Performance profiling in professional mixed martial arts (MMA): comparing winning and losing performances.

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Abstract

The purpose of the study was to differentiate between winning and losing performances in professional MMA contests using performance profiles. 16 contests across 8 weight categories were analysed using a bespoke analysis template. Profiles for winners and losers were constructed using offensive striking (OS), defensive striking (DS), offensive grappling (OG) and defensive grappling (DG) data. Winners had significantly higher success rates for OS ($P < 0.05$, $d = 0.50$) and OG ($P < 0.05$, $d = 0.77$) than losers. Winners also had significantly more dominant control than losers for OS ($P < 0.05$, $d = 0.86$), OG ($P < 0.05$, $d = 0.77$) and DG ($P < 0.05$, $d = 0.66$). Winners displayed significantly greater OS ($P < 0.05$, $d = 0.61$) in the ground domain. Winners displayed higher levels of technical efficiency for OS and OG as well as the ability to maintain dominant positions during the bout. This allowed the winning athletes more opportunities to strike and attempt submissions which can lead to the stoppage of a contest. The findings suggest that an athlete's striking efficiency and grappling control are key components of winning a professional MMA contest.

Declaration

This work is original and has not been previously submitted in support of a Degree, qualification or other course.

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1. Introduction

Differentiating a winning from a losing performance in sport is of paramount importance to both coaches and athletes alike, especially when competing at an elite level. Sporting performances are complex in nature and as a result, both winning and losing performances are multifaceted and dynamic leading to variability when comparing across multiple performances by the same athlete or team (Lames & McGarry, 2007). As a result of this, successful performance varies though there are common traits and trends which can be seen across successful and unsuccessful performances. These factors can be focussed on to develop a greater understanding of performance in the sport with an aim to both improving losing performances and maintaining winning performances. Performance profiles are developed through a compilation of multiple performances with these traits and trends identified through the quantification of key performance indicators (KPI).

The underpinning principle of performance profiling is that by collating data from multiple sporting performances, it allows coaches and athletes to examine a ‘normative’ performance for an athlete (Hughes, Evans & Wells, 2001). Individual performances are more likely to be influenced by a number of factors such as location, importance of the performance and opposition quality which have all been found to influence isolated performances (O’Donoghue, 2005). By using multiple performances, the influence of these, often circumstantial variables, on a performance will be reduced. This allows a longitudinal approach to athlete development from a coaching perspective and can prove more beneficial than cross-sectional analysis (Hughes et al., 2001). It is important for the athlete and coach to be able to compare current performances to previously established norm values; performance profiling enables this comparison which can highlight potential aspects that may require attention (O'Donoghue, Mayes, Edwards & Garland, 2008).

Although performance profiling has been widely employed within the sporting literature, there are criticisms which suggest that there are limitations to the technique and that it is unsuitable for examining sports performance. One such criticism arises from the need for performance profiles to be classified as 'normative'. Lames and McGarry (2007) argue that the nature of sports performance is dynamic and revolves around an interaction process between the athletes involved. This leads to the performance being characterised by the athlete's unstable context-dependent behaviour. As a result of this, Lames and McGarry (2007) state that the indicators which make up a performance profile will not be consistent across performances hence a performance profile drawn from such data will not reach a stable 'normative' state. This can be witnessed from findings which have seen an interaction effect based on external factors in athletic competition such as the location of and the importance of the contest (O'Donoghue, 2005). In light of these conclusions from the present literature it could be suggested that 'normative' profiles may not be established in some research studies, however, it is reasonable to suggest that certain KPI will have more stable tendencies (Hughes et al., 2001), depending on the sport being analysed and the importance they have in successful performances. Profiling winning performances can demonstrate this; a KPI such as scoring a goal in football will always be a relevant KPI across winning performances as it is the key determinant in the victor of the match. Generally speaking performance profiling is advocated as a useful tool for performance analysis (PA), although the criticisms raised suggest that the suitability of performance profiling should be considered by the researcher depending on the focus and needs of the research.

Whilst much profiling research can be found where invasion games are considered, the same cannot be said for combat sports. Still, in recent years the use of performance profiling has increased in popularity with studies investigating boxing (El-Ashker, 2011; Davis, Wittekind & Beneke, 2013), kickboxing (Ouergui, Hssin, Franchini, Gmada, & Bouhlel, 2013; Ouergui et al., 2014), karate (Tabben et al., 2014), muay thai kickboxing (Cappai et al., 2012), taekwondo (Matsushigue, Hartmann & Franchini, 2009; Tornello et al., 2014) and wrestling (Atan & Imamoglu, 2005, Tropin, 2014). The aforementioned studies have examined the difference in performance profiles of winners versus losers across differing subject samples and have been able to develop the existing body of knowledge on combat sports performance. Although there are differences among these combat sports in terms of their techniques and also the format of competition, there have been common findings which are presented across the majority of these studies. One such finding is that the technical efficiency of the athlete is often linked to the winning athlete's performance profile. Therefore, an athlete's ability to execute techniques, particularly defensive and complex techniques, successfully at a high percentage gives the athlete a greater likelihood of winning as well as a more varied arsenal of techniques to use during a contest. It is the development of knowledge such as this that enables coaching strategies to be put into place to develop and cultivate skills which are vital for an aspiring athlete. These studies demonstrate the validity of determining winning performance profiles across combat sports as a useful tool for both researchers and coaches.

At present there is very little research focussing on the hybrid combat sport of mixed martial arts (MMA), particularly from a performance analysis perspective. As a result, there is a lack of empirical studies which appraise MMA performance at any level. Although many of the techniques utilised in other combat sports are allowed within MMA competition, the nature of MMA is unlike many other combat sports and thus the results found from other studies, particularly on the performance profiles of winners versus losers cannot be transferred across to MMA. To date there is only one study which has examined MMA performance using performance analysis techniques. This study was carried out by Del Vecchio, Hirata and Franchini (2011) and examined the effort to pause ratio of amateur MMA athletes at a regional tournament. The data collected provides an insight into some of the metabolic demands that are placed on amateur MMA athletes during competition. Although the findings are beneficial when examining the physical conditioning of amateur MMA athletes, the data provides no indication of the techniques used by the athletes nor does it differentiate between winning and losing performance at an amateur level. In addition, the findings are only representative for a sample of 52 amateur athletes competing at a regional level, meaning that these findings may not be suitable for generalisation across all levels of MMA performance, particularly at professional level given the difference in rules and competition format. As with many other areas concerned with MMA performance, there is a lack of scientific research that has quantified professional MMA performance and this should be addressed to better understand the nature of combat and arguably more importantly, the difference between victory and defeat in this new and developing sport. Additionally, a focus on professional contests will provide an insight for aspiring amateurs into the necessary skills needed to advance to a professional level within the sport.

The proposed study intends to address this shortage in the literature and determine the difference between winning and losing performances in professional MMA, with a view to informing both future research in the sport as well as within the applied world informing both coaches and athletes alike. As well as the technical and tactical information which will be drawn from the present study, it will enable better understanding of professional MMA contests which can in turn be used to aid the development of both conditioning and simulation protocols for MMA athletes.

2. Methods

2.1 Participants

A sample of 32 male professional MMA athletes (winners n = 16, losers n = 16) competing in 16 contests organised, sanctioned and regulated by the Cage Warriors Fighting Championships™ (CWFC) MMA promotion were recruited. The sample of 32 subjects was determined using a sample size calculation (GPower statistical software, version 3.1, Germany); the calculation can be found in Appendix 1. Four athletes were selected from each of the eight recognised weight categories (-56.7kg, 56.8kg to 61.2kg, 61.3kg to 65.8kg, 65.9 to 70.3kg, 70.4kg to 77.1kg, 77.2kg to 83.9kg, 84.0kg to 93.0kg, 93.1kg to 120.2kg) under the unified rules of MMA (New Jersey Athletic Commission, 2002). To be eligible for selection, the participants must have competed under professional rules, in a non-title bout (three 3 minute rounds in duration with a 1 minute rest period between each round) within the last 3 calendar years

(01/01/2012 to 01/01/2015) on a CWFC event (n = 39). Title contests and contests which ended in a manner where no winner and loser were declared e.g. draw or no contest were excluded. Athlete selection was carried out using a random sampling strategy; winning and losing athletes were classified according to the official results published by CWFC following the events.

2.3 Design

This research conducted descriptive research using a retrospective cross-sectional study design. When testing the analysis template for reliability, a repeated measures design was used to test for intra-observer reliability followed by an independent groups study design to test for inter-observer reliability across two analysts. The dependant variables in the study were the performance profiles, made up of KPI frequencies of the winning or losing athletes, with the independent variable being the outcome of the contest.

2.4 Analysis template

The analysis template used in the proposed study has been based on previous unpublished research conducted by the primary researcher which developed a reliable analysis system to assess professional MMA performance. The KPI used within the template were extracted from previous literature related to combat sports (Cappai et al., 2012; López-González, Alonso-Rodríguez, Bárcenas-Durón, & Rodríguez-Alonso, 2012; Ouergui et al., 2013; Thomson, Nicholas & Lamb, 2013) along with their operational definitions where possible, failing this KPI were included based on the subject knowledge of the primary and secondary analyst and suitable governing body/sporting organisations definitions (International Brazilian Jiu Jitsu Federation, 2013) were used with the aim of reducing subjectivity. The KPI and their operational definitions from the previous template are included in Appendix 2. Additional KPI were included in the revised template based on the findings from the previous unpublished research, these additional KPI are also included in Appendix 2. All KPI were validated by an external expert coach before finalisation of the template.

2.5 Reliability assessment

The template was tested for both intra- and inter-observer reliability using the method as described by Cooper *et al*. (2007). To be deemed reliable, the level of agreement for each individual KPI should be above 95% based on the frequency count across the two trials (Cooper *et al*., 2007). A pre-determined value for each KPI was allowed as an acceptable margin of error. The value in the present study was determined based on previous research (Cooper *et al*., 2007; Thomson et al., 2013) which used a value of ±1 as an acceptable margin of error when comparing the frequency counts in a time cell.

Intra-observer reliability testing consisted of the lead analyst randomly selecting a contest from the sample and analysing the contest using the developed template. The lead researcher repeated the analysis after 7 days to reduce memory effects (Cooper *et al*., 2007). Once both trials had been completed, reliability of the system was calculated using the method described by Cooper *et al*. (2007). For inter-observer reliability the secondary analyst appraised the same contest and this trial was then tested against the initial trial by the lead analyst using the same methods described above. Both the lead and secondary analyst for the proposed study were experienced analysts (6 years combined experience), competitive amateur MMA athletes with 8 years combined experience and have 8 years combined coaching experience in MMA.

2.6 Analysis procedure

Subsequent to the template being deemed reliable across both intra- and inter-observer conditions, the template was transferred onto LongoMatch analysis software (version 0.20.7, Barcelona) on a private password-protected personal computer for analysis. A schematic representation of the coding process is presented below in Figure 1. Given the high number of KPI which were involved in the analysis, the analyst viewed the footage at one quarter of the regular viewing speed (12.5 frames per second) and was permitted to rewind the footage *ad libitum* to allow for accurate coding. All contests in the -57kg weight category were analysed initially moving onto the next weight category in ascending weight order.

Following completion of the analysis for a contest, the data was exported into Microsoft excel (Office 2010, Washington, USA) for processing. Upon completion of processing, the data was exported into IBM SPSS statistical analysis software (version 22.0, Chicago, IL, USA) to begin the statistical analysis procedure.

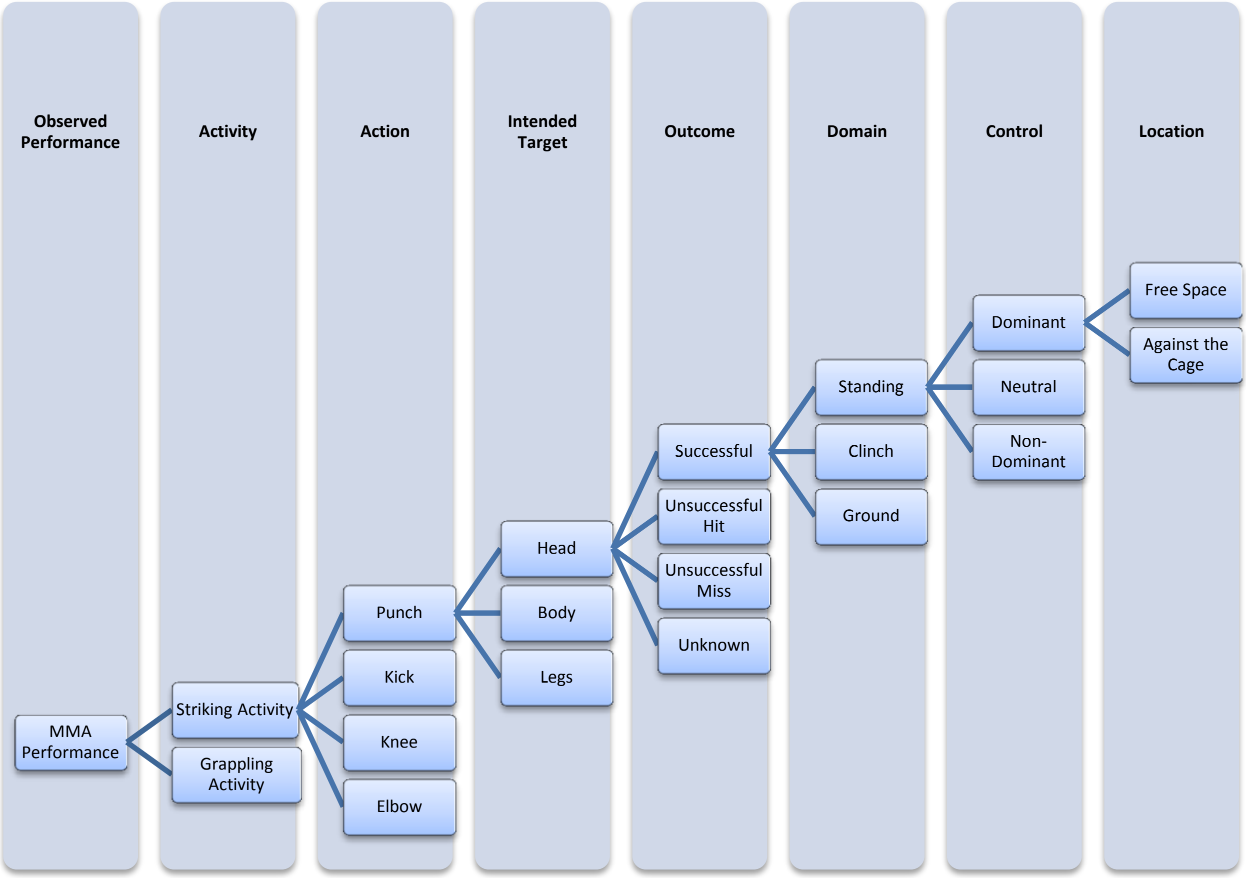


Figure 1. A schematic representation of the analysis process used to code a strike.

2.7 Statistical analysis

Initially, the normality assumption was addressed using a Shapiro-Wilk test, given that the majority of the indicators did not meet the criteria for normal distribution, non-parametric tests were used throughout the study. Descriptive statistics were presented for KPI frequencies as well as method of victory and significant strikes. Mann Whitney U tests were carried out to identify significant differences between KPI groups (striking offence, grappling offence, striking defence and grappling defence), due to the high number of individual KPI, for winners and losers. Findings were presented as median values with 95%

confidence limits (CLs) due to the non-parametric nature of PA data. Previous research has advocated the use of median values and CLs when collating performance profiles as measures of central tendency and variance due to their resistance to outlying data points (James, Mellalieu & Jones, 2011). Effect sizes were also calculated to determine the magnitude of the difference once statistical significance was found, effect sizes were categorised using Cohen's classifications (Cohen, 1988). The alpha level (α) was set at 0.05 throughout the study.

3. Results

3.1 Reliability analysis

The findings from the intra-observer reliability testing using the percentage agreement (%PA) method developed by Cooper et al. (2007) are presented in table 1.

Table 1. Intra-observer reliability results for all KPI.

KPI	Median	%PA	CI	%PA ± 1	CI ± 1
Punch	0.00 (1.00)	88.9	68.4 to 100	100	100 to 100
CS Punch	0.00 (1.00)	66.67	35.9 to 97.5	100	100 to 100
Kick	0.00 (1.00)	100	100 to 100	100	100 to 100
CS Kick	0.00 (1.00)	100	100 to 100	100	100 to 100
Knee	0.00 (1.00)	100	100 to 100	100	100 to 100
CS Knee	0.00 (1.00)	100	100 to 100	100	100 to 100
Elbow	0.00 (1.00)	100	100 to 100	100	100 to 100
CS Elbow	0.00 (1.00)	100	100 to 100	100	100 to 100
Takedown	0.00 (1.00)	100	100 to 100	100	100 to 100
Transition	0.00 (1.00)	100	100 to 100	100	100 to 100
Submission	0.00 (1.00)	100	100 to 100	100	100 to 100
Submission transition	0.00 (1.00)	100	100 to 100	100	100 to 100
Arm defence	0.00 (0.25)	66.7	35.9 to 97.5	100	100 to 100
Trunk defence	0.00 (0.5)	77.8	50.6 to 100	100	100 to 100
Leg defence	0.00 (1.00)	100	100 to 100	100	100 to 100
Footwork defence	0.00 (0.25)	66.7	35.9 to 97.5	100	100 to 100
No defence	0.00 (1.00)	88.9	68.4 to 100	100	100 to 100
CS No defence	0.00 (0.50)	77.8	50.6 to 100	100	100 to 100
Sprawl	0.00 (1.00)	100	100 to 100	100	100 to 100
Transition Block	0.00 (1.00)	88.9	68.4 to 100	100	100 to 100
Submission Defence	0.00 (1.00)	100	100 to 100	100	100 to 100

In 12 of the 21 KPIs 100% agreement was achieved over two trials. The lowest %PA scores were seen in the CS punch, arm defence and footwork defence KPI’s all with a value of 66.7% agreement. When accepting the ±1 margin of error value, 100% agreement was achieved for all 21 KPIs across trials.

The results from the inter-reliability testing of the analysis template using the %PA method developed by Cooper et al. (2007) are presented in table 2.

Table 2. Inter-observer reliability results for all KPI.

KPI	Median	%PA	CI	%PA ± 1	CI ± 1
Punch	0.00 (1.00)	77.8	51 to 100	100	100 to 100
CS Punch	0.00 (1.00)	77.8	51 to 100	100	100 to 100
Kick	0.00 (1.00)	100	100 to 100	100	100 to 100
CS Kick	0.00 (1.00)	100	100 to 100	100	100 to 100
Knee	0.00 (1.00)	100	100 to 100	100	100 to 100
CS Knee	0.00 (1.00)	100	100 to 100	100	100 to 100
Elbow	0.00 (1.00)	100	100 to 100	100	100 to 100
CS Elbow	0.00 (1.00)	100	100 to 100	100	100 to 100
Takedown	0.00 (1.00)	100	100 to 100	100	100 to 100
Transition	0.00 (0.5)	77.8	51 to 100	100	100 to 100
Submission	0.00 (1.00)	100	100 to 100	100	100 to 100
Submission transition	0.00 (1.00)	100	100 to 100	100	100 to 100
Arm defence	0.00 (0.25)	66.7	36 to 98	100	100 to 100
Trunk defence	0.00 (0.5)	77.8	51 to 100	100	100 to 100
Leg defence	0.00 (1.00)	100	100 to 100	100	100 to 100
Footwork defence	0.00 (0.25)	66.7	36 to 98	100	100 to 100
No defence	0.00 (0.5)	77.8	51 to 100	100	100 to 100
CS No defence	0.00 (0.125)	55.6	23 to 88	100	100 to 100
Sprawl	0.00 (1.00)	100	100 to 100	100	100 to 100
Transition Block	0.00 (1.00)	77.8	51 to 100	100	100 to 100
Submission Defence	0.00 (1.00)	100	100 to 100	100	100 to 100

As with the intra-observer testing, 100% agreement was achieved for 12 of the 21 KPIs. CS no defence resulted in the least %PA with a value of 55.6%, while both arm defence and footwork defence scored low with values of 66.7% agreement. However, when allowing for the ±1 margin of error value, 100% agreement was achieved between the two analysts for all KPI.

3.2 Winner vs loser analysis

Median KPI values are presented for winners (Table 3) and losers (Table 4). Winners scored greater median frequencies for the punch, knee, elbow, trunk defence, footwork defence, sprawl and transition block KPIs. Losing athletes demonstrated greater median frequencies for the CS punch, takedown, transition, arm defence, no defence and CS no defence KPIs.

Table 3. Descriptive statistics for all KPIs by winning athletes

	Winning athletes																
KPI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Median
Punch	47.00	10.00	25.00	34.50	28.50	6.00	15.50	3.00	18.00	22.00	40.00	21.00	15.00	86.00	66.00	22.00	22.00
CS Punch	6.00	13.00	42.00	1.00	8.00	1.00	2.50	3.00	4.00	3.00	0.00	18.00	0.00	57.00	5.00	10.00	4.50
Kick	0.00	1.00	1.00	1.00	3.00	2.00	5.50	0.00	4.00	1.00	0.00	0.00	4.00	6.00	1.00	2.00	1.00
CS Kick	0.00	0.00	0.00	0.00	1.00	0.00	0.50	0.00	3.00	0.00	0.00	1.00	0.00	0.00	2.00	1.00	0.00
Knee	0.00	0.00	4.00	1.00	1.00	1.00	8.00	1.00	22.00	4.00	0.00	1.00	0.00	3.00	3.00	3.00	1.00
CS Knee	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elbow	6.00	0.00	7.00	5.50	7.50	11.00	0.50	0.00	8.00	0.00	2.00	1.00	12.00	3.00	5.00	8.00	5.25
CS Elbow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Takedown	1.00	0.00	1.00	3.50	0.00	0.00	2.00	0.00	0.00	0.00	1.00	2.00	0.00	0.00	2.00	1.00	0.50
Transition	8.00	4.00	6.00	2.50	9.00	5.00	7.50	0.00	18.00	17.00	4.00	4.00	3.00	12.00	4.00	10.00	5.50
Submission	4.00	0.00	0.00	0.50	2.00	1.00	0.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Submission transition	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arm defence	13.00	9.00	11.00	6.00	6.50	0.00	1.50	1.00	15.00	14.00	3.00	6.00	1.00	21.00	10.00	9.00	7.75
Trunk defence	1.00	3.00	10.00	0.50	4.50	1.00	2.50	0.00	2.00	2.00	1.00	0.50	1.00	2.00	2.00	3.00	2.00
Leg defence	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Footwork defence	1.00	5.00	6.00	1.50	2.00	0.00	0.50	0.00	6.00	1.00	0.00	3.00	0.00	12.00	2.00	3.00	1.75
No defence	11.00	4.00	5.00	1.50	2.50	1.00	18.00	1.00	15.00	17.00	3.00	8.00	0.00	6.00	0.00	5.00	4.50
CS No defence	3.00	9.00	17.00	3.00	6.50	2.00	5.50	1.00	21.00	5.00	0.00	17.50	0.00	40.00	7.00	15.00	6.00
Sprawl	0.00	0.00	4.00	1.00	3.00	0.00	3.50	0.00	4.00	3.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00
Transition block	9.00	2.00	5.00	6.50	13.50	6.00	4.00	0.00	7.00	7.00	3.00	4.00	7.00	8.00	13.00	9.00	6.75
Submission defence	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00

Table 4. Descriptive statistics for all KPIs by losing athletes

	Losing athletes																
KPI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Median
Punch	14.00	12.00	29.00	9.00	12.50	1.00	14.50	1.00	33.00	42.00	6.00	9.00	2.00	37.00	14.00	17.00	13.25
CS Punch	4.00	9.00	15.00	3.50	8.50	2.00	1.50	1.00	19.00	6.00	0.00	12.00	0.00	45.00	7.00	13.00	6.50
Kick	2.00	6.00	2.00	0.50	0.00	0.00	3.50	2.00	0.00	0.00	0.00	6.00	1.00	2.00	0.00	1.00	1.00
CS Kick	1.00	0.00	0.00	0.50	0.00	0.00	3.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00
Knee	0.00	3.00	0.00	0.50	0.00	0.00	4.00	0.00	1.00	1.00	0.00	2.00	0.00	1.00	0.00	1.00	0.25
CS Knee	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Elbow	5.00	0.00	0.00	0.00	0.00	0.00	3.50	0.00	0.00	2.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
CS Elbow	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Takedown	0.00	0.00	5.00	0.50	3.50	0.00	3.50	1.00	4.00	3.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00
Transition	10.00	3.00	7.00	7.50	13.00	6.00	8.00	0.00	5.00	11.00	3.00	4.00	7.00	14.00	13.00	8.00	7.25
Submission	1.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	1.00	0.00
Submission transition	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arm defence	37.00	9.00	25.00	26.50	16.50	4.00	6.00	0.00	30.00	14.00	26.00	8.00	19.00	92.00	70.00	13.00	17.75
Trunk defence	0.00	0.00	2.00	0.50	2.00	2.00	1.50	0.00	3.00	4.00	1.00	2.00	0.00	5.00	0.00	0.00	1.25
Leg defence	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Footwork defence	1.00	1.00	7.00	2.50	1.50	0.00	3.00	3.00	4.00	1.00	4.00	7.50	0.00	1.00	0.00	1.00	1.25
No defence	13.00	1.00	10.00	10.50	20.50	13.00	16.50	0.00	9.00	9.00	12.00	10.50	8.00	3.00	4.00	18.00	10.25
CS No defence	6.00	12.00	27.00	2.00	7.50	3.00	3.50	1.00	13.00	4.00	0.00	16.50	0.00	58.00	8.00	13.00	6.75
Sprawl	1.00	0.00	1.00	3.50	0.00	0.00	2.00	0.00	0.00	0.00	1.00	2.00	0.00	0.00	2.00	1.00	0.50
Transition block	9.00	2.00	1.00	2.50	9.50	5.00	6.50	0.00	20.00	17.00	5.00	4.50	4.00	18.00	4.00	9.00	5.00
Submission defence	4.00	0.00	0.00	0.00	2.50	2.00	0.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 2 shows the method of victory across the sample, TKO was most frequent accounting for 37% of the contests and decision was the least frequent method of victory (13%).

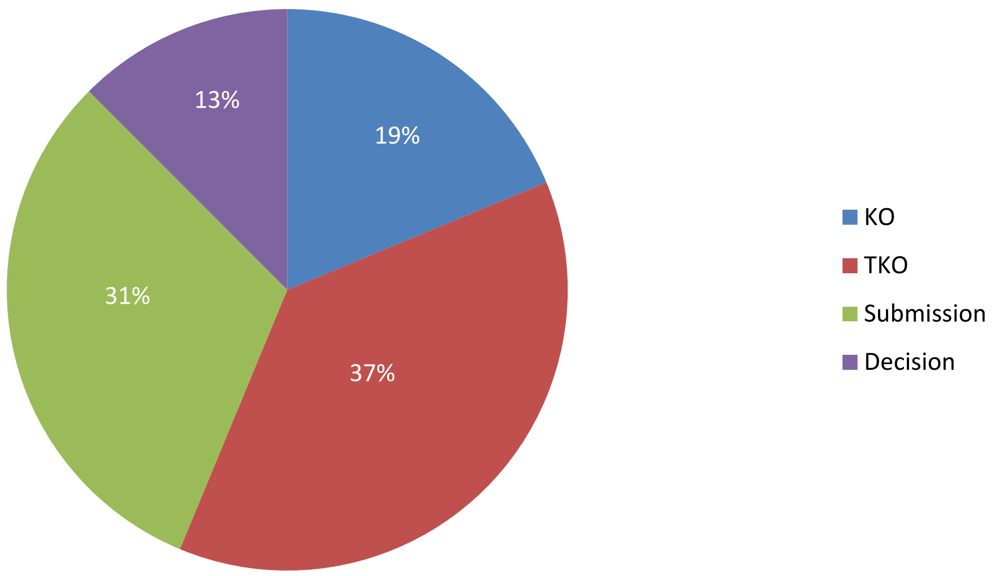


Figure 2. Method of victory by winning athletes

Table 5 presents the significant strike frequencies for the winning athletes. The most frequent type of significant strike landed by winners was a staggering strike (31) followed by a knockdown (6). Only one cut was caused by the winning athletes and three contests were won by knockout.

Table 5. Descriptive statistics for significant strikes by winning athletes

Athlete	Knockout	Knockdown	Staggered	Cut
Winner 1	0	0	2	0
Winner 2	0	1	0	0
Winner 3	0	0	5	0
Winner 4	1	0	1	0
Winner 5	0	2	1	0
Winner 6	0	0	0	0
Winner 7	0	0	0	0
Winner 8	1	0	0	0
Winner 9	0	0	3	1
Winner 10	1	1	0	0
Winner 11	0	0	4	0
Winner 12	0	1	1	0
Winner 13	0	1	2	0
Winner 14	0	0	10	0
Winner 15	0	0	2	0
Winner 16	0	0	0	0
Total	3	6	31	1

Among the losing athletes seven staggering strikes on the winners were recorded and caused one cut was caused as a result of strikes. No knockouts or knockdowns were caused as a result of the losing athletes striking. The results are presented below in Table 6.

Table 6. Descriptive statistics for significant strikes by losing athletes

Athlete	Knockout	Knockdown	Staggered	Cut
Loser 1	0	0	1	1
Loser 2	0	0	1	0
Loser 3	0	0	0	0
Loser 4	0	0	0	0
Loser 5	0	0	0	0
Loser 6	0	0	0	0
Loser 7	0	0	0	0
Loser 8	0	0	0	0
Loser 9	0	0	0	0
Loser 10	0	0	0	0
Loser 11	0	0	0	0
Loser 12	0	0	3	0
Loser 13	0	0	0	0
Loser 14	0	0	1	0
Loser 15	0	0	0	0
Loser 16	0	0	1	0
Total	0	0	7	1

The total frequencies across all KPI groups displayed no significant differences between winners and losers. Striking offence and striking defence both showed notable differences among winners and losers; with winners executing more offensive strikes on average per bout and losers exhibiting more defensive techniques, however neither were deemed statistically significant (P = 0.054 and P = 0.057 respectively). The results are displayed below in Figure 3.

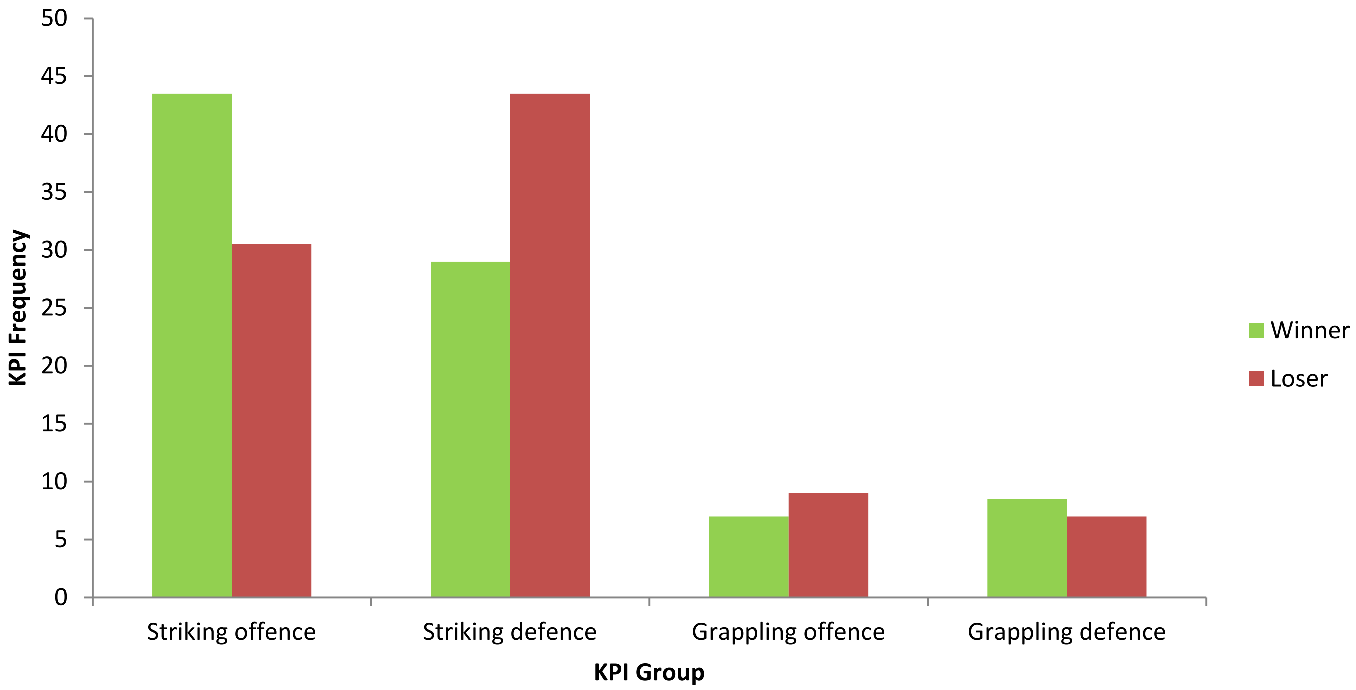


Figure 3. KPI frequencies for winners vs losers across all KPI groups

Winners achieved a success rate of 61.31% ± 46.34% to 66.67% CLs for offensive striking which was significantly higher than the success rate of the losers 47.08% ± 32.61% to 62.50% CLs respectively. Losers demonstrated that the majority of their offensive strikes were executed using their lead limbs, 61.67% ± 46.79% to 67.71% CLs. These results were significantly higher than those found for the winning athletes' lead limbs which were used to execute 42.09% ± 29.59% to 57.14% CLs of their total offensive strikes. When using rear limbs, winners had significantly higher success rates when compared to the losers, 57.92% ± 42.86% to 70.41% CLs and 36.47% ± 32.29% to 53.21% CLs respectively. When the contest took place in the standing domain, the losers showed significantly higher percentages of offensive striking, 86.95% ± 42.07% to 96.88% CLs, than the winning athletes (48.53% ± 14.29% to 76.67% CLs). Significant differences were present when comparing the offensive striking activity of winners and losers on the ground. Winners executed 37.73% ± 8.75%

to 81.54% CLs of their total offensive striking while on the ground, in contrast, the losers executed only 2.11% ± 0.00% to 37.50% CLs of their striking offence while on the ground. No significant differences were found between winners and losers for their offensive striking activity while in the clinch domain. Significant differences were found when comparing the offensive striking activity of athletes across different domains; winners demonstrated higher percentages (47.42% ± 14.29% to 79.38% CLs) of offensive strikes while in dominant control when compared with losers (4.51% ± 0.00% to 19.15% CLs). Losing athletes had a higher percentage of their offensive striking take place in neutral control, 73.71% ± 45.01% to 96.88%, than the winners of the contests who executed 43.69% ± 16.67% to 63.77% CLs while in neutral control. No significant differences in offensive strikes were evident between winners and losers when comparing non-dominant control or their location in the cage (free space or against the cage). The data for offensive strikes can be found below in Figure 4, asterisks are used to represent significant results.

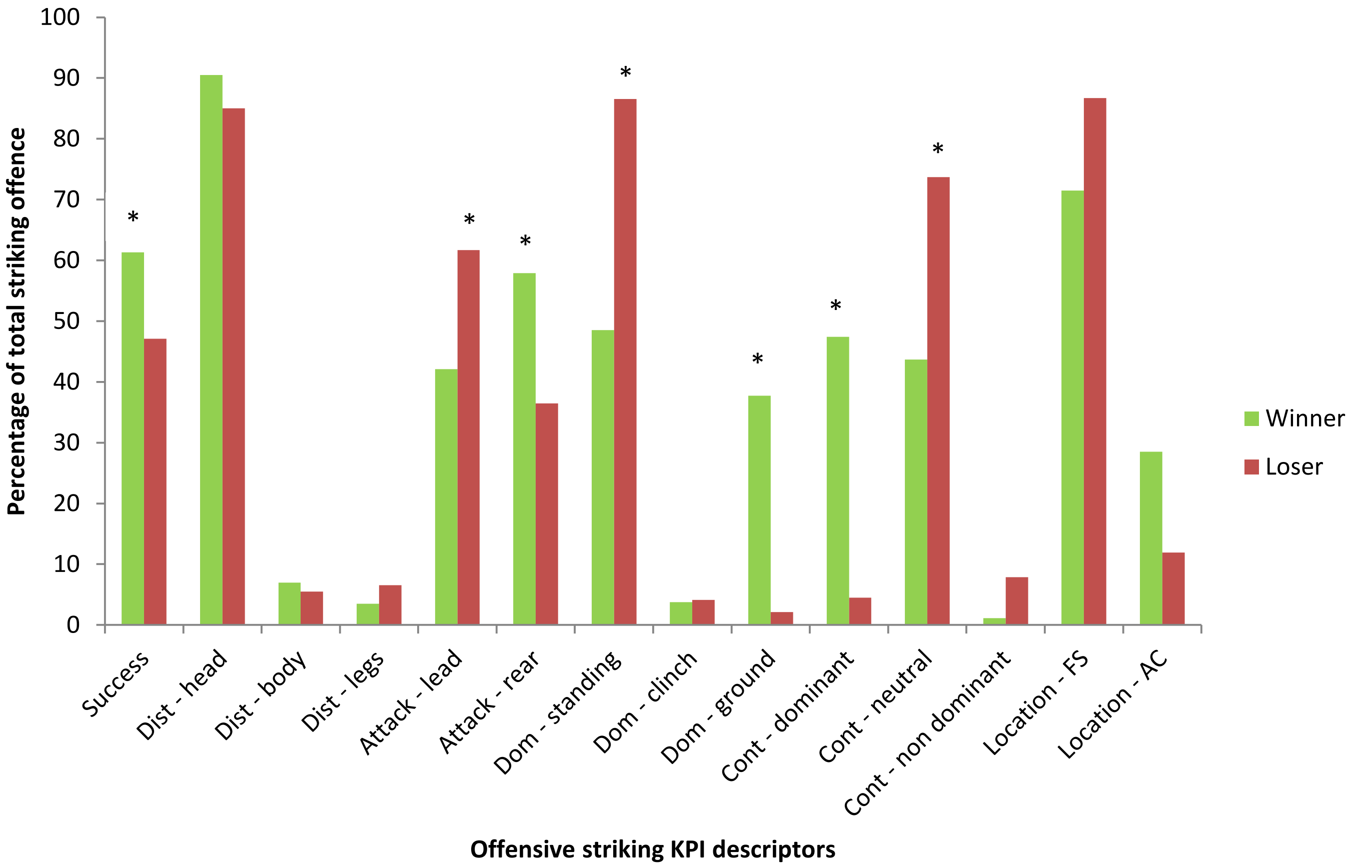


Figure 4. Offensive striking comparison between winners and losers.

Striking defence data is presented below in Figure 5; asterisks are used to denote significance. The percentage of striking defences for winners was significantly higher in the standing domain when compared to losers (87.39% ± 42.86% to 96.88% CLs vs 47.98% ± 18.18% to 75.00% CLs). For losers, however, the percentage of striking defences was significantly higher than winners in the ground domain at 36.09% ± 9.29% to 80.49% CLs compared to the winners 1.12% ± 0.00% to 28.57% CLs. While in neutral control winners executed a significantly higher percentage (77.38% ± 45.71% to 96.88% CLs) of their striking defences compared to losers (40.35% ± 16.40% to 65.22% CLs). All other striking defence descriptors showed no significant differences when winners and losers' data were compared.

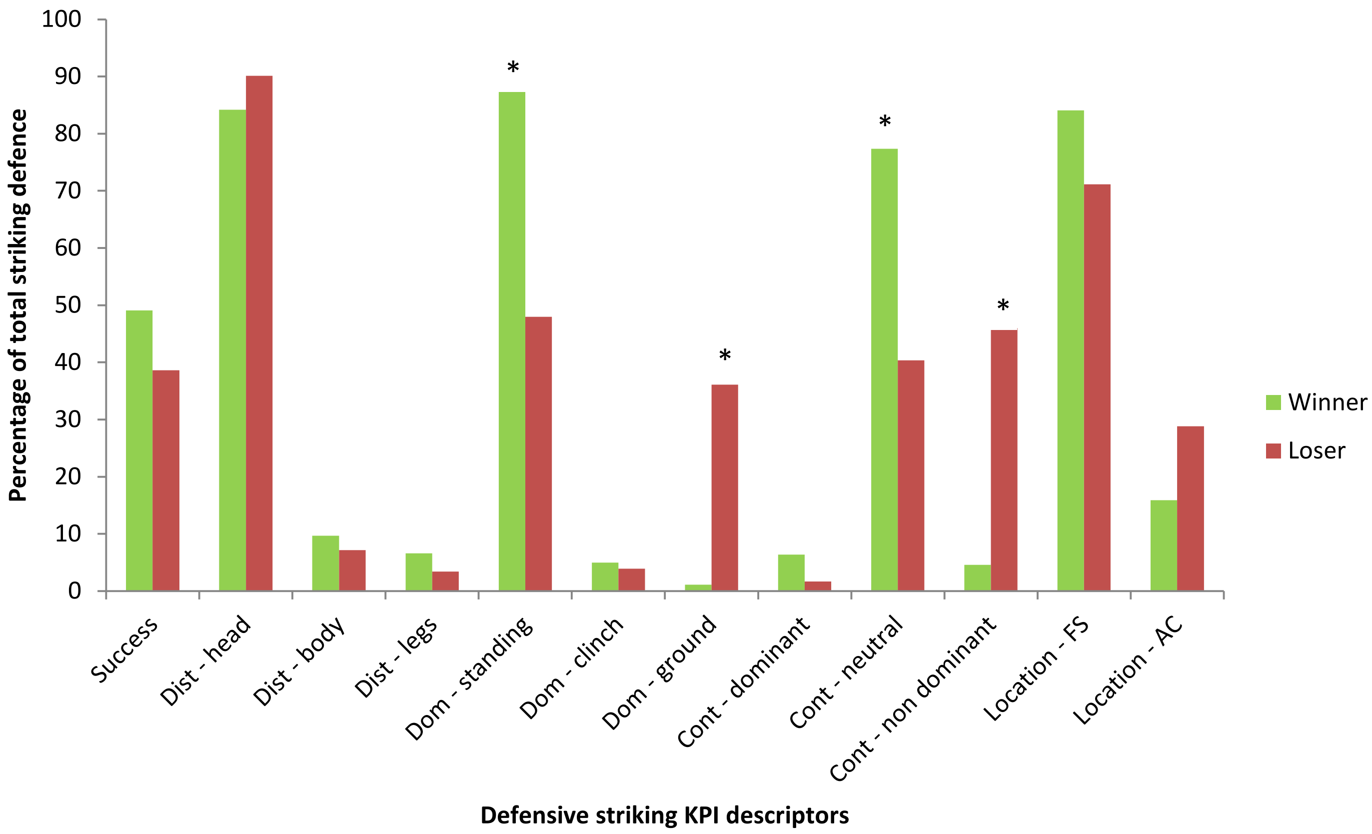


Figure 5. Defensive striking comparison between winners and losers.

For winning athletes, their percentage of success for offensive grappling actions was significantly higher, achieving 83.09% ± 70.83% to 100% CLs, than the losing athletes who achieved 66.67% ± 46.40% to 80.00% CLs. While in dominant control, winning athletes executed 47.92% ± 5.88% to 76.92% CLs of their offensive grappling which was significantly higher than the losers who executed 0.00% ± 0.00% to 12.50% CLs of their offensive grappling in a dominant position. Losers demonstrated that the majority of their offensive grappling actions were initiated while in a non-dominant position 70.84% ± 33.33% to 85.71% CLs. Winners performed significantly less offensive grappling actions while in a non-dominant position with 18.8% ± 0.00% to 50.00% CLs of their offensive grappling occurring within this control, shown below in Figure 6 (asterisks are used to denote significance). All other offensive grappling descriptors showed no significant differences between winners and losers.

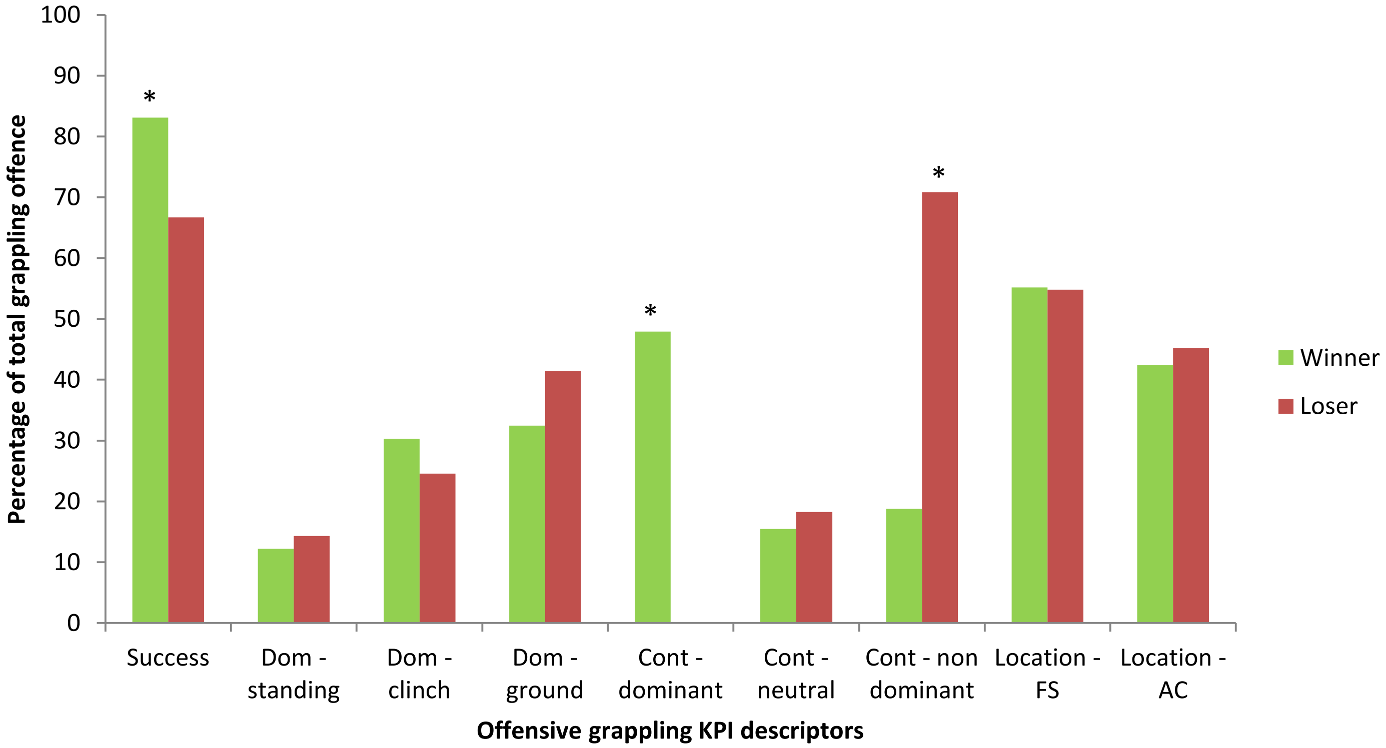


Figure 6. Offensive grappling comparisons between winners and losers.

Winners were found to have a significantly higher percentage of success when performing defensive grappling techniques in comparison with losers, 30.50% ± 11.11% to 51.79% vs 20.42% ± 0.00% to 28.57% CLs. While in dominant control, winners executed a higher percentage of their defensive grappling (76.99% ± 36.36% to 92.31% CLs) compared to losing athletes (24.45% ± 0.00% to 57.14% CLs). Losing athletes performed 48.34% ± 6.25% to 67.78% CLs of their defensive grappling while in a non-dominant position which was significantly higher than the winners defensive grappling activity while in non-dominant positions, 1.14% ± 0.00% to 10.84% CLs. No other significant differences were found between winners and losers for defensive grappling KPI. Defensive grappling findings are presented below in Figure 7 (asterisks are used to denote significant differences).

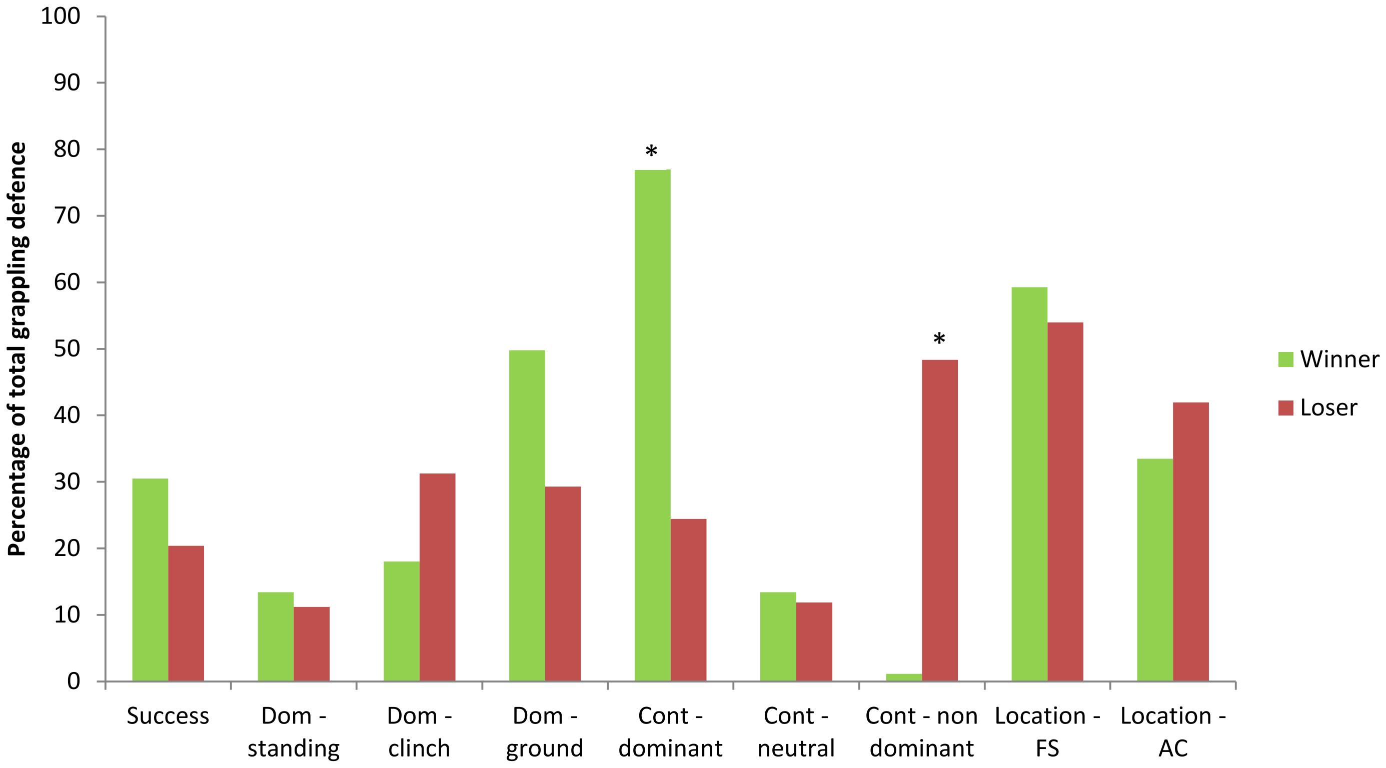


Figure 7. Defensive grappling compared between winners and losers.

4. Discussion

Given the novel nature of the current study, the findings present an opportunity to develop a scientific body of knowledge which can support the new hybrid combat sport of MMA. Median KPI frequency values for winners and losers are presented in Tables 3 and 4, the results demonstrate that the winners attempted more complex striking techniques, particularly knee and elbow strikes, and also more complex defensive striking techniques such as trunk and footwork defences. Previous research has found that the ability for winning taekwondo athletes to execute complex defensive techniques in particular is a key determinant of a successful performance (Cular, Krstulovic, Tomljanovic, 2011). One finding of interest from the present research, which is in contrast to existing literature on other striking-based combat sports (El-Ashker, 2011; Davis *et al*., 2013; Ouergui *et al*., 2013), is the lack of statistical significance when comparing the total frequency of offensive striking between winning and losing athletes. The findings from the present research show that winners had a higher average frequency for offensive striking techniques when compared to losers; however, statistical significance was not achieved ($P > 0.05$). Previous research by Ouergui *et al*. (2013) found that, in kickboxing, winning athletes demonstrated a higher output of offensive striking. It could be argued that the ability to simply perform at a high work rate and deliver a greater quantity of offensive strikes is not a determining factor in the outcome of the professional MMA bouts. However, given the exact α value observed ($P = 0.054$; $d = 0.48$) the findings were close to being statistically significant with a moderate effect size. A larger sample may have found significant differences across the groups; future research should further investigate this area. Losing athletes had a higher average frequency of defensive techniques over the course of a contest. This would be expected given the offensive output seen from the winners, however as before, statistical significance was not achieved when comparing the two groups. In terms of grappling activity, both offensive and defensive technique frequencies were similar between winners and losers and any differences were not statistically significant. This further suggests that the frequency count of an action alone within professional MMA competition is not a determining factor in the outcome of a contest.

A more detailed analysis including the descriptors of each KPI group led to significant findings enabling the differentiation in performance profiles across winners and losers in professional MMA contests. One of these findings was the significant difference in the percentage of successful offensive strikes by the winning athletes ($P < 0.05$; $d = 0.50$). The results indicated that the winners of the contests had significantly higher success rate than the losers (Figure 4). This finding is in agreement with other literature on striking-based combat sports which have also seen the efficiency of attacks by athletes as a determining factor in the outcome of contests (Cappai *et al*., 2012; Ouergui *et al*., 2013; Tabben *et al*., 2014). Coupled with the previous finding on offensive striking frequency it would suggest that, in MMA competition, in terms of offensive striking, efficiency is more important than frequency. Therefore the present findings would suggest that athletes should strive to improve their overall striking efficiency prior to competition. This could be achieved through the improvement of technique, speed and accuracy. Not only was efficiency found to be significantly different across athletes, the use of the lead and rear limbs during attacks differed significantly between groups. The results showed that winning athletes carried out the majority of their offensive strikes using their rear limbs ($P < 0.05$; $d = 0.51$). In contrast the losing athletes demonstrated the majority of their offensive output to be conducted using their lead limbs ($P < 0.05$; $d = 0.49$) (Figure 3). Within striking-based combat sports it is common practice for athletes to execute techniques from a set combat stance whereby the athlete has designated lead limbs and rear limbs. MMA athletes follow this practice based on their adaptation of striking from numerous styles such as boxing, muay thai and karate (Amtmann & Berry, 2003). An athlete’s dominant limbs (e.g. right or left handed/footed) are set as their rear striking limbs, which allows the athlete to generate more power during their strikes as a result of the increased muscular recruitment and speed of the athlete's dominant limbs (Neto, Silva, de Miranda Marzullo, Bolander & Bir, 2012). In addition, the stance places the dominant limbs at the rear meaning that there is increased rotation at the hip and torso to perform the strike, the increased rotation from these larger muscle groups enables a greater 'effective mass' used for the strike. Previous research has demonstrated that by increasing an athletes 'effective mass' involved in the strike, the total force generated by the strike is also increased (McGill, Chaimberg, Frost & Fenwick, 2010). The culmination of these factors leads to a more powerful strike being delivered from the rear limbs when an athlete is in their combat stance. With winning athletes utilising their rear limbs for the majority of their striking attempts it means that there is an increased likelihood of a powerful strike landing. In comparison, the losers (who on average carry out more of their offensive striking activity with their lead limbs) will have a reduced potential to generate powerful strikes. This is demonstrated in Tables 3 and 4, as the winners had more knockouts, knockdowns, staggering strikes and strikes that caused a cut than the losers.

Another possible explanation for this finding could be due to the metabolic demands placed on athletes performing rear limb techniques. Previous research (Franchini et al., 2011) found that the increase in muscular recruitment results in a higher metabolic cost to the athletes; this could lead to a quicker depletion of stamina and cause the athlete to fatigue at a faster rate when using more rear limb techniques. Should the winners in MMA contests be more conditioned than the losers, they would have a greater capacity to execute rear limb techniques more frequently, as was seen within the present study. To date, no research has investigated the physiological differences between winning and losing athletes within MMA and as it is a potential explanation for the present findings, it is an area which warrants further investigation.

The results demonstrated that winners and losers utilised both offensive and defensive striking within each domain very differently. Winners engaged in a large proportion of their offensive striking while on the ground; 41.9% of their total offensive striking output occurred on the ground, which was significantly more ($P < 0.05$; $d = 0.61$) than the losers (15.4%). The dynamic of ground striking exchanges are heavily in favour of the athlete who is in the top position. The athlete on top generally has many advantages in ground striking exchanges, such as greater postural movement and control, being able to restrict the movement of the athlete on the bottom and they are able to strike downwards rather than against gravity to name but a few benefits (Del Vecchio *et al*., 2011). As a result, it is widely accepted, among MMA athletes and coaches, that the athlete on top is deemed to be in control at that time.

The data for the control descriptor within the present research showed that the winners conducted significantly more offensive striking ($P < 0.05$; $d = 0.86$), offensive grappling ($P < 0.05$; $d = 0.77$) and defensive grappling ($P < 0.05$; $d = 0.66$) while in a position of dominant control (Figures 3, 4 and 5). The combination of these findings would suggest that an athlete's ability to maintain control of the contest through the use of dominant positions, particularly when combat takes place on the ground, is a key component of a winning performance profile. The ability to keep dominant control on the ground allows for a greater striking output, as demonstrated by the winners' data, it also means that the losing athlete is forced to increase their defensive actions to avoid absorbing damage (losing athletes demonstrated a significantly higher percentage of their striking defence while on the ground, $P < 0.05$; $d = 0.63$); this limits their opportunities to try and escape from the bottom position as striking defence becomes the primary concern (Figures 3 and 4). The losing athletes grappling offence while in a non-dominant position reflects this prioritisation leading to a significant difference ($P < 0.05$; $d = 0.80$) when compared with winning athletes grappling offence in a non-dominant position. Not only is there a beneficial aspect for striking exchanges, many submission holds are initiated from a dominant top position (Del Vecchio *et al*., 2011) meaning that without the dominant position, an athletes ability to initiate submission attempts is greatly reduced, consequently, so is their chance of ending the contest at that moment in time.

The lack of previous research on this topic renders the present findings as speculative at this point in time. The addition of scientific literature on this topic will enable the comparison of the results described herein. Future research should look to further investigate the performance profiles of winning and losing athletes to consolidate the differences between the two groups. In addition, the comparison of amateur profiles of winning and losing athletes would enable the evaluation of progression from amateur athletes to a professional standard, providing insight for both aspiring amateurs and coaches.

A limitation of the present study is the sample size; due to time constraints of the present research the sample was limited to 16 contests. In future research a wider array of contests should be included; in particular, contests which last 3 rounds and go to a judge’s decision as this will provide a larger data set to analyse. This in turn would enable findings to compare the profiles of athletes in accordance with judge’s scoring, an aspect of MMA competition which warrants further investigation. In addition to the sample size, a further limitation was the level of technical depth which was explored, i.e. KPI such as punches, kicks, knees and elbows were grouped into offensive striking, due to the large number of KPI across all four KPI groups. By individually investigating KPIs, or one KPI group in particular, this may allow for specific differentiations between winners and losers on a technical level which the present study could not investigate.

In conclusion, the present research has served as an initial investigation into the differentiation between winning and losing during professional MMA competition through the use of performance profiling. The ability for an athlete to maintain dominant control was found to be the most significant differentiating factor between winners and losers. Controlling which domain and position the fight takes place in improves an athlete's chance of winning a contest because it will allow increased striking and submission opportunities, which were the most common methods used to end bouts. It was also found that the use of efficient offensive striking was a key difference between winners and losers as well as the predominant use of the rear limbs during attacks by winning athletes. Future research would benefit from a larger sample size in order to gather a more varied data set. Further research is needed in this area in order to consolidate or challenge the results found herein.

5. References

Amtmann, J., & Berry, S. (2003). Strength and conditioning for reality fighting. *Strength & Conditioning Journal*, *25*(2), 67-72.

Atan, T., & İmamoğlu, O. (2005). Competition analysis of World Greco-Roman and World free-style wrestling championships. *International Journal of Performance Analysis in Sport*, *5*(1), 31-40.

Cappai, I., Pierantozzi, E., Tam, E., Tocco, F., Angius, L., Milia, R., Squatrito, S., Concu, A., & Crisafulli, A. (2012). Physiological responses and match analysis of Muay Thai fighting. *International Journal of Performance Analysis in Sport*, *12*(3), 507-516.

Cohen, J. (1988). Statistical power analysis for the behavioural sciences, Hillsdale, NJ: Lawrence Erlbaum Associates.

Cooper, S. M., Hughes, M., O'Donoghue, P., & Nevill, A. M. (2007). A simple statistical method for assessing the reliability of data entered into sport performance analysis systems. *International Journal of Performance Analysis in Sport*, *7*(1), 87-109.

Cular, D., Krstulovic, S., & Tomljanovic, M. (2011). The differences between medalists and non-medalists at the 2008 Olympic games taekwondo tournament. *Human movement*, *12*(2), 165-170.

Davis, P., Wittekind, A., & Beneke, R. (2013). Amateur boxing: activity profile of winners and losers. *International Journal of Sports Physiology and Performance*, *8*(1), 84-91.

Del Vecchio, F. B., Hirata, S. M., & Franchini, E. (2011). A review of time-motion analysis and combat development in mixed martial arts matches at a regional level tournaments 1. *Perceptual and Motor Skills*, *112*(2), 639-648.

El-Ashker, S. (2011). Technical and tactical aspects that differentiate winning and losing performances in boxing. *International Journal of Performance Analysis in Sport*, *11*(2), 356-364.

Franchini, E., Sterkowicz, S., Szmatlan-Gabrys, U., Gabrys, T., & Garnys, M. (2011). Energy system contributions to the special judo fitness test. *International Journal of Sports Physiology and Performance*, *6*(3), 334-343.

Hughes, M., Evans, S., & Wells, J. (2001). Establishing normative profiles in performance analysis. *International Journal of Performance Analysis in Sport*, *1*(1), 1-26.

International Brazilian Jiu Jitsu Federation. (2013). Rule book: General competition guidelines competition format manual. Retrieved from the International Brazilian Jiu Jitsu Federation website: http://www.ibjjf.org

James, N., Mellalieu, S., & Jones, N. (2005). The development of position-specific performance indicators in professional rugby union. *Journal of Sports Sciences*, *23*(1), 63-72.

Lames, M., & McGarry, T. (2007). On the search for reliable performance indicators in game sports. *International Journal of Performance Analysis in Sport*, *7*(1), 62-79.

López-González, D., Alonso-Rodríguez, A., Bárcenas-Durón, M. A., & Rodríguez-Alonso, S. (2012). Quantitative indicators of technical-tactical performance: an example with freestyle and female top 10 wrestlers from the 2011 world senior championships. *International Journal of Wrestling Science*, *2*(2), 1-11.

Matsushigue, K. A., Hartmann, K., & Franchini, E. (2009). Taekwondo: Physiological responses and match analysis. *The Journal of Strength & Conditioning Research*, *23*(4), 1112-1117.

McGill, S. M., Chaimberg, J. D., Frost, D. M., & Fenwick, C. M. (2010). Evidence of a double peak in muscle activation to enhance strike speed and force: an example with elite mixed martial arts fighters. *The Journal of Strength & Conditioning Research*, *24*(2), 348-357.

Neto, O. P., Silva, J. H., de Miranda Marzullo, A. C., Bolander, R. P., & Bir, C. A. (2012). The effect of hand dominance on martial arts strikes. *Human movement science*, *31*(4), 824-833.

New Jersey Athletic Commission. (2002). Mixed Martial Arts Unified Rules of Conduct: Additional Mixed Martial Arts Rules. Retrieved from the New Jersey State Athletic Control Board website: http://www.state.nj.us

O'Donoghue, P. (2005). Normative profiles of sports performance. *International Journal of Performance Analysis in Sport*, *5*(1), 104-119.

O'Donoghue, P., Mayes, A., Edwards, K. M., & Garland, J. (2008). Performance norms for British national super league netball. *International Journal of Sports Science and Coaching*, *3*(4), 501-511.

Ouergui, I., Hssin, N., Franchini, E., Gmada, N., & Bouhlel, E. (2013). Technical and tactical analysis of high level kickboxing matches. *International Journal of Performance Analysis in Sport*, *13*(2), 294-309.

Ouergui, I., Hssin, N., Haddad, M., Franchini, E., Behm, D. G., Wong, D. P., Gmada, N., & Bouhlel, E. (2014). Time-Motion Analysis of Elite Male Kickboxing Competition. *The Journal of Strength & Conditioning Research*, *28*(12), 3537-3543.

Tabben, M., Coquart, J., Chaabène, H., Franchini, E., Ghoul, N., & Tourny, C. (2014). Time-motion, tactical and technical analysis in top-level karatekas according to gender, match outcome and weight categories. *Journal of Sports Sciences*, (ahead-of-print), 1-9.

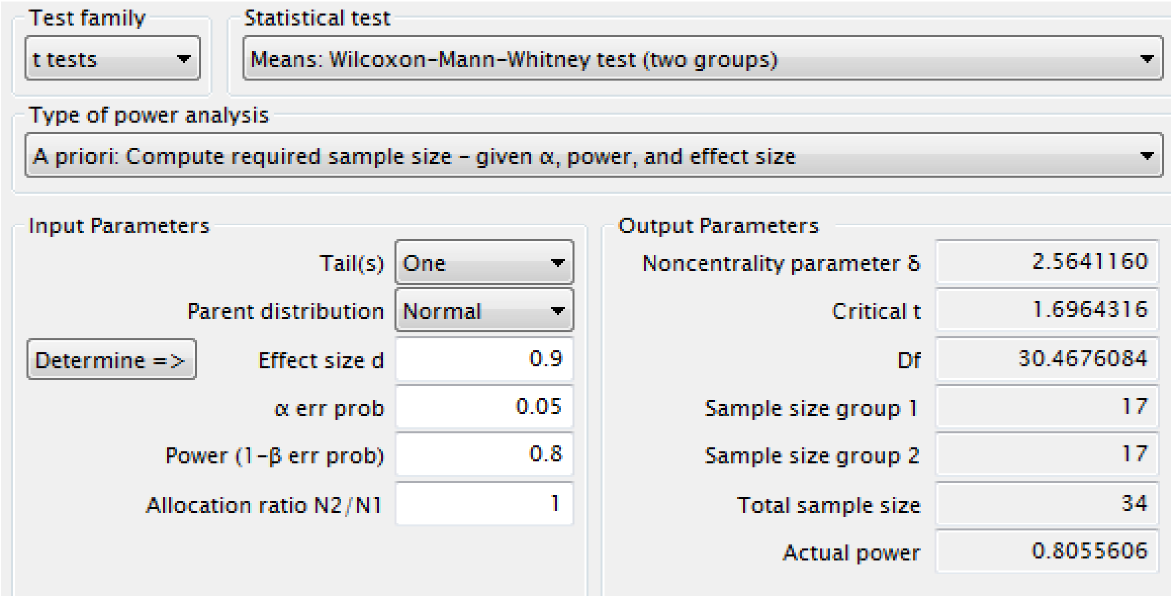
Tornello, F., Capranica, L., Minganti, C., Chiodo, S., Condello, G., & Tessitore, A. (2014). Technical-Tactical Analysis of Youth Olympic Taekwondo Combat. *The Journal of Strength & Conditioning Research*, *28*(4), 1151-1157.

Thomson, E., Lamb, K., & Nicholas, C. (2013). The development of a reliable amateur boxing performance analysis template. *Journal of Sports Sciences*, *31*(5), 516-528.

Tropin, Y. M. (2014). Comparative analysis of technical and tactical preparedness Greco-Roman style wrestler at the Olympic Games-2008 and the Olympic Games-2012. *Fiziceskoe Vospitanie Studentov*, *4*, 92-95.

6. Appendices

Appendix 1. Gpower sample size power calculation



Appendix 2. KPI and operational definitions used within the present analysis template.

Key performance indicator (KPI)	Category	Domain available	Descriptive variables coded	Definition / description used within the present study
Punch	Offensive striking	Standing, clinch and ground	1, 2, 3, 4, 5, 6	A strike thrown by the athlete in any direction using the dominant or non-dominant arm where the striking impact area is the knuckle region.
CS Punch		Standing	1, 2, 3, 4, 5, 6	As above, however, the strike must be initiated either up to 1 second prior or 2 seconds post to an opponent's strike.
Kick		Standing, clinch and ground	1, 2, 3, 4, 5, 6	A strike thrown by the athlete in any direction using the dominant or non-dominant leg where the striking region is on the shin (tibia), anywhere between the knee (tibiofemoral joint) and the ankle (talocrural joint).
CS Kick		Standing	1, 2, 3, 4, 5, 6	As above, however, the strike must be initiated either up to 1 second prior or 2 seconds post to an opponent's strike.
Knee		Standing, clinch and ground	1, 2, 3, 4, 5, 6	A strike thrown in any direction by the athlete using the dominant or non-dominant leg where the striking impact area is either the front (patella) or side (media/lateral condyle) of the knee region.
CS Knee		Standing	1, 2, 3, 4, 5, 6	As above, however, the strike must be initiated either up to 1 second prior or 2 seconds post to an opponent's strike.

Elbow		Standing, clinch and ground	1, 2, 3, 4, 5, 6	A strike thrown in any direction by the athlete using the dominant or non-dominant arm where the striking impact area is the elbow (olecranon)
CS Elbow		Standing	1, 2, 3, 4, 5, 6	As above, however, the strike must be initiated either up to 1 second prior or 2 seconds post to an opponent's strike.
Arm defence	Defensive striking	Standing, clinch and ground	1, 2, 3, 4, 5, 6	A defensive technique performed by the athlete using the dominant, non-dominant or both arms to prevent/avoid a strike.
Trunk defence		Standing, clinch and ground	1, 2, 3, 4, 5, 6	A defensive technique performed by the athlete using the trunk to prevent/avoid a strike.
Leg defence		Standing and clinch	1, 2, 3, 4, 5, 6	A defensive technique performed by the athlete using the shin (tibia) anywhere between the knee (tibiofemoral joint) and ankle (talocrural joint) to prevent/avoid a strike.
Footwork defence		Standing	1, 2, 3, 4, 5, 6	A defensive technique performed by the athlete where movement is used to prevent/avoid a strike.
No striking defence		Standing, clinch and ground	1, 2, 3, 4, 5, 6	An occurrence when the athlete exhibits no visible, conscious effort to prevent/avoid an incoming strike thrown by the opponent.
CS No defence		Standing	1, 2, 3, 4, 5, 6	An occurrence when the athlete exhibits no visible, conscious effort to prevent/avoid an incoming strike thrown by the opponent while engaged in a counter-striking exchange.

Takedown	Offensive grappling	Standing and clinch	2, 3, 4, 5, 6	An offensive grappling action when an athlete forces his opponent back-down, sideways, into a seated position on the ground or where the opponent has at least 3 points of contact (hand, knee or foot) with the ground after standing on two feet at some point during the movement and keeps the fight on the ground and himself in the top position for 3 seconds.
Transition		Clinch and ground	2, 3, 4, 5, 6	An offensive grappling action when an athlete performs any action with the intention of improving their current grappling position in any grappling domain (in the clinch or on the ground).
Submission		Clinch and ground	2, 3, 4, 5, 6	A submission hold is classed as any technical position where the aim is to cause an opponent to concede defeat by 'tapping out' (tapping on the ground or athlete twice) by either choke, strangulation or joint lock.
Submission transition		Clinch and ground	2, 3, 4, 5, 6	An attempt made by an athlete to transition from one submission hold, which is already underway, to another while still maintaining control and in one continuous motion.
Sprawl	Defensive grappling	Standing and clinch	2, 3, 4, 5, 6	A defensive grappling action performed by the athlete when any technique or movement is used to defend an incoming takedown attempt by the opponent.
Transition block		Clinch and ground	2, 3, 4, 5, 6	A defensive grappling action performed by an athlete using any body part to prevent the advance in position of their opponent while grappling (in the clinch or on the ground).

Submission defence		Clinch and ground	2, 3, 4, 5, 6	A defensive grappling action performed by an athlete when they are in a submission hold, using any technique to escape the hold and avoid conceding defeat by 'tapping out'

Descriptive variables key

1	intended target	6	grappling position
2	success		
3	domain		
4	control		
5	location		