

1 **Worth the weight?: Post weigh-in rapid weight gain is not related to winning or**
2 **losing in professional mixed martial arts**

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5 Christopher Kirk^{1,2}, Carl Langan-Evans², James P Morton²

6

7 ¹University of Derby
8 College of Life and Natural Sciences
9 Kedleston Rd., Derby
10 United Kingdom
11 DE22 1GB

12

13

14

15 ²Liverpool John Moores University
16 Research Institute for Sport and Exercise Sciences
17 Tom Reilly Building, Liverpool
18 United Kingdom, L3 3AF

19

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23 **Corresponding author:**

24 Christopher Kirk

25 Email::C.Kirk@Derby.ac.uk

26

27 CK Orcid: 0000-0002-6207-027X

28 @ChrisKirk_ASP

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34 Abstract

35 Body mass (BM) manipulation via rapid weight loss (RWL) and rapid weight gain (RWG) is
36 common practice amongst mixed martial art (MMA) athletes to ensure qualification for the
37 division in which the athlete wishes to compete in. Professional MMA competitors in
38 California are required to weigh-in twice: 24 hours (h) prior to competition and immediately
39 prior to the bout, after which they have typically engaged in RWG. In analysing data from 5
40 MMA events sanctioned by the Californian State Athletic Commission, we used Bayesian
41 analyses to compare bout winners (n=31) and losers (n=31) in terms of in-competition BM
42 (CompMass, kg) and the amount of BM regained between the two weigh-ins (MassDiff, kg).
43 These data do not support the hypothesis that differences in CompMass ($BF_{10}=0.667$, $d = 0.23$)
44 or MassDiff ($BF_{10} = 0.821$, $d = .23$) determines winning or losing. In addition, there was no
45 statistical difference between bouts ending via strikes, submission or decision for either
46 CompMass ($BF_{10}=0.686$, $\omega^2 < 0.01$) or MassDiff ($BF_{10}=0.732$, $\omega^2 = 0.054$). In conclusion, we
47 report for the first time that the magnitude of RWG does not predict winning or losing in a
48 professional cohort of MMA athletes. Additionally, we also report that MMA athletes typically
49 compete at a BM that is at least 1-2 divisions higher than the division in which they officially
50 weighed-in. These analyses may provide impetus for governing bodies and coaches to enact
51 change at both professional and amateur levels to reduce negative health consequences
52 associated with extreme RWL and RWG.

53 **Key words:**Body composition; body mass regulation; weight cutting

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55 **Word count = 2,210**

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59 **Introduction**

60 Mixed martial arts (MMA) is combat sport characterised by striking and grappling based
61 actions, in which the participants compete in specified divisions (colloquially known as ‘weight
62 classes’) according to their body mass (BM). There is a strong belief amongst participants and
63 coaches that having a BM greater than the opponent provides a direct competitive advantage
64 (Langan-Evans, Crighton, Martin, & Wilson, 2017), with evidence suggesting that this offers
65 psychological support for performers (Pettersson, Ekström, & Berg, 2013). To achieve the BM
66 required for their chosen division, MMA participants regularly engage in rapid weight loss
67 (RWL) prior to their official weigh-in, followed by rapid weight gain (RWG) in the 24 hours
68 (h) between the weigh-in and the bout itself (Gann, Tinsley, & La Bounty, 2015). Methods
69 employed are a combination of diet restriction and activities designed to induce extreme
70 hypohydration including: fluid restriction, training in plastic clothing, use of saunas and
71 excessive fluid consumption (water loading). The magnitudes of RWL reported amongst MMA
72 participants is typically greater than related sports such as boxing, wrestling and Brazilian jiu
73 jitsu (Barley, Chapman, & Abbiss, 2017; Daniele, Weinstein, Wallace, Palmieri, & Bianco,
74 2016; Horswill, Scott, Dick, & Hayes, 1994). It is noteworthy that MMA athletes often partake
75 in RWL and RWG practices on the basis of advice from coaches and training partners with
76 little intervention from medical professionals or dieticians (Barley et al., 2017; Crighton, Close,
77 & Morton, 2016; Hillier et al., 2019; Matthews & Nicholas, 2017; Santos-Junior et al., 2019).

78 There is emerging evidence that the magnitude of RWG may be an important factor for success
79 in grappling sports such as judo (Reale, Cox, Slater, & Burke, 2016), though this effect is
80 apparently absent in striking sports such as boxing (Reale, Cox, Slater, & Burke, 2017). In
81 relation to MMA, Coswig et al. (2018) demonstrated that winners of competitive MMA bouts
82 regained 3% more BM than bout losers after both groups lost 7-8% BM prior to weigh-in.
83 Nonetheless, the small sample size of 8 winners and 7 losers precludes the conclusion that the

84 magnitude of RWL and subsequent RWG is an important determinant of success. Despite
85 such limited data in this area, professional MMA athletes partake in large magnitudes of RWL
86 and RWG, the result of which can be detrimental to health. For example, a recent case study
87 (n=1) conducted by our laboratory reported that of the 18.1% (14.5 kg) BM lost by the
88 participant during an 8 week period, 9.3% (7.3 kg) was due to severe hypohydration in the final
89 24 h before weigh-in. This led to reduced resting metabolic rate, hypogonadal endocrine profile
90 and acute kidney injury (Kasper et al., 2018). The influences of severe hypohydration on brain
91 trauma (Kempton et al., 2009) and hormonal changes (Coswig, Fukuda, & Del Vecchio, 2015)
92 have been suggested as the main physiological causes of injury, sickness, kidney disease and
93 in extreme situations, death (Crighton et al., 2016; Langan-Evans et al., 2017; Matthews &
94 Nicholas, 2017; Murugappan et al., 2018).

95 To combat these issues, the California State Athletic Commission (CSAC) now conduct a
96 second weigh-in on the day of competition to determine whether participants have regained
97 more than 10% of their weigh-in BM (CSAC, 2017). Since the introduction of this process in
98 2017, CSAC have released the day of bout weigh-in results of five professional MMA events
99 to the public domain. Through analysing these data, the aim of the present study was to test the
100 hypothesis that the amount of RWG between the official weigh-in and the day of bout weigh-
101 in would be predictive of who won the bout, and whether the bout ended due to strikes,
102 submission or decision (Kirk, 2018). It was also hypothesised that different divisions would
103 display different magnitudes of RWG.

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105 **Methods**

106 The data used for this study were collected at five professional MMA events (four Ultimate
107 Fighting Championship and one Bellator MMA) held in the state of California, USA by the

108 CSAC. As previously discussed, participants were required by the CSAC to weigh-in 24 h prior
109 to their bout and again on the day of the bout. These data represent the occasions released to
110 the public domain by the CSAC via the media. The following analyses were completed
111 following institutional ethical approval, and approval from the CSAC. Data were recorded by
112 the authors from various media outlets, cross referencing between each to ensure accuracy. The
113 CSAC reported each of the following variables in lbs, converted by the authors into kg in
114 keeping with SI units: participant's official BM as measured 24 h prior to the bout (OffMass);
115 participant's BM after RWG on the day of the bout (CompMass). It is not known how or
116 precisely when CompMass measurements were taken, other than they occurred on the day of
117 the bout prior to competition. The amount of BM regained between these two points by each
118 participant (MassDiff) was then calculated as follows:

$$119 \quad \text{CompMass} - \text{OffMass} = \text{MassDiff}$$

120 The winner of each bout, the bout outcome (strikes, submission or decision (Kirk, 2018)), and
121 the division in which the bout took place was also recorded. Draws, disqualifications and no
122 contests were excluded from the sample, as were bouts where any participant's CompMass was
123 not recorded/reported.

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125 **Statistical Analyses**

126 Bout winners and losers were compared for statistically relevant differences in CompMass and
127 MassDiff via two-tailed Bayesian t tests using a JZS Cauchy prior = 0.707. Cohen's d effect
128 size was calculated using the standard deviation of the mean scores as the denominator.
129 Bayesian one-way ANOVA with omega squared (ω^2) effect size was calculated for differences
130 in CompMass and MassDiff between each bout outcome. Bayesian one-way ANOVA with ω^2
131 was calculated for MassDiff between divisions. ANOVA post-hoc comparisons were

132 calculated using a default t-test with a Cauchy prior. The data were also viewed to determine
133 which division participants would, on average, be classed as based on their CompMass,
134 regardless of the their OffMass.

135 The following Bayes factor (BF) thresholds were used for each Bayesian test: 1-2.9 =
136 anecdotal; 3-9.9 = moderate; 10-29.9 = strong; 30=99.9 = very strong; ≥ 100 = decisive
137 (Wetzels & Wagenmakers, 2012). Each BF was used to specify evidence in favor of either the
138 hypothesis (BF_{10}) or the null hypothesis (BF_{01}). Due to a default prior being used BF robustness
139 checks were also performed. Where a BF was found to cross a threshold using a wider prior,
140 both thresholds are reported (Quintana & Williams, 2018). Cohen's d thresholds were set at:
141 trivial $d \leq 0.1$; small $d \geq 0.2$; moderate $d \geq 0.6$; large $d \geq 1.2$. ω^2 thresholds were set at: small
142 $\omega^2 \geq 0.01$; moderate $\omega^2 \geq 0.06$; large $\omega^2 \geq 0.14$. Each of the named statistical tests were
143 completed using JASP 0.10.2.0 (JASP Team, Amsterdam, Netherlands).

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145 **Results**

146 **Effect of Rapid Weight Gain on Winning and Losing**

147 Descriptive results are presented in Table 1. When comparing RWG between bout winners and
148 losers, the difference between the in-bout mass of winners and losers was anecdotal
149 (CompMass $BF_{10} = 0.667$, $d = 0.23$). The median [IQR] difference between winner's and
150 loser's CompMass = 0.8 [-0.7:2.7] kg, with range = -9 – 14 kg. Importantly, the evidence in
151 favour of bout winners regaining more mass than bout losers was also anecdotal (MassDiff
152 $BF_{10} = 0.821$, $d = .23$). The median [IQR] difference between winner's and loser's MassDiff =
153 0.95 [-0.6:2.3] kg, with range = -8.5 – 13.4 kg.

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156 Differences between Bout Outcomes

157 Differences in CompMass ($BF_{10} = 0.686$, $\omega^2 < 0.01$) and MassDiff ($BF_{10} = 0.732$, $\omega^2 = 0.054$)
158 did not appear to have any effect on whether the bout ended via strikes, submission or decision.
159 Though there was a trend for winners to regain a greater %BM in bouts ending due to strikes
160 or submission, these differences were not found to be statistically relevant. When considering
161 bouts ending due to strikes, the data favoured the null hypothesis that CompMass did not affect
162 the outcome ($BF_{01} = 2.129 - 3.761$, $d = 0.27$), with the evidence for MassDiff having an effect
163 in these bouts being anecdotal ($BF_{10} = 0.651$, $d = 0.33$). Similarly, in terms of bouts that were
164 won by submission, there was only anecdotal evidence for either CompMass ($BF_{10} = 1.1$, $d =$
165 0.6) or MassDiff ($BF_{10} = 1.8$, $d = 0.72$) differentiating between winners and losers. For bouts
166 that ended in decision, the evidence favoured the null hypothesis of there being no effect on
167 the result for both CompMass ($BF_{01} = 4.8$, $d = 0.05$) and MassDiff ($BF_{01} = 4.8$, $d = 0.06$).

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INSERT TABLE 1 HERE

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170 Differences between Divisions

171 When comparing MassDiff between divisions (Table 2), there was found to be anecdotal
172 evidence of each division regaining BM at different magnitudes ($BF_{10} = 1.3$, $\omega^2 = 0.05$). Post
173 hoc testing did, however, find the following differences between individual divisions: light
174 heavyweight (LHW) and women's strawweight (WSW) $BF_{10} = 5.4$ (moderate); welterweight
175 (WW) and featherweight (FW) $BF_{10} = 3.7$ (moderate); WW and flyweight (FIW) $BF_{10} = 7.5$
176 (moderate); FW and WSW $BF_{10} = 5.4$ (moderate); FIW and women's featherweight (WFW)
177 $BF_{10} = 4$ (moderate); FIW and WSW $BF_{10} = 25.9$ (strong).

178 The mean CompMass of each division placed the participants in at least the division above
179 which they were competing in. Six divisions displayed a mean CompMass placing the
180 participants near to the upper limit of two divisions above their OffMass. It should be noted,
181 differences between heavyweight (HW) and other individual divisions were not calculated as
182 no HW participants reduced BM prior to official weigh-in.

183 ***INSERT TABLE 2 HERE***

184

185 **Discussion**

186 Despite widespread perceptions amongst athletes and coaches, we provide novel data
187 demonstrating that the amount of BM regained after official weigh-in appears to provide no
188 competitive advantage in professional MMA athletes. Indeed, these data suggest that the
189 magnitude of RWG does not predict success, regardless of whether the bout ends due to strikes,
190 submission or decision.

191 Similar to other grappling inclusive sports such as judo (Reale et al., 2016), previous
192 observations from Coswig et al. (2018) provided preliminary evidence to suggest that the
193 magnitude of RWG amongst MMA winners was significantly greater than losers. However,
194 using a larger sample size, the present data suggest this is not the case for those participants
195 studied here. Importantly, our data also extend recent research conducted on a mixed cohort of
196 amateur and professional MMA athletes (Brechney, Chia, & Moreland, 2019) which suggested
197 that bout losers engaged in a greater magnitude of RWL than bout winners. Furthermore, it is
198 noteworthy that MMA athletes in the present study were, on average, regaining an absolute
199 BM large enough to place them in a division that was 1-2 divisions above their OffMass,
200 regardless of winning or losing. Given the apparent lack of a competitive advantage and also
201 the dangers of engaging in extreme RWL and RWG (Kasper et al., 2018), these data therefore

202 suggest that athletes may be better served by reducing the magnitude of RWL and competing
203 at least one division higher.

204 In contrast to judo (Reale et al., 2016) and the initial MMA findings by Coswig et al. (2018),
205 any potential benefits of RWG appear to be absent in striking-based events (Reale, Cox, et al.,
206 2017). A separate analysis of 71 boxing championship bouts found no effect of RWG on
207 success (Daniele et al., 2016). Given that MMA is a sport where the technical requirements of
208 successful performance can vary widely between grappling and striking movements (Kirk,
209 2018), the assumption that having a greater BM is a prerequisite for success does not seem to
210 hold true. It appears more likely that a strategy of RWL/RWG that accommodates the middle
211 of the striking-grappling spectrum would be more suitable. This may allow participants to
212 achieve a BM applicable to both grappling and striking modes whilst reducing or potentially
213 avoiding any negative health related outcomes.

214 The belief that RWG offers a competitive advantage appears to be most pronounced in the
215 lighter mass divisions of FW, BW and FIW, where participants regained more relative BM than
216 those in lightweight (LW) and above. This result also occurred in the three female divisions.
217 Though these data cannot directly infer the magnitude of RWL, it would be reasonable to
218 assume that this would be similar or greater to the amount of BM regained via RWG (Barley
219 et al., 2017). Overall, the evidence presented here and by others (Brechney et al., 2019)
220 represents emerging data that extreme RWL and RWG is not predictive of success. At present,
221 there may be concerns amongst MMA athletes that those who do reduce RWL and change
222 divisions would be at a disadvantage to those who do not. To that end, there should be a
223 consistent, co-ordinated effort for researchers to work directly with athlete facing practitioners
224 to induce cultural change within the sport. As this would take some time, competitors in the
225 interim will need systems in place to ensure adequate health and safety alongside optimal
226 performance. Such systems have been successfully utilised in Olympic combat sports (Reale,

227 Slater, & Burke, 2017) and should be developed within MMA. We suggest these analyses
228 presented here are replicated periodically as more data become available.

229

230 **Novelty Statement**

231 In summary, we report for the first time that the magnitude of RWG does not predict winning
232 or losing amongst professional MMA athletes. Additionally, we also report that MMA athletes
233 typically compete at a BM that is at least 1-2 divisions higher than the division in which they
234 officially weighed-in.

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236 **Practical Application**

237 Given that our analyses do not support the notion that extreme RWL and RWG is required for
238 success in MMA, the present data may provide impetus for governing bodies to enact
239 legislative change at both professional and amateur levels to discourage extreme RWL and
240 RWG. Our results should also be used to encourage athletes and coaches to make use of more
241 sustainable RWL and RWG practices.

242

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245 and also for taking the lead in starting to change the culture of 'weight cutting' in MMA and
246 other combat sports. The study was designed by CK; data were collected and analyzed by CK;
247 data interpretation and manuscript preparation were undertaken by CK, CLE and JPM. All
248 authors approved the final version of the paper. Authors state no conflict of interest. No author
249 has any financial interest or received any financial benefit from this research.

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Table 1 – Descriptive statistics of bout winners and bout losers (mean ± SD), as categorised according to the full cohort and bouts won by strikes, submission or decision.

	Bout Winner		Bout Loser	
	CompMass (kg)	MassDiff (kg)	CompMass (kg)	MassDiff (kg)
Full Cohort	77.3 ± 13.8	6.9 ± 2.9 [10.1 ± 0.04%]	76.4 ± 13.4	6 ± 2.8 [9.1 ± 0.05%]
Strikes	79.5 ± 14.2	6.9 ± 3.4 [10.4 ± 0.05%]	78.3 ± 15.3	5.7 ± 3.2 [8.5 ± 0.05%]
Submission	77.3 ± 11.2	5.7 ± 2.4 [8.3 ± 0.04%]	75.1 ± 2.4	4.2 ± 2.3 [6.2 ± 0.03%]
Decision	75.4 ± 13.8	7.2 ± 2.5 [10.6 ± 0.03%]	75.2 ± 12.5	8.6 ± 8.9 [10.5 ± 0.04%]

Nb. [%] = mean ± SD %BM regained in each group (MassDiff as a percentage of OffMass)

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Table 2 – Mass variables by division (mean ± SD)

Division	Full Divisional Cohort			Winners		Losers	
	Division Mass	CompMass	MassDiff	CompMass	MassDiff	CompMass	MassDiff
	Limit (kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
Heavyweight	120.5	109.1 ± 5.6	1.1 ± 2.2 [1 ± 2.1%]	109.1 ± 6.9	1 ± 2.3 [0.9 ± 2.1%]	109 ± 5.7	1.1 ± 2.5 [1.1 ± 2.3%]
Light heavyweight	93.1	100.1 ± 1.4	7.2 ± 1.4 [7.8 ± 1.5%] ^a	100.9 ± 1.5	8.2 ± 1.1 [8.9 ± 1.2%]	99.3 ± 0.7	6.2 ± 0.6 [6.6 ± 0.7%]
Middleweight	84	92.2 ± 3.2 ◊	7.7 ± 3.4 [9.1 ± 4%]	94.1 ± 2.6	9.5 ± 3 [11.3 ± 3.5%]	90.2 ± 2.5	5.9 ± 2.9 [7 ± 3.5%]
Welterweight	77.2	82.1 ± 2.9 ◊	5.6 ± 1.5 [7.4 ± 1.8%] ^{b, c}	82.3 ± 3.2	5.8 ± 1.6 [7.6 ± 1.9%]	82 ± 2.6	5.4 ± 1.5 [7.1 ± 1.8%]
Lightweight	70.5	77 ± 4.8 ◊	5.6 ± 4.6 [8 ± 6.6%]	77.7 ± 5.5	7.2 ± 5.2 [10.2 ± 7.3%]	74.7 ± 4.2	4.1 ± 4.1 [5.8 ± 5.8%]
Featherweight	65.9	73.6 ± 3 #	7.8 ± 2.7 [11.8 ± 4%] ^{b, d}	73.6 ± 3.1	7.8 ± 2.4 [11.8 ± 3.6%]	73.6 ± 3	8.7 ± 3 [11.8 ± 4.6%]
Bantamweight	61.3	68.5 ± 2 #	6.9 ± 1.9 [11.1 ± 3.1%] ^f	69 ± 1.7	7.3 ± 1.5 [11.9 ± 2.5%]	68 ± 2.2	6.4 ± 2.2 [10.4 ± 3.5%]
Flyweight	56.8	65 ± 1.2 #	8.2 ± 0.8 [14.4 ± 1.3%] ^{c, e}	65.3 ± 1.8	8.4 ± 1.3 [14.8 ± 2.1%]	64.8 ± 0.4	8 ± 0.4 [14 ± 0.6%]

Women's featherweight	65.9	71.6 ± 1	◇	5.8 ± 1.2 [8.7 ± 1.9%] ^e	71.1 ± 0.4	5 ± 0 [7.6 ± 0%]	72 ± 1.5	6.5 ± 1.4 [9.9 ± 2.2%]
Women's bantamweight	61.3	68.5 ± 3.3	#	6.9 ± 3.4 [11.2 ± 5.5%]	66 ± 1.9	4.3 ± 1.8 [6.9 ± 2.7%]	71 ± 1.9	9.5 ± 2.1 [15.4 ± 3.3%]
Women's flyweight *	56.8	64 ± 3.1	#	7.1 ± 2.6 [12.4 ± 4.5%] ^g	66.2	8.9 [15.6%]	61.8	5.2 [9.2%]
Women's strawweight	52.3	57.5 ± 1.3	#	5 ± 1.3 [9.5 ± 2.4%] ^{a, d, f}	57.5 ± 1.4	5.2 ± 1.2 [9.9 ± 2.3%]	57.4 ± 1.3	4.9 ± 1.5 [9.2 ± 2.8%]

Nb. ◇ = participants are on average near to the mass limit of the division above; # = participants are on average near to the mass limit of two divisions above; a/b/c/d/e/f = division displays moderate ANOVA post hoc differences in MassDiff to division with the same corresponding letter; g = division displays strong ANOVA post hoc differences in MassDiff to division with the same corresponding letter; * = one bout sampled in this division; [%] = mean ± SD %BM regained in each group (MassDiff as a percentage of OffMass)

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