 10:1 (Del Vecchio, Bianchi, Hirata, & Chacon-Mikahil, 2007). These ratios reflect the typical pace and types of action in each sport, ranging from quick strikes to extended wrestling or grappling. However, no similar data have been cited for mixed martial arts competitions. The quantification of the time structure has many implications for the sport, such as structuring more specific strength and conditioning training programs, shifts between or integration of skill sets, and technical-tactical preparation. The main objective of the present study was to quantify the effort-pause ratio in mixed martial arts matches. Additionally, the segments of time defined as effort were classified according to the mode of action (standing or groundwork) and intensity (low and high), as well as identifying the number of actions performed per round.

Because mixed martial arts involves both stand-up fighting and groundwork, we expected effort-pause ratio would be intermediate between grappling (judo and wrestling) and impact (karate and taekwondo) combat sports. It was also expected that the number of actions would decrease as rounds proceeded, and that most fights would end due to submission or blow techniques.

## METHOD

### *Participants*

Male mixed martial arts athletes ( $N=52$ ) participated ( $M$  age = 24 yr.,  $SD=5$ ) with a mean amount of experience in mixed martial arts training of 5 yr. ( $SD=3$ ). All male athletes were professionals and had participated at least in five previous mixed martial arts matches and had black belt equivalent rank in at least one combat sport (judo, Brazilian jiu-jitsu, and/or muay thai).

### *Procedure*

All matches were analyzed independently by two experienced evaluators following the checklist shown in Fig. 1. This approach has been used consistently (Franchini, Sterkowicz, Meira, Gomes, & Tani, 2008; Matsushigue, *et al.*, 2009; Santos, Franchini, & Lima-Silva, *in press*), and both objec-

STEPS TO MATCH ANALYSIS

1. Insert match video
2. Search the moment of athletes' presentation
3. Start the chronometer with the beginning signal
4. In specific Excel sheet, write the time of effort and pauses in each round and the interval between rounds
5. Note:
  - Total match duration: 452 sec.
  - Situation of end: groundwork high-intensity (GHI)
  - Technique used: rear naked choke
  - Round and time of effort in the end: 2nd round; 72 sec.

Round 1					Round 2					
Pause	SHI	SLI	GHI	GLI	Interval	Pause	SHI	SLI	GHI	GLI
		68			62			6		
	2						4			
		86							11	
	4									7
				11					6	
4										8
		24				7				
	3							12		
				6			4			
		30							21	
	17									10
		22							72	
	7									

SHI: Standing high-intensity combat; SLI: Standing low-intensity combat.  
 GHI: Groundwork high-intensity; GLI: Groundwork low-intensity.

FIG. 1. Checklist and a match analysis of two rounds

tive and reliable data have been previously found. A third person and one of the authors of the present investigation did an additional quantification of each match as a further reliability check. From 26 matches, 13 were selected at random to be analyzed twice, with a 1-wk. interval between analyses. The Student *t* test showed no differences ( $t = -0.07, p = .94$ ) between the data, and the intra-class correlation coefficient was higher than .98 for all the variables considered in the present study, indicating the high reliability of this approach.

The measurement of time spent in each action segment was conducted by using a DVD player and a chronometer. Each bout was analyzed to note actions performed and the duration of each effort and pause segment. Typically, each evaluator spent three times the match duration to perform the analysis.

The following time-related variables were considered: (1) total match duration, (2) pause time within each round, (3) standing high-intensity

combat, (4) standing low-intensity combat, (5) high-intensity groundwork combat, and (6) low-intensity groundwork combat. To determine the intensity of the action, the following aspects were considered: high-intensity, when fast movements were performed in order to gain a specific position, to defend a favorable position by the opponent, or in an attempt to strike the opponent with power; or low-intensity, stable positions requiring little effort to maintain low speed displacements or movements without opposition (such as in closed guard with no movement attempt). Time-related data were considered only in absolute terms as this is more useful for trainers and coaches.

### *Design*

This was an observational descriptive study that analyzed 26 recorded mixed martial arts bouts during two events in Campinas, São Paulo, Brazil (named Max Fight®), featuring athletes at the state and national levels. These matches were filmed with the organizers' permission. Two cameras were strategically positioned in the last row of the bleachers, to permit the observation of all actions performed by each athlete in 26 matches. Each match had a maximum of three rounds, each round lasted 5 min. with a 1-min. rest interval between rounds. As 19 matches ended before three rounds, a total of 54 rounds was analyzed (nine matches finished in the first, six in the second, and 11 in the third round).

### *Statistical Analyses*

To show the magnitudes of the measures, they were presented as mean (minimal and maximal value), absolute, and relative frequencies. The distribution of the data was analyzed by the Shapiro–Wilks test, and the results showed a normal Gaussian distribution. A Mauchly's test of sphericity was used to test this assumption, and a Greenhouse-Geisser correction was used when necessary. A one-way analysis of variance (ANOVA) with repeated measurements was conducted to compare the type and duration of actions in the different rounds. A Bonferroni test was applied when a significant difference was found in the ANOVA. A chi-squared test was applied to compare the percentages calculated for each variable (high or low intensity in standing or ground position, pauses, type of match decision, and round when the match was decided) and their characteristics in the different periods of the combat, type of match decision, and round when the match was decided (Kirkwood & Sterne, 2003).

## RESULTS

When all 26 matches were considered, the mean total time of the matches was 449 (9 to 917) sec. Durations are presented in Table 1. Fig. 2 presents the typical sequence observed during each segment of the match.

The only difference found was in the time of low-intensity ground-

TABLE 1  
EFFORT AND PAUSE DURATIONS ACCORDING TO ROUNDS  
(VALUES ARE MEAN AND RANGE, EXPRESSED IN SEC.)

Block	Round 1			Round 2			Round 3		
	M	SD	Range	M	SD	Range	M	SD	Range
Pause	10	6	4-21	8	5	4-16	8	4	4-13
High-intensity standing	9	8	3-40	7	6	3-16	6	6	3-15
Low-intensity standing	15	17	4-46	18	17	4-45	18	13	6-60
High-intensity groundwork	14	13	6-47	13	14	4-27	8	11	3-15
Low-intensity groundwork	21	19	4-47	36	26	8-98	21*	6	13-33
Effort-pause ratio		6:1			9:1			6:1	

\*Different from Round 2,  $p < .04$ .

work ( $F_{2,12} = 4.54, p = .034; \eta^2 = 0.43$ ), which was longer in the second compared to the third round ( $p < .05$ ). No other difference was found concerning the time structure across rounds. Interestingly, the rest between rounds that should last 1 min. varied considerably, from a mean of 102 sec. ( $SD = 32$ ; range 68-173 sec.) between the first and second rounds, and a mean of 99 sec. ( $SD = 30$ ; range 54-141 sec.) between the second and third rounds. When the end of the match was analyzed, half ended in high-intensity groundwork actions, followed by high- and low-intensity standing actions (26.9 and 11.5%, respectively) and pauses (7.7%). The less common form of ending a match was the tap out (submission) in low-intensity groundwork (3.9%;  $\chi^2 = 71.52, p < .001$ ; Cramér's  $\phi = 0.74$ ).

Fifteen matches (57.7%) ended in knockout, six (23.1%) by submission, and five (19.2%) by judges' decision ( $\chi^2 = 26.94, p < .0001$ ; Cramér's  $\phi = 0.67$ ). In the 21 matches ended by knockout or submission, seven

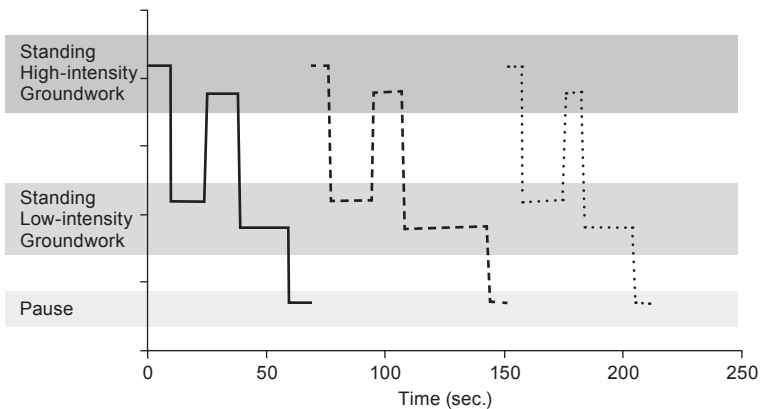


FIG. 2. Typical sequence of effort and pause actions during different segments in a mixed martial arts match. Segment 1 (—); Segment 2 (---); Segment 3 (.....).

(33.3%) were defined by high-intensity standing actions, seven (33.3%) by high-intensity ground striking actions (especially “ground and pound” occurrences), three (14.3%) ended by choke application (rear naked choke and guillotine choke), three (14.3%) by joint locks (two applied to the elbow and two directed to the ankle), and one by medical intervention (4.8%;  $\chi^2=32.49, p<.0001$ ; Cramér’s phi=0.76). Eleven of the bouts (42.3%) ended in the third round, seven (26.9%) ended in the second round, and three (11.5%) ended in the first round. The chi-squared test indicated that a higher proportion ended in the third round compared to the other rounds ( $\chi^2=26.94, p= \leq .0001$ ; Cramér’s phi=1.0). Table 2 presents the type and number of action sequences per round.

TABLE 2  
NUMBER AND TYPE OF ACTIONS PER ROUND (VALUES ARE MEAN AND RANGE)

Block	Round 1			Round 2			Round 3		
	M	SD	Range	M	SD	Range	M	SD	Range
Pause	2	1	1-5	2	1	1-3	3	2	1-5
High-intensity standing	4	2	1-8	3	2	1-7	4	4	1-15
Low-intensity standing	4	3	1-9	4	2	1-8	5	5	1-16
High-intensity groundwork	3	2	1-9	3	2	1-5	3	3	1-8
Low-intensity groundwork	3	2	1-9	2	2	1-5	3	1	4-7

DISCUSSION

The main results indicated that MMA matches are composed of two or three periods of activity in each round, with a mean time of 53 to 79 sec. interspersed with 8 to 10 sec. of pause plus reaction. During each period of activity, there are typically three to four sequences of high-intensity standing combat actions (lasting 6 to 9 sec.), four or five sequences of low-intensity standing combat actions (lasting 15 to 18 sec.), three high-intensity groundwork sequences (lasting 8 to 14 sec.), and two to five low-intensity groundwork sequences (duration of 21 to 36 sec.). Another important finding was that half of the matches ended during high-intensity groundwork sequences, and 26.9% were decided during high-intensity standing sequences, suggesting that high-intensity actions are key elements in these matches.

The effort-pause in these matches was 9:1 to 6:1, more similar to judo (Marcon, Franchini, Jardim, & Barros Neto, 2010; Franchini, Del Vecchio, Matsushigue, & Artioli, 2011) and wrestling (Nilsson, *et al.*, 2002) where an effort-pause ratio of 3:1 has been typically reported. However, when the interval between rounds was not taken into account, the ratio between high-intensity to low-intensity effort plus pauses was 1:2 to 1:4, or more similar to karate (Beneke, *et al.*, 2004) and taekwondo (Matsushigue, *et al.*, 2009). Thus, the intermittent characteristic of high-intensity actions last-

ing 6 to 14 sec., followed by low-intensity efforts and combat interruption lasting 46 to 62 sec., suggests that the mixed martial arts athlete needs to be prepared to maintain high-intensity activity for the duration of each round. This approach has been recommended in other combat sports, such as judo (Franchini, Takito, & Bertuzzi, 2005), karate (Beneke, *et al.*, 2004; Roschel, Batista, Monteiro, Bertuzzi, Barroso, Loturco, *et al.*, 2009), taekwondo (Bridge, Jones, & Drust, 2009; Matsushigue, *et al.*, 2009), kung fu (Artioli, Gualano, Franchini, Batista, Polacow, & Lancha, 2009), boxing (Ghosh, Goswami, & Ahuja, 1995; Morton, Robertson, Sutton, & MacLaren, 2010), muay-thai (Crisafulli, Vitelli, Cappai, Milia, Tocco, & Melis, 2009), kick boxing (Buse, 2009), and wrestling (Kraemer, Vescovi, & Dixon, 2004; Ngai, Levy, & Hsu, 2008).

During the segments of activity, the only difference observed was in the time spent in low-intensity groundwork, with a shorter time in the third compared to the second round. This can be attributed to the common attempt made by the athlete who is losing the match to strongly avoid spending time in disadvantageous positions. Most of the matches ended in the third round, involving high-intensity actions, predominantly executed during groundwork.

Knowledge of effort-pause ratio specific to mixed martial arts is important for coaches involved in the technical and tactical preparation of athletes as well as strength coaches involved in conditioning these athletes. Although the data from the present study are derived from state and national level athletes, high-intensity intermittent efforts and 1:2 to 1:4 effort-pause ratios seem to be a good approach to physical conditioning in this sport. This effort-pause ratio range is in the middle of that observed in grappling (e.g., judo and wrestling) and striking (e.g., karate and taekwondo) combat sports. The knowledge of effort-pause ratio during mixed martial arts matches can be important for training organization concerning technical-tactical and strength and conditioning preparations. In this way, high-intensity intermittent efforts and 1:2 to 1:4 effort-pause ratios should be considered especially in the competitive period, 3 to 5 weeks before main competitions. Applying this to training, a specific circuit protocol might include, for example, two segments of low-intensity standing effort for 15 sec., followed by a lower-body, high-intensity standing effort for 9 sec. After this would be a 10-sec. passive rest interval followed by three segments of low-intensity groundwork with technical displacement for 20 sec., followed by high-intensity groundwork combat ("ground and pound") for 15 sec., and a 10-sec. passive rest or low-intensity groundwork technical displacements for 20 sec. Another example would be two sets of the following sequence: 15 sec. of low-intensity,

upper-body actions; 9 sec. of high-intensity, upper-body actions; 15 sec. of low-intensity, lower-body actions; 9 sec. high-intensity, lower-body actions; 10-sec. rest; plus three sets of the following actions during groundwork combat: 3 sec. high-intensity and 5 sec. low-intensity actions.

Based on these results, specific attention should be paid to high-intensity ground striking and grappling for the objective of submission by choke or joint lock. Specifically in the groundwork actions of "ground and pound," where athletes are on the ground, the one with the positional advantage seeks to repeatedly strike the other opponent to knock him out or gain a chance for submission, and joint locks and choke movements should be used during the high-intensity period. Additionally, more than half of all matches finished in high-intensity groundwork conditions. Thus, training sessions that simulate these positions are highly recommended.

It is important to consider that this study's conclusions are limited to regional level mixed martial arts tournaments, and that the number of matches analyzed is small. Thus, further studies should focus on higher level competitions and a higher number of matches should be used to improve the knowledge about this combat sport.

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