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Original Article

Effect of rule changes on technical-tactical actions correlated with injury incidence in Professional Mixed Martial Arts

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Abstract:
This study compared the injury incidence, motor actions and the time-motion of combat before and after the changes in Mixed Martial Arts (MMA) rules. The sample was composed of 3,538 male matches, with 1,756 rounds prior to 2011, and 1,802 after the 2012 rule changes. The analyses showed higher frequency after rule changes of total strike attempts (41.5±25.9 and 43.6±26.4 for Before vs. After; p=0.03), single strike attempts (31.0±22.8 and 34.8±24.8 for Before vs. After; p≤0.001), single head strike attempts (24.1±19.6 and 27.4±21.5 for Before vs. After; p≤0.001), single body strike attempts (4.0±4.2 and 4.4±4.3 for Before vs. After; p≤0.001), single strike landed (13.3±11.1 and 14.7±11.0 for Before vs. After; p≤0.001), single head strike landed (8.1±8.5 and 9.2±8.3 for Before vs. After; p≤0.001), and single leg strike landed (2.3±3.15 and 2.5±3.2 for Before vs. After; p=0.02). There was a higher exposure time after the changes (383.3 vs. 480.2; for Before vs. After, p=0.019). Furthermore, there was a higher frequency of bouts ended in the last round (5º) after the rule changes (90 vs. 150; p=0.006). Our results showed higher exposure time and frequency of technical-tactical actions correlated with injury incidence in professional MMA.
Key words: - Motor Control; Martial Arts; Trauma; Risk Factors; Time and Motion Studies

Introduction

There are limited data elucidating injury epidemiology in professional Mixed Martial Arts (MMA) via technical-tactical analysis of bouts (James, Haff, Kelly, & Beckman, 2016; Karpman, Reid, Phillips, Qin, & Gross, 2015; Miarka, Vecchio, Camey, & Amtmann, 2016). MMA is an increasingly popular combat sport involving aggressive actions that present substantial injury risk (Karpman et al., 2015), which adopts an arrangement of striking and grappling actions, both standing and on the ground. Considering such a high participation rate in MMA and the suggested relatively high injury risk (Karpman et al., 2015), athletes' safety presents a high priority. Technical-tactical analysis has been applied to investigate movements during MMA competition to produce accurate recording of action patterns (Kirk, Hurst, & Atkins, 2015; Miarka, Vecchio, et al., 2016). MMA bouts are typically decided by submission (a verbal or physical signal by one competitor to discontinue), knockout (KO), technical knockout (TKO) due to referee stoppage, or unanimous or split judges' decision. However, bouts may also end because of a corner or doctor stoppage, athlete retirement, or disqualification (Lystad, Graham, & Poulos, 2015).

There has been increased interest in the incidence and types of injuries sustained in MMA, especially in how it is compared with other combat sports such as boxing, which is Olympic sanctioned (Karpman et al., 2015). The overall injury incidence in MMA competitors appears slightly higher than for boxers, but MMA athletes experience more minor contusion/bruising injuries (Bartsch, Benzel, Miele, Morr, & Prakash, 2012; Karpman et al., 2015). Boxers are more likely to experience serious injury such as concussion/head trauma involving loss of consciousness or eye injury such as retinal detachment (Bartsch et al., 2012; Karpman et al., 2015). In addition, facial trauma in MMA has been associated with temporomandibular disorders because of the intensity and duration of training needed for elite-level competitions, and high-performance athletes can have two to five times more traumatic injuries than recreational athletes (Bonotto et al., 2015). In MMA matches, upper eyelid and eyebrow lacerations are common and are especially troublesome given the effect of hemorrhaging from facial injuries on the athlete's vision, and thus their ability to continue in the match (Bastidas, Levine, & Stile, 2012).

Preceding authors have discussed the incidence, risk factors, and characteristics of knockouts (KOs) and technical knockouts (TKOs) due to repetitive strikes in MMA (Lawrence, Hutchison, Cusimano, Singh, & Li, 2014). During the rounds, the specific actions are considered acyclic with open tasks involving striking (punches, kicks, knees and elbow attacks) and grappling actions (tackles, twists and projections using legs), as

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well as submissions such as chokes and locks (Kirk et al., 2015). MMA was originally promoted as a violent and brutal sport, but it has dramatically changed by revising its rules about TKOs and has improved regulations to minimize injury risk (Rainey, 2009). Competitions have shown a recent increase in popularity and it is a full combat sport with a high injury rate, particularly non-fatal injuries to the head (Hutchison, Lawrence, Cusimano, & Schweizer, 2014; Warner, 2014). Therefore, the mechanisms and seriousness of injuries, particularly connected to the rule changes which were proposed in 2011 aiming to reduce aggression and the incidence of injuries (Mullen et al., 2012) need to be studied, and also the relation between technical-tactical actions and injuries are essential to understand the mechanisms and to help prevent MMA competitors from suffering future injuries.

Professional MMA events such as UFC and Strikeforce are considered a complex system composed of different actions which produce specific physical attributes (Amtmann, Amtmann, & Spath, 2008). This means there is also a growing need for better understanding of the injury process with technical-tactical profiles, especially when it involves professional matches. The present research concludes by introducing a novel hypothesis inspired by an ecological approach on the integration of technical-tactical and time-motion information about differences between bouts before and after the rule changes , established to ensure fair competition between competitors and to promote an environment of good sportsmanship. In this context, the present study proposed to investigate the motor actions and its association with injury frequencies and the combat intensity before and after the changes in the MMA rules of 2012.

Material & methods

Experimental approach to the problem

This retrospective cohort study adhered to guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement (Lystad, Pollard, & Graham, 2009), and aimed to measure the effect of the rule changes on technical-tactical actions correlated with injury incidence in MMA bouts. For this, the study was divided into three stages. First, we created a protocol based on previous studies that assessed technical and tactical variables in combat sport analysis (Amtmann et al., 2008; Chaabene et al., 2014a; Del Vecchio, Hirata, & Franchini, 2011a; Miarka et al., 2014; Miarka, Vecchio, et al., 2016; Tabben et al., 2015), which were incorporated into the assessment and validation analysis procedures (Miarka, Vecchio, et al., 2016). Afterward, a retrospective cohort analysis was conducted with bouts from 2011 (before the rule changes) and 2012 (after the changes). These recorded bouts contained information regarding the event, contestants, and fight outcome, while all injuries were diagnosed and managed by attending ringside doctors (Lystad, 2015). Next, a stratified selection of bouts with similar conditions was done in professional UFC and Strikeforce events (Kirk et al., 2015; Miarka, Vecchio, et al., 2016; Tabben et al., 2015), and finally comparisons between bouts before and after the rule changes were conducted. The study was performed according to the Code of Ethics of the World Medical Association and was approved by the ethics advisory board of the University where the study was performed.

Sample

All events were hosted in the United States promoted by UFC® and Strikeforce® and all weight divisions were included. The study ensured anonymity and confidentiality, replaced the personal identification of athletes, and there were no ethical problems in the analysis or interpretation of data obtained in public events as predisposed by previous protocols (Miarka, Brito, & Amtmann, 2017; Miarka, Brito, Moreira, & Amtmann, 2017; Miarka, Coswig, Vecchio, Brito, & Amtmann, 2015). The following events were included in the present study: Strikeforce Barnett vs Cormier, Strikeforce Barnett vs Kharitonov, Strikeforce Diaz vs Cyborg, Strikeforce Diaz vs Daley, Strikeforce Fedor vs Henderson, Strikeforce Fedor vs Silva, Strikeforce Feijão vs Henderson, Strikeforce Melendez vs Masvidal, Strikeforce Overeem vs Werdum, Strikeforce Rockhold vs Kennedy, Strikeforce Rockhold vs Jardine, Strikeforce Rousey vs Kufman, Strikeforce Tate vs Rousey, Strikeforce Challengers 13-20, UFC TUF Finale 13-16, UFC 125-126, UFC 128, UFC 130, UFC 132-133, UFC 135-137, UFC 139, UFC141, UFC 143, UFC 145-146, UFC 148, UFC 150, UFC 155, UFC Fight Night 23-25, UFC on Fox 1-5, UFC on FUEEL TV 1, UFC on FUEEL TV 3-4, UFC on FX 1, UFC on FX 3-5, UFC on Versus 3-6. We analyzed 3,538 male professional UFC and Strikeforce matches, with 1,756 rounds prior to 2011, and 1,802 rounds after the 2012 rule changes.

Injury data collection, protocol of time-motion analysis, intra and inter-specialist validation

Analysis protocol of the injury incidence and technical-tactical actions were analyzed considering an Intra and Inter-specialist validation. An injury was categorized as 3 conditions: a) bleeding by at least one of the athletes; b) interruption of the match by an athlete as a result of an injury; c) interruption of the match by the judge as a result of injury, following the previous investigations that investigated MMA injuries (Bledsoe, Hsu, Grabowski, Brill, & Li, 2006; Hutchison et al., 2014; Lystad, Gregory, & Wilson, 2014; Ngai, Levy, & Hsu, 2008). The technical-tactical actions and the number of injuries were observed by five researchers, according to frequency of occurrence per round, and following previously established protocols (Miarka, Bello, et al., 2018; Miarka, Brito, & Amtmann, 2017; Miarka, Brito, Moreira, et al., 2017; Miarka, Coswig, et al., 2016). To ensure ecological validity and check the elite status of the sample, the matches were analyzed by the FightMetric team using professional-quality records. All available videos of sufficient quality (standard 480/60i definition) taken from a landscape view of the entire competition area were included in the analysis. When appropriate and considering the inclusion criteria, both athletes were assessed in a single match and individual athletes were evaluated more than once when multiple-combination videos were available following the previously published protocols (Miarka, Brito, & Amtmann, 2017; Miarka, Brito, Moreira, et al., 2017; Miarka, Coswig, et al., 2016; Miarka et al., 2015). The reliability between the measures obtained for each technical variable was verified with the Cohen kappa, and the effect size (ES) and the confidence interval for ES (CIES) were verified to establish the magnitude of the differences between the groups with an agreement of 0.54 (p=0.007, ES=0.26, 95%CIES=0.5; 5.0) for strike attack attempts, 0.85 (p≤0.001, ES=0.26, 95%CIES = 0.41; 0.6) for takedown attempts, 1.0 (p≤0.001, ES=0.26, 95%CIES=0.67;1.4) for chokes, 1.0 (p≤0.001; ES=0.26, 95%CIES=0.41; 1.0) for submissions and 0.85 for locks (p≤0.001, ES=0.26, 95%CIES=0.41; 0.61). These tests were processed using SPSS software (version 20.0, SPSS, Inc., Chicago, IL, USA).

Statistical Analysis

Incidence rates are expressed per 1000 athlete-exposures (A-E) for 2011 bouts before the rule changes versus 2012 bouts after the rule changes. Injury incidence was calculated according to the formula i = n/e, where n is the number of injuries during competition [(Nº of injuries/ Nº of A-E) × 1000 = Nº of injuries per 1000 A-E] described by Čierna, Štefanovský, Matejová, and Lystad (2017). The Kolmogorov-Smirnov (K-S) test was used to determine the normal distribution of the data. The null hypothesis was rejected for all variables of the present study. Descriptive data on the frequency of dependent variables (i.e. landed strikes, strike attempts, takedown attempts, submissions, chokes and locks) are presented as mean, standard deviation (SD), median, first quartile (1Q) and third quartile. The Mann-Whitney test was applied for non-parametric data to compare results (winnervs.loser). The ES measurement was subsequently calculated for the non-parametric analysis, defined as $ES=Z/\sqrt{N}$, where ES represents the effect size, Z is derived from the Mann-Whitney test conversion, and N is the total number of observations. This analysis considers ES values for small size (ES<0.10), medium (ES<0.30) or great effect (ES>0.50). In addition, a Spearman correlation was used to verify the correlation between the incidence of injuries and the actions performed per round, and a Logistic Regression Analysis was performed to verify the association between technical-tactical actions to rounds with injuries before and after the rule changes. A significance level of $p \leq 0.05$ was used. All analyzes were performed using SPSS 20.0.

Results

Total analyzed data, athlete exposure (A-E), exposure time and injuries are shown in Table 1.

Table 1. Sample included in this study, athlete and time-exposures and number of injuries.

Sample	2011	2012	Total	**X^2calc; df; *p***
Bouts	726	770	1,496	0.64; 4; 0.42
Rounds	1,736	1,802	3,538	0.61; 4; 0.43
Athlete-exposures (A-E)	1,452	1,540	2,882	1.27; 4; 0.25
Exposure time (min)	383.3	480.2	863.5	5,47; 4; 0.019
Number of injuries	110	87	197	1.35; 4; 0.24
Injuries/1000 A-E	75.8	56.5	68.4	1.37; 4; 0.24

A-E – Athlete exposure, df – degrees of freedom.

When comparing frequencies, a longer exposure time was observed in 2012 (p=0.019), with no difference between the number of bouts, rounds, injuries or injuries/1000 A-E. Table 2 shows the descriptive analysis for number of rounds, ending rounds and combat time separated by high and low effort times.

Table 2. Descriptive analysis of Rounds and Ending Rounds and time separated by low and high intensity.

Moment	**2011**	**2012**
Round; Frequency (%)		
1st Round	760 (43.8%)	770 (42.7%)
2nd Round	528 (30.4%)	540 (30.0%)
3rd Round	404 (23.3%)	424 (23.5%)
4th Round	26 (1.5%)	38 (2.1%)
5th Round	18 (1.0%)	30 (1.7%)
Total	1,736 (100.0%)	1,802 (100.0%)
Ending round; Frequency (%)		
1st Round	232 (13.4%)	230 (12.8%)

2nd Round	248 (14.3%)	232 (12.9%)
3rd Round	1,134 (65.3%)	1,158 (64.3%)
4th Round	32 (1.8%)	32 (1.8%)
5th Round	90 (5.2%)	150 (8.3%*)
Total	1,736 (100.0%)	1,802 (100.0%)
Effort time (sec.); Mean±SD		
Low	144.6±89.9	156.9±93.5*
High	62.5±75.4	55.4±71.8*
Total	269.6±69.0	267.6±72.7

*Significant difference compared with 2011, $p \leq 0.05$.

Before the rule changes we observed a lower frequency of bouts ending in the 5th round (X2=14.567, df=4, p=0.006). No effects were observed when compared to the number of rounds between 2011 and 2012 (p>0.05 for all comparison). Bouts before the rule changes demonstrated shorter moments with lower effort time by round than after the rule changes (t=-3.908, p≤0.001, 95%C.I. -18.4; -6.1), while a longer high effort time by round was observed during 2011 than in 2012 (t=-2.825, p=0.005, 95%C.I. 2.2; 12.0). Table 3 shows descriptive comparisons for attempted attacks. Significant results were on total strike attempts, single strike attempts, single strike attempts and single body strikes landed.

Table 3. Descriptive and comparisons for attempted attacks.

Action	**Mean±SD**	**Percentiles 25th (50th; 75th)**	**Comparisons R**	**Sig de r**	**U**	**P**	**ES**
Knock downs							
Before	0.1±0.4	0 (0; 0)	-0.01	0.718			
After	0.1±0.3	0 (0; 0)	0.079*	0.01			
Total	0.1±0.3	0 (0; 0)			699	0.74	0.01
Total Strikes Attempted							
Before	41.5±25.9	23 (38; 56)	0.196*	0.001			
After	43.6±26.4	25 (41; 58)	0.094*	0.002			
Total	42.4±26.2	24 (39; 57)			667	0.03	0.04
Single Strikes Attempted							
Before	31.0±22.8	14 (26; 43)	0.15*	0.001			
After	34.8±24.8	16 (30; 47)	0.085*	0.006			
Total	32.7±23.8	15 (28; 44)			635	≤0.001	0.08
Single Head Strikes Attempted							
Before	24.1±19.6	10 (20; 32)	0.164*	0.001			
After	27.4±21.5	12 (22; 37)	0.094*	0.002			
Total	25.5±20.6	11 (21; 34)			635	≤0.001	0.08
Single Body Strikes Attempted							
Before	4.0±4.2	1 (3; 6)	0.05	0.067			
After	4.4±4.3	1 (3; 7)	0.041	0.178			
Total	4.2±4.2	1 (3; 6)			654	≤0.001	0.06
Single Strikes Attempted							
Before	3.0±3.8	0 (2; 4)	0.002	0.951			
After	3.0±3.6	0 (2; 5)	-0.021	0.499			
Total	3.0±3.7	0 (2; 4)			679	0.15	0.03
Takedown Attempt							
Before	1.4±1.8	0 (1; 2)	1	1			
After	1.3±1.7	0 (1; 2)	0.0	0.001			
Total	1.4±1.7	0 (1; 2)			694	0.62	0.01
Submissions Attempted							
Before	0.2±0.5	0 (0; 0)	-0.008	0.769			
After	0.2±0.5	0 (0; 0)	0.045	0.139			
Total	0.2±0.5	0 (0; 0)			685	0.1	0.03
Submission Chokes Attempted							
Before	0.2±0.4	0 (0; 0)	0.014	0.607			
After	0.1±0.4	0 (0; 0)	0.058	0.061			
Total	0.2±0.4	0 (0; 0)			694	0.41	0.02
Submission Locks Attempted							
Before	0.1±0.3	0 (0; 0)	-0.035	0.206			
After	0.1±0.3	0 (0; 0)	-0.006	0.834			
Total	0.1±0.3	0 (0; 0)			691	0.06	0.04

**p≤0.05 vs. after rules changes.

There was a significant difference for Total Strikes Attempted (p=0.03), Single Strikes Attempted, Single Head Strikes Attempted, Single Body Strikes Attempted (p≤0.001, for all comparisons), where the means observed after the rule changes were higher. Table 4 shows the descriptive and comparison statistics of scored attacks. Significant results were on isolated attack actions of scored strikes, isolated attacks on scored head strikes, attempted isolated attack targeted on the scored leg strike attempts.

Table 4. Descriptive and comparisons for scored attacks.

Action	Mean±SD	Percentiles 25th (50th; 75th)	Comparisons R	Sig de r	U	P	ES
Total Strikes Landed							
Before	22.6±17.2	10 (19; 31)	0.219**	0.001			
After	22.3±15.8	11 (19; 30)	0.128**	0.001			
Total	22.4±16.6	10 (19; 31)			698	0.882	0.01
Single Strikes Landed							
Before	13.3±11.1	5 (11; 19)	0.215**	0.001			
After	14.7±11.0	7 (13; 20)	0.154**	0.001			
Total	14.0±11.1	6 (12; 19)			639	≤0.001	0.08
Single Head Strikes Landed							
Before	8.1±8.5	2 (6; 11)	0.249**	0.001			
After	9.2±8.3	3 (7; 12)	0.189**	0.001			
Total	8.6±8.0	3 (6; 12)			626	≤0.001	0.09
Single Body Strikes Landed							
Before	2.9±3.3	1 (2; 4)	0.071**	0.01			
After	3.0±3.2	1 (2; 4)	0.058	0.058			
Total	3.0±3.3	1 (2; 4)			682	0.22	0.02
Single Leg Strikes Landed							
Before	2.3±3.15	0 (1; 3)	0.014	0.621			
After	2.5±3.2	0 (1; 4)	-0.021	0.499			
Total	2.4±3.2	0 (1; 3)			663	0.02	0.05
Takedown Attempt							
Before	0.5±0.8	0 (1; 3)	1	1			
After	0.4±0.7	0 (1; 3)	0	0.001			
Total	0.5±0.8	0 (0; 1)			682	0.15	0.03
Damage							
Before	0.1±0.2	0 (0; 0)	0.137**	0.001			
After	0.1±0.2	0 (0; 0)	0.04	0.198			
Total	0.1±0.2	0 (0; 0)			694	0.23	0.02

**p≤0.05 vs. after rules changes.

There were no significant effects according to the observations compared to the rule changes between 2011 and 2012. The analysis showed a comparison p≤0.05 for all actions of total strike attack attempts (p≤0.03), attack attempts of isolated strike attack (p≤0.001), isolated strike-oriented attack attempt (p≤0.001), isolated attack attempt oriented towards the trunk/shoulder strike (p≤0.001), isolated attack of punctured strike (p≤0.001), isolated attack directed at punctured head strike (p≤0.001), or isolated attack attempt oriented to the punctured strike (p=0.02). Table 5 demonstrates a logistic regression analysis of technical-tactical variables associated with injuries of 2011 versus 2012.

Table 5. Logistic regression analysis of technical tactical actions of 2011 versus 2012 rounds with injuries included in the model.

Variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Total Strikes								
Scored	.036	.088	.173	1	.678	1.037	.873	1.231
Attempted	-.043	.074	.338	1	.561	.958	.828	1.108
Single Strikes								
Scored	-.006	.202	.001	1	.975	.994	.669	1.476
Attempted	.002	.171	.000	1	.989	1.002	.717	1.401
Head Strikes								
Scored	-.002	.187	.000	1	.992	.998	.693	1.439
Attempted	.025	.155	.025	1	.874	1.025	.756	1.389
Body Strikes								
Scored	-.146	.252	.333	1	.564	.864	.527	1.418
Attempted	.150	.218	.471	1	.493	1.162	.757	1.783
Takedowns								
Scored	-.324	.232	1.945	1	.163	.723	.459	1.140
Attempted	-.096	.129	.559	1	.455	.908	.706	1.169
Constant	.415	.406	1.048	1	.306	1.515		

B= regression coefficient; S.E: = standard error; df = degrees of freedom; Sig = p value, Exp(B) = Exponentiation of B; CI = confidence interval.

The present model is able to predict 68.2% of rounds with injuries before the rule changes and 44.8% after the rule changes (Nagelkerke R=0.78). The chance of injuries (calculated using Oppositional Defiant Disorder - ODD) in the UFC rounds increased by 16.2% with body strikes attempted, 2.5% with head strikes attempted and 3.7% with total strikes scored, while 27.7% of takedowns scored, 9.2% of takedown attempts and 14.6% of body strikes scored reduced after the rule changes.

Dicussion

The present study aimed to compare time-motion and motor actions and injuries correlated with moments before and after the changes in the MMA rules of 2012. Results indicated significant differences between 2011 and 2012 bouts; the rounds in 2012 demonstrated a longer effort time than 2011, with shorter high effort time. However, it is important to highlight that bouts after the changes demonstrated higher values in strike attempts during shorter high effort times and isolated attempts during low effort times. Present logistic regression analysis confirmed that body and head strike attempts were more associated with rounds with injuries after the rule changes, while rounds with injuries before the rule changes were associated with grappling actions and body strikes scored. Despite the longer time in low intensity, athletes presented an increase in their strike action attempts without scores; this could indicate that actions are faster, less precise and stronger than before the rule changes.

It is important to note that other matches are ended when athletes are injured in combat sports different from MMA, and lacerations, abrasions, cuts or epistaxis that induces blood loss are not common, probably due the use of helmets and the prohibition of specific actions such as elbow blows (Pieter, 2010; Pieter, Rostami, & Ziaee, 2010). The low intensity moment during combat has the interference of strategic developments, as athletes use this period to receive feedback from their coaches and from previous actions during the round (Miarka, Vecchio, et al., 2016). Athletes try to recover from acute injuries using something to stanch the blood flow from lacerations and cuts during the rest period between rounds (Amtmann, 2012; Chaabene et al., 2014b; del Vecchio, Hirata, & Franchini, 2011b; Miarka, Vecchio, et al., 2016). Regarding time-motion analysis, the present study agrees with a preceding study, which demonstrated that combat with low intensity comparisons presented differences between outcomes during the 1st rounds with 136.5 (65; 216) seconds, the 2nd rounds with 141.5 (72; 239) seconds, and the 3rd rounds with 134 (69; 224) seconds (Miarka, Vecchio, et al., 2016). Differences between high and low intensity actions were observed among the weight classes throughout the bouts, and the difference was very clear in the first round where the two lighter weight classes (Bantamweight and flyweight) tend to be more active during both standing and ground actions (Miarka et al., 2015). It is important to point out that more time was spent in the standup phase; however, time spent during groundwork tended to be more intense with less recovery time (Miarka, Vecchio, et al., 2016). There is probably also a dependence of the weight categories on type, mechanism and severity of the lesions, and the non-analysis of this factor can be pointed out as a limitation of the present article. Kirk et al. (2015) and associates found that subjects participating in simulated MMA bouts presented similar results of submission attempts (~0 per round) and a slightly higher rate of takedowns with ~2.5+3.2 successful takedowns; this study did not observe other differences between outcomes.

MMA injuries are associated with actions that increase the possibility of winning, since previous studies have demonstrated that MMA winners have increased total strike attempts particularly oriented to the opponent's head, higher total submission attempts, which can indicate improvement in position often associated with controlling an opponent which helps to win in MMA (Miarka, Vecchio, et al., 2016). Moreover, in a preceding report comparing the actions during the 3rd round showed that losers try to do more submission attempts than in the other two rounds (Miarka, Vecchio, et al., 2016). Our results did not demonstrate associations between grappling actions with injuries after the rule changes. Previously published research shows that most of the analyzed matches ended in the third round and involved high-intensity actions, predominantly executed during groundwork combat (del Vecchio et al., 2011b)

The present technical-tactical and time-motion analysis provides a challenge applied reference to sport science and prophylactic workouts for coaches/athletes (Kirk et al., 2015). This study reveals important factors to the success of MMA athletes with injury prevention, as preceding studies of other combat sports (Miarka, Dal Bello, et al., 2018; Pococco et al., 2013; Scoggin et al., 2010). Developed technical proficiency and tactical approaches to meet bout demands presents substantial injury risk to competitors and demonstrated a pattern of technical-tactical actions with a higher frequency of strike actions oriented to the head during bouts after the rule changes.

Preceding studies indicate that the most common injuries sustained include lacerations, abrasions, contusions, strains, and sprains (Bledsoe et al., 2006; Rainey, 2009; Scoggin et al., 2010). This study included data from MMA contests sanctioned by the UFC, which may limit the generalizability of the findings reported herein. For pragmatic reasons, this study did not adopt a strict operational injury definition, following preceding reports (Lystad et al., 2014). Because injury recording was at the discretion of the attending Doctor-stoppage situations, one can expect a number of injuries to go unreported, presumably minor or less serious injuries

(Lystad et al., 2014). This may result in underestimating the actual risk of injury while potentially overestimating the relative proportion of more severe injuries such as fractures. Injuries were diagnosed by Doctor-stoppage situation; however, in the absence of advanced diagnostic technologies, there is the potential for misdiagnosis and misreporting (Lystad et al., 2014). Moreover, a large proportion of injuries did not include diagnostic details such as anatomic region and type of injury. Also, the present study did not verify the types of injuries sustained per athlete, because previous research had already consolidated that risk of severe injuries such as concussion/head trauma and/or spinal injury (Kochhar, Back, Mann, & Skinner, 2005; Ngai et al., 2008; Walrod, 2011), or the difference by weight categories and female athletes. We agree that future studies should explore such analyzes. Indeed, knowing these results are fundamental to establish competitive strategies, as defeated athletes have 3x more injury risk, and losers by KO or TKO have 2x more injury risk in comparison to losing by submission (Lystad et al., 2014). The present results are consistent with previous studies regarding incidence of injuries sustained in MMA and boxing (Buse, 2006; Karpman et al., 2015).

Concussions and blunt force to the head are a major concern in contact and combative sports (Buse, 2006). We observed that the incidence of concussions involving loss of consciousness in MMA fighters was approximately half of the boxing group (Karpman et al., 2015). This could be due to the nature of common MMA maneuvers that are more like wrestling with less hard blows to the face and jaw than boxing, and MMA athletes have a common focus on submission holds as opposed to “knockout” maneuvers (Karpman et al., 2015). Previous research indicates that the most common conclusion to an MMA fight is a technical knockout followed by a tap out (i.e. submission) (Bledsoe et al., 2006). As MMA is a new sport, the rules of the sport are constantly evolving with greater emphasis on safety and injury prevention (Woodward, 2009). Additional priority could possibly be given to maneuvers that do not involve high concussion risk or blows to the head. Concerning dangerous injuries, the present focus was to verify what actions occurred during the combats to generate serious injury to the point of stopping the fight. With this data it is possible to have a summary of how and when athletes are predisposed to serious injury in MMA; in the same way, the present study can suggest rules that allow a TKO according to the number of attacks per round time, which showed to be higher in Doctor-stoppage situations with severe injuries.

Conclusions

Comprehensive knowledge about the risk of injury during sport activity and related risk factors represents an essential basis to develop effective strategies for injury prevention. Injuries in MMA are frequent and often significant, and technical-tactical analysis with injury investigation is strongly recommended. In accordance with our goals and methodology applied, we conclude that the rule changes of 2012 did not reduce the frequencies of technical-tactical actions correlated with injury incidence in Professional MMA. Bouts after the changes demonstrated higher values of strike attempts during shorter high effort times and isolated attempts during low effort times. A regression analysis confirmed that body and head strike attempts were more associated to rounds with injuries after the rule changes, while round injuries before the changes were associated with grappling actions and scored body strikes.

Conflict of interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

References

Amtmann, J. (2012). Anticipating and training for the worst-case metabolic scenario: a comment on Del Vecchio, Hirata, and Franchini (2011). Percept Mot Skills, 114(1), 123-124. doi:10.2466/05.PMS.114.1.123-124

Amtmann, J. A., Amtmann, K. A., & Spath, W. K. (2008). Lactate and rate of perceived exertion responses of athletes training for and competing in a mixed martial arts event. The Journal of Strength and Conditioning Research, 22(2), 645-647.

Bartsch, A. J., Benzel, E. C., Miele, V. J., Morr, D. R., & Prakash, V. (2012). Boxing and mixed martial arts: preliminary traumatic neuromechanical injury risk analyses from laboratory impact dosage data. J Neurosurg, 116(5), 1070-1080. doi:10.3171/2011.12.JNS111478

Bastidas, N., Levine, J. P., & Stile, F. L. (2012). The "sweet science" of reducing periorbital lacerations in mixed martial arts. Ann Plast Surg, 68(1), 43-45. doi:10.1097/SAP.0b013e31820eb325

Bledsoe, G. H., Hsu, E. B., Grabowski, J. G., Brill, J. D., & Li, G. (2006). Incidence of injury in professional mixed martial arts competitions. J Sports Sci Med, 5(CSSI), 136-142.

Bonotto, D., Namba, E. L., Veiga, D. M., Wandembruck, F., Mussi, F., Afonso Cunali, P., . . . Azevedo-Alanis, L. R. (2015). Professional karate-do and mixed martial arts fighters present with a high prevalence of temporomandibular disorders. Dent Traumatol. doi:10.1111/edt.12238

Buse, G. J. (2006). No holds barred sport fighting: a 10 year review of mixed martial arts competition. Br J Sports Med, 40(2), 169-172. doi:10.1136/bjsm.2005.021295

Chaabene, H., Franchini, E., Miarka, B., Selmi, M. A., Mkaouer, B., & Chamari, K. (2014a). Time-motion analysis and physiological responses to karate official combat sessions: is there a difference between winners and defeated karatekas? The International Journal of Sports Physiology and Performance, 9(2), 302-308.

Chaabene, H., Franchini, E., Miarka, B., Selmi, M. A., Mkaouer, B., & Chamari, K. (2014b). Time-motion analysis and physiological responses to karate official combat sessions: is there a difference between winners and defeated karatekas? Int J Sports Physiol Perform, 9(2), 302-308. doi:10.1123/ijspp.2012-0353

Čierna, D., Štefanovský, M., Matejová, L., & Lystad, R. P. (2017). Epidemiology of Competition Injuries in Elite European Judo Athletes: A Prospective Cohort Study. Clinical Journal of Sport Medicine. doi:10.1097/JSM.0000000000000526

Del Vecchio, F. B., Hirata, S. M., & Franchini, E. (2011a). A review of time-motion analysis and combat development in mixed martial arts matches at regional level tournaments. Perceptual and Motor Skills, 112(2), 639-648.

del Vecchio, F. B., Hirata, S. M., & Franchini, E. (2011b). A review of time-motion analysis and combat development in mixed martial arts matches at regional level tournaments. Percept Mot Skills, 112(2), 639-648. doi:10.2466/05.25.PMS.112.2.639-648

Hutchison, M. G., Lawrence, D. W., Cusimano, M. D., & Schweizer, T. A. (2014). Head Trauma in Mixed Martial Arts. Am J Sports Med, 42(6), 1352-1358. doi:10.1177/0363546514526151

James, L. P., Haff, G. G., Kelly, V. G., & Beckman, E. M. (2016). Towards a Determination of the Physiological Characteristics Distinguishing Successful Mixed Martial Arts Athletes: A Systematic Review of Combat Sport Literature. Sports Med. doi:10.1007/s40279-016-0493-1

Karpman, S., Reid, P., Phillips, L., Qin, Z., & Gross, D. P. (2015). Combative Sports Injuries: An Edmonton Retrospective. Clin J Sport Med. doi:10.1097/JSM.0000000000000235

Kirk, C., Hurst, H. T., & Atkins, S. (2015). Measuring the Workload of Mixed Martial Arts using Accelerometry, Time Motion Analysis and Lactate. International Journal of Performance Analisys in Sport, 15(1), 359-370.

Kochhar, T., Back, D. L., Mann, B., & Skinner, J. (2005). Risk of cervical injuries in mixed martial arts. Br J Sports Med, 39(7), 444-447. doi:10.1136/bjsm.2004.011270

Lawrence, D. W., Hutchison, M. G., Cusimano, M. D., Singh, T., & Li, L. (2014). Interrater agreement of an observational tool to code knockouts and technical knockouts in mixed martial arts. Clin J Sport Med, 24(5), 397-402. doi:10.1097/JSM.0000000000000047

Lystad, R. P. (2015). Injuries to Professional and Amateur Kickboxing Contestants: A 15-Year Retrospective Cohort Study. Orthop J Sports Med, 3(11), 2325967115612416. doi:10.1177/2325967115612416

Lystad, R. P., Graham, P. L., & Poulos, R. G. (2015). Epidemiology of training injuries in amateur taekwondo athletes: a retrospective cohort study. Biol Sport, 32(3), 213-218. doi:10.5604/20831862.1150303

Lystad, R. P., Gregory, K., & Wilson, J. (2014). The Epidemiology of Injuries in Mixed Martial Arts A Systematic Review and Meta-analysis. Orthop J Sports Med, 2(1), 2325967113518492.

Lystad, R. P., Pollard, H., & Graham, P. L. (2009). Epidemiology of injuries in competition taekwondo: a meta-analysis of observational studies. J Sci Med Sport, 12(6), 614-621. doi:10.1016/j.jsams.2008.09.013

Miarka, B., Bello, F. D., Brito, C. J., Tabben, M., Oguma, A., Amtmann, J., . . . Chamari, K. (2018). Injuries during a World Judo Championship:
differences between sex, weight category and
competition phase. International Journal of Performance Analisys in Sport, 18(2), 1-16.

Miarka, B., Brito, C. J., & Amtmann, J. (2017). Performance probabilities and outcome effects in technical–tactical factors with bout phase changes of mixed martial arts. International Journal of Performance Analysis in Sport, 17(4), 510-520.

Miarka, B., Brito, C. J., Moreira, D. G., & Amtmann, J. (2017). Differences By Ending-Rounds And Other Rounds In Time-Motion Analysis Of Mixed Martial Arts: Implications For Assessment And Training. J Strength Cond Res. doi:10.1519/JSC.0000000000001804

Miarka, B., Coswig, V., Brito, C. J., Slimani, M., Amtmann, J., & Vecchio, F. B. D. (2016). Comparison of combat outcomes: technical and tactical analysis of female MMA. International Journal of Performance Analysis in Sport, 16, 13.

Miarka, B., Coswig, V. S., Vecchio, F. B. D., Brito, C. J., & Amtmann, J. (2015). Comparisons of Time-motion Analysis of Mixed Martial Arts Rounds by Weight Divisions. International Journal of Performance Analysis in Sport, 15, 12.

Miarka, B., Cury, R., Julianetti, R., Battazza, R., Julio, U. F., Calmet, M., & Franchini, E. (2014). A comparison of time-motion and technical–tactical variables between age groups of female judo matches. Journal of Sports Science, 32(16), 1529-1538.

Miarka, B., Dal Bello, F., Brito, C. J., Tabben, M., Oguma, A., Amtmann, J., . . . Chamari, K. (2018). Injuries during a World Judo Championship: differences between sex, weight category and competition phase. International Journal of Performance Analysis in Sport, 1-16.

Miarka, B., Vecchio, F. B., Camey, S., & Amtmann, J. (2016). Comparisons Technical-Tactical and Time-Motion Analysis of Mixed Martial Arts by Outcomes. J Strength Cond Res, 30(7), 1975-1984. doi:10.1519/JSC.0000000000001287

Mullen, C. J., Davis, A., Garner, E., Foster, A., Lembo, N., Kliparchuk, D., . . . Cooper, J. (2012). Association of Boxing Commissions, MMA Judging Committee: MMA Judging Criteria Revisions 2012 Report Clearwater Florida Annual Conference.

Ngai, K. M., Levy, F., & Hsu, E. B. (2008). Injury trends in sanctioned mixed martial arts competition: a 5-year review from 2002 to 2007. Br J Sports Med, 42(8), 686-689. doi:10.1136/bjsm.2007.044891

Pieter, W. (2010). Competition injury rates in young karate athletes. Science & Sports, 25(1), 32-38. doi:10.1016/j.scispo.2009.07.001

Pieter, W., Rostami, M., & Ziaee, V. (2010). An addendum to injury rates in Iranian taekwondo athletes; a prospective study. Asian J Sports Med, 1(2), 117-121.

Pocecco, E., Ruedl, G., Stankovic, N., Sterkowicz, S., Del Vecchio, F. B., Gutierrez-Garcia, C., . . . Burtscher, M. (2013). Injuries in judo: a systematic literature review including suggestions for prevention. Br J Sports Med, 47(18), 1139-1143. doi:10.1136/bjsports-2013-092886

Rainey, C. E. (2009). Determining the prevalence and assessing the severity of injuries in mixed martial arts athletes. N Am J Sports Phys Ther, 4(4), 190-199.

Scoggin, J. F., 3rd, Brusovanik, G., Pi, M., Izuka, B., Pang, P., Tokumura, S., & Scuderi, G. (2010). Assessment of injuries sustained in mixed martial arts competition. Am J Orthop (Belle Mead NJ), 39(5), 247-251.

Tabben, M., Coquart, J., Chaabène, H., Franchini, E., Ghoul, N., & Tourny, C. (2015). Time-motion, tactical and technical analysis in top-level karatekas according to gender, match outcome and weight categories. Journal of Sports Science, 33(8), 841-849.

Walrod, B. (2011). Current review of injuries sustained in mixed martial arts competition. Curr Sports Med Rep, 10(5), 288-289. doi:10.1249/JSR.0b013e31822dc2c2

Warner, M. (2014). Head Trauma in Mixed Martial Arts: Letter to the Editor. Am J Sports Med, 42(7), NP43-44. doi:10.1177/0363546514539633

Woodward, T. W. (2009). A review of the effects of martial arts practice on health. WMJ, 108(1), 40-43.