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Weight loss strategies in combat sports and concerning habits in mixed martial arts

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1 **Research article**

2
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4 Habits in Mixed Martial Arts

5
6 **Original Investigation**

7
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25
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31 **ABSTRACT**

32 **Purpose:** Combat sports are typically divided into weight classes
33 and body mass manipulation to reach a weight class is
34 commonplace. Previous research suggests that mixed martial
35 arts (MMA) weight loss practices may be more extreme than
36 other combat sports. We sought to investigate the magnitude of
37 weight lost and prevalence of weight loss strategies in different
38 combat sports. **Methods:** Competitors (n=637) from Brazilian
39 jiu jitsu (BJJ), boxing, judo, MMA, muay Thai/kickboxing
40 (MT/K), taekwondo (TKD) and wrestling completed an online
41 questionnaire seeking information regarding their weight loss
42 practices. **Results:** Body mass manipulation was commonly
43 undertaken by all combat sports athletes, with a particularly high
44 incidence of gradual dieting, increased exercise and fluid
45 restriction. Skipping meals was higher in TKD and wrestling
46 (84%) compared with the other combat sports (~58%), whilst
47 training in heated rooms and forced oral fluid loss (spitting) was
48 higher in wrestling (83% and 47%, respectively) compared with
49 other combat sports (~45% and ~19%, respectively). MMA
50 athletes reported the highest usage of sauna (76%) and water
51 loading (67%) whilst also reporting the second highest use of
52 training in rubber/plastic suits (63%). **Conclusions:** Body mass
53 manipulation was present in all combat sports with the
54 prevalence and magnitude of acute weight loss greater in MMA.
55 The incidence of and practices reported will assist support staff
56 to be fully aware of the variety of methods these athletes and
57 coaches may use to achieve weight loss. Additionally, the results
58 could aid regulatory bodies in the further development of
59 policies on weight cutting.

60 **Keywords:** Weight cutting, Dehydration, Rehydration,
61 Recovery, Diet

62

63 **INTRODUCTION**

64 Typically combat sports are divided into weight divisions in an
65 effort to standardise competitors size and strength. Athletes are
66 weighed prior to competition, with the time between weigh-in
67 and competition varying (from less than 1 h up to 24 h).^{1,2} To
68 gain a weight advantage over opponents, athletes will often aim
69 to lose substantial weight over the days and weeks leading up to
70 weigh-in, which is colloquially termed “weight cutting”.
71 Following this, athletes aim to rapidly regain some of this weight
72 and arrive at the competition heavier than their allocated weight
73 class. This practice has been observed in many combat sports
74 such as mixed martial arts (MMA), boxing, taekwondo (TKD),
75 karate, wrestling, judo and kickboxing.³⁻⁷

76 There are a large range of methods employed by combat sports
77 athletes to lose weight, though the most common methods are
78 body fluid manipulation and food (calorie) restriction.^{4,8,9} Whilst
79 there is data on the methods and magnitude of weight loss for
80 more traditional combat sports such as boxing, taekwondo,
81 wrestling and judo there is a paucity of comprehensive data for
82 other combat sports including MMA and Muay Thai/kickboxing
83 (MT/K).^{4,6-10} Generally, these sports have a longer period
84 between weigh-in and competition and a greater number of
85 professional divisions, compared with more traditional combat
86 sports. Research indicates that the magnitude of weight loss in
87 MMA may be greater than traditional combat sports.^{6,11}
88 Additionally, there is evidence to suggest that a method of
89 weight loss called “water loading”, where athletes consume large
90 volumes of fluid for several days before beginning severe fluid
91 restriction with the aim of inducing hormonal responses to aid in
92 weight loss is prevalent in combat sports.^{6,9} However, the
93 prevalence of water loading in MMA and MT/K is unclear.

94 Developing a greater understanding of the various weight loss
95 strategies used in combat sports and their prevalence is important
96 as some strategies have been reported to negatively influence
97 exercise performance¹²⁻¹⁵ and provides a potential risk to
98 competitor’s health.^{6,16,17} Therefore, the present study sought to
99 investigate the reported magnitude and strategies of weight loss
100 and regain during competition preparation across different
101 combat sports and sources of influence regarding these practices.
102 The insights gained will have importance to support staff
103 working with athletes in these sports by providing clear evidence
104 for which practices may be being undertaken to achieve
105 substantial weight loss.

106 **METHODS**

107 *Overview*

108 Combat sports athletes who had competed within the previous
109 12 months were recruited to complete an online survey
110 investigating weight loss practices. Athletes were recruited from
111 combat sports gyms, combat sport commissions, regulatory
112 bodies and online forums from around the world. The study was
113 approved by the Human Research Ethics Committee of the host
114 institution in Australia and participants provided informed
115 consent via electronic signature after reading an explanation of
116 the study. A total of 1051 combat sports athletes were initially
117 recruited, participants who did not complete the entire survey
118 (n=353), gave answers in the wrong unit of measurement and did
119 not provide sufficient information to allow for conversion
120 (n=21), competed in divisions with no weight limit (n=6), were
121 not competitively active (n=14) or competing in a combat sport
122 in which there was not enough participants to give the group
123 sufficient statistical power (<30) were excluded from final
124 analysis (n=20). Resulting in a total of 637 combat sports
125 athlete's responses being included in the final analysis. Of these
126 athletes 25% competed in Brazilian Jiu Jitsu (BJJ), 6% in boxing,
127 12% in Judo, 11% in Mixed Martial Arts (MMA), 12% Muay
128 Thai/Kickboxing (MT/K), 6% Taekwondo (TKD) and 27% in
129 wrestling.

130 *Procedures*

131 A previous survey developed and validated in judo by Artioli,
132 Scagliusi, Kashiwagura, Franchini, Gualano, Junior¹⁸ was
133 modified and provided to the participants in a manner similar to
134 previous studies investigating weight loss in multiple combat
135 sports.⁸⁻¹⁰ The survey was modified by replacing the references
136 to judo with generalised language referring to combat sports
137 overall and the levels of competition were changed to reflect the
138 different types of combat sports. Questions referring to weight
139 loss directly before a weigh-in and weight regained before a
140 competition were added to the survey. The survey contained 34
141 questions including personal de-identifying characteristics (age,
142 time competing etc.), competitive level, weight, dietary history
143 and weight loss behaviours (Table 1). The survey was conducted
144 using online questionnaire software (Qualtrics, Qualtrics, USA).

145 *Data analysis*

146 Descriptive statistics (i.e. mean, SD and frequency) were used to
147 display athlete responses to questions. Based on the sample size,
148 data was not assessed for normality prior to analysis. This
149 decision was based on previous research analysing the
150 robustness of analysis of variance (ANOVA) when non-
151 normally distributed data is used, indicating that provided the

152 sample is greater than 25,¹⁹ even in regards to the use of Likert
153 scales²⁰ assessment for normality is not required. One-way
154 independent ANOVA testing was used to examine differences in
155 weight loss and weight loss methods between combat sports
156 prior to competition. The decision to use parametric testing on
157 Likert-type measurements was based on previous research²⁰⁻²².
158 When significant interactions were observed the Tukey-Kramer
159 post-hoc test was conducted to determine where differences
160 occurred, with this test chosen due to the uneven sample sizes.²³
161 Differences in frequencies (i.e competitive level, gender and
162 percentage of participants who have lost weight to compete)
163 were assessed using the Chi-square test followed by the
164 Bonferroni post-hoc correction. Statistical significance was
165 accepted at $P < 0.05$, with all statistical analyses performed using
166 SPSS version 24 (SPAA Inc., Chicago IL, USA).

167

168 **RESULTS**

169 Stature differed significantly ($P<0.001$) between sports and a
170 greater percentage of females competed in TKD than in other
171 combat sports (Table 1). There were significant ($P<0.001$)
172 differences in the average age of athletes between sports with
173 boxing, judo, MMA and MT/K being of similar ages. However,
174 wrestlers were significantly younger than boxing ($P=0.041$),
175 judo ($P<0.001$), MMA ($P<0.001$) and MT/K athletes ($P<0.001$),
176 whilst TKD was significantly younger than judo ($P=0.012$). The
177 BJJ athletes were significantly older than wrestlers ($P<0.001$)
178 TKD ($P<0.001$) and boxers ($P=0.008$) (Table 1). Other
179 significant differences between sports were reported for the age
180 at which athletes began competing ($P<0.001$), the frequency at
181 which they competed ($P<0.001$), and rate of championship
182 competition ($P<0.001$) (Table 1). Interestingly the country of
183 origin most commonly reported by the recruited athletes was the
184 United States of America (USA), Australia (AU) or the United
185 Kingdom (UK).

186 *Insert table 1 about here*

187 The frequency of competition at regional/state and amateur level
188 was similar between combat sports (Table 2). Exposure to
189 national/international competition differed significantly
190 ($P<0.001$) between sports with judo competing at this level more
191 often than BJJ ($P=0.002$), boxing ($P=0.042$), MT/K ($P=0.002$)
192 and wrestling ($P=0.002$), whilst the rate was higher in TKD than
193 BJJ, boxing, MMA, MT/K and wrestling (for all comparisons,
194 $P=0.002$) (Table 2). Amateur level competition differed
195 significantly ($P=0.002$) between sports with more MMA athletes
196 competing at the amateur level than BJJ and wrestling ($P=0.02$
197 and $P=0.002$, respectively). Additionally, more MT/K athletes
198 reported competing at the amateur level than BJJ, judo and
199 wrestling (for all comparisons, $P=0.002$). A smaller percentage
200 of athletes reported competing at the semi-professional level.
201 However, TKD athletes reported a greater percentage than BJJ
202 and wrestling athletes (for both comparisons, $P=0.002$), whilst
203 MMA and MT/K reported a higher percentage than BJJ (for both
204 comparisons, $P=0.02$) and wrestling (for both comparisons,
205 $P=0.02$). Under half of all athletes had competitive experience at
206 the professional level, though higher rates of professional
207 competition were reported in MMA compared with BJJ, boxing,
208 judo, MT/K and wrestling (for all comparisons, $P=0.002$), whilst
209 TKD reported a greater rate than BJJ ($P=0.02$) and wrestling
210 ($P=0.002$) (Table 2).

211 *Insert table 2 about here*

212 The weight of athletes without an upcoming competition differed
213 significantly ($P<0.001$) between sports (Table 3). The weight

214 class in which respondents reported competing in varied
215 significantly ($P<0.001$) between combat sports (Table 3). The
216 majority ($\geq 85\%$) of all groups reported using a weight loss
217 strategy prior to competition. Athletes reported beginning this
218 weight reduction 14 to 28 days prior to weigh-in, except
219 wrestling which reported a significantly shorter time period of 7
220 days when compared with BJJ ($P=0.001$), boxing ($P=0.001$),
221 MMA ($P<0.001$), MT/K ($P=0.002$) and TKD ($P<0.001$) (Table
222 3). A significant interaction ($P<0.001$) was observed between
223 sports for the most amount of weight athletes reported ever
224 losing for a competition ($\sim 9.5\%$ of body mass), with MMA
225 reporting a significantly greater reduction ($>12\%$ body mass)
226 compared with BJJ, MT/K, TKD and wrestling ($P<0.001$,
227 $P=0.002$, $P=0.012$ and $P=0.001$, respectively) (Table 3).
228 Likewise, typical weight lost for a competition was similar
229 across the combat sports ($\sim 6\%$ of body mass), except MMA
230 which reported a significantly greater weight loss of approx.
231 11.5% body mass ($P<0.001$ when compared with BJJ, boxing,
232 Judo, MT/K, TKD, wrestling). Compared with the other combat
233 sports MMA reported losing a greater portion of weight within
234 14 days ($\sim 6.5\%$ of body mass) of weigh-in compared with BJJ
235 ($P<0.001$), judo ($P<0.001$) and MT/K ($P<0.001$). Additionally,
236 MMA reported losing a greater portion of weight within 24 h of
237 weigh-in ($\sim 4\%$ of body mass, respectively) compared with all
238 other combat sports ($P<0.001$), whilst wrestling reported a
239 greater amount compared with BJJ ($P<0.001$) (Table 3). In most
240 combat sports, it was reported that the majority of weight lost in
241 the 24 h before weigh-in was recovered prior to competition and
242 the majority of weight lost was typically regained 7 days
243 following weigh-in (Table 3). The period of time between
244 weigh-in and competition differed significantly ($P<0.001$)
245 between combat sports with MMA, MT/K and TKD all reporting
246 a longer time period when compared with BJJ ($P<0.001$ all
247 comparisons), boxing ($P<0.001$, $P=0.004$ and $P<0.001$,
248 respectively), judo ($P<0.001$, $P=0.041$ and $P=0.004$,
249 respectively) and wrestling ($P<0.001$ all comparisons) (Table 3).

250 *Insert table 3 about here*

251 When examining how athletes ranked the influence of others on
252 their weight loss, training partners, coaches and opponents were
253 commonly ranked in the top 3 influences across all combat sports
254 (Table 4). However, as an exception boxing, MMA and MT/K
255 typically ranked the matchmaker higher in influence whilst
256 parents were ranked higher in TKD and wrestling compared with
257 MT/K and MMA (Table 4).

258 *Insert table 4 about here*

259 Gradual dieting, restricting fluid ingestion and increased
260 exercise were among the most common methods of weight loss

261 in all the combat sports (Table 5). Gradual dieting was less
262 prevalent in wrestling than BJJ and MMA (for both comparisons
263 $P<0.001$), whilst the rate was higher in MMA than judo
264 ($P=0.016$). Restricting fluid intake was less prevalent in BJJ than
265 wrestling ($P=0.001$). Skipping meals was more prevalent in
266 TKD than BJJ ($P=0.018$), boxing ($P=0.001$) and MT/K
267 ($P=0.005$), whilst wrestling had a higher prevalence than BJJ
268 ($P<0.001$), boxing ($P<0.001$), MMA ($P=0.003$) and MT/K
269 ($P<0.001$). Sauna use was prevalent in MMA athletes with over
270 75% of athletes reporting its use, which was significantly greater
271 than BJJ ($P<0.001$) and judo ($P=0.04$). Additionally, wrestling
272 reported a higher use of the sauna than BJJ ($P=0.024$). The use
273 of plastic/rubber suits was significantly higher in MMA than BJJ
274 ($P<0.001$), judo ($P<0.001$) and TKD ($P=0.014$), whilst wrestling
275 was greater than BJJ ($P=0.001$) and MMA ($P=0.024$). Water
276 loading was significantly more prevalent in MMA than BJJ
277 ($P=0.046$), judo ($P=0.031$) and wrestling ($P<0.001$) (Table 5).
278 Forced oral fluid loss or “spitting” was of low prevalence
279 ($\leq 30\%$) in all combat sports except wrestling which reported a
280 greater prevalence than BJJ ($P<0.001$), boxing ($P=0.001$), judo
281 ($P<0.001$), MMA ($P=0.045$) and MT/K ($P<0.001$) (Table 5).
282 The use of laxatives, diuretics, diet pills and vomiting were of
283 low prevalence in all combat sports and no significant main
284 effects were observed (Table 5).

285 *Insert table 5 about here*

286 **DISCUSSION**

287 The present study sought to investigate the strategies used for
288 and the magnitude of weight loss prior to competition across
289 different combat sports. The main observations were that: i)
290 manipulation of body mass for competitions was reported in all
291 combat sports, ii) whilst all combat sports engaged in weight loss
292 prior to competition, MMA athletes lost a significantly greater
293 magnitude of weight overall, within two weeks and 24 h of
294 weigh-in, iii) increased exercise and fluid manipulation were the
295 most common methods of weight loss in combat sports,
296 particularly MMA. This work substantially increases the
297 understanding and prevalence of the various weight loss
298 strategies used by combat sports athletes and particularly the
299 novel aspects as they pertain to MMA

300 Athletes from all sports except TKD were predominantly males
301 under the age of 30 y who had competed at a state and/or
302 international level which is similar to previous studies of combat
303 sports athletes.^{8,9} Over 85% of athletes in each combat sport
304 examined, reported manipulating their body mass to make
305 weight for competition. The magnitude of reported weight loss
306 for a competition ranged from 4-12% of body mass overall,
307 which included, 3.5-7% of body mass within two weeks of
308 weigh-in and 1.5-4% of body mass within 24 h of weigh-in.
309 Interestingly, the amount of body mass loss reported as real-
310 world practice suggests that communication of well controlled
311 scientific research is not impacting on the applied practice. As
312 well controlled studies of acute loss of body mass (<5% body
313 mass) in combat athletes have observed detrimental effects on
314 performance in aerobic, anaerobic and strength-power
315 tasks,^{6,12,17} or at least no increase in competitive success.^{24,25} We
316 also provide further evidence that weight loss practices in MMA
317 may be more extreme than other combat sports⁶ with MMA
318 reporting significantly greater weight loss than other combat
319 sports within two weeks and 24 h of weighing-in (Table 3). The
320 greater magnitude of weight loss in MMA may be explained by
321 the longer period allowed between weigh-in and competition
322 which may encourage the athletes to attempt to lose more
323 weight. However, MMA also lost greater weight prior to
324 competition when compared with MT/K or TKD, despite no
325 differences in time between the weigh-in and competition, which
326 would contradict this explanation (Table 3). Alternatively, the
327 larger magnitude of weight loss in MMA could be related to
328 more athletes reporting to compete at the professional level
329 however, this is not entirely supported by the data as a similar
330 percentage of TKD athletes also reported competing at the
331 professional level and the magnitude of weight loss in TKD was
332 similar to other combat sports assessed (Table 2 and 3).
333 Interestingly, most athletes reported that the weight lost within
334 24 h of competition was typically regained prior to competition.

335 These findings conflict with previous research indicating that
336 even when provided with 24 h of *ad libitum* fluid/food intake
337 athletes may not be adequately rehydrating.^{2,12} Clearly, further
338 research is needed to assess the recovery strategies and their
339 efficacy in combat sports following weigh-ins.

340 In the present study, a wide range of weight loss techniques were
341 reported and several differences were observed between combat
342 sports. Gradual dieting, restricting fluid ingestion and increased
343 exercise were commonplace in all combat sports examined
344 (Table 5). These results support previous research investigating
345 weight loss in combat sports such as wrestling, boxing, judo,
346 taekwondo and jujitsu.^{4,7-9,26} Skipping meals was especially high
347 in TKD and wrestling (84%) while training in heated rooms and
348 spitting was higher in wrestling alone (Table 5). The high
349 prevalence of skipping meals and spitting in wrestling could be
350 due to the increased frequency of competitions (Table 1). Indeed,
351 skipping meals would provide short term reductions in body
352 weight due to the reduced weight of food within the
353 gastrointestinal tract, as well as longer-term weight loss due to
354 the likelihood of calorie restriction if used frequently. The high
355 prevalence of spitting and fluid restriction may also be used in
356 combat sports with regular competition in order to induce
357 dehydration without the physiological strain possibly caused by
358 thermal stress and/or increased exercise.²⁷ The prevalence of
359 water loading was over 60% in MMA, MT/K and boxing, which
360 is higher than previously reported (~20%) in Australian boxers.⁹
361 MMA athletes also reported higher usage of thermal stress
362 weight loss techniques (sauna and training in rubber/plastic
363 suits) compared with other combat sports (Table 5). The high use
364 of these weight loss methods, along with the greater magnitude
365 of reported weight loss in MMA athletes highlights a concerning
366 weight loss culture in MMA. Across all combat sports
367 individuals with the most influence on weight loss habits were a
368 training partner, coach or their opponent, indicating that weight
369 loss culture differences between sports are not the result of sport
370 specific individuals having a greater influence on the athlete
371 (Table 4). These results indicate the individuals and groups most
372 important to target for education on the positive and negative
373 effects of various weight loss practices. However, it is also
374 important to note that since competitive level, stature, body mass
375 and gender distribution differ across each of the groups in the
376 present study, caution should be taken when directly comparing
377 combat sports. Instead, the results of the present study provide a
378 descriptive analysis which improves our understanding of the
379 reported weight loss practices currently used within combat
380 sports and individuals perceived to influence such strategies.

381 Research has indicated that some of the aggressive weight loss
382 habits observed in this study may negatively influence exercise
383 performance over shorter recover periods (~3 h) and even up to

384 24 h.^{12-14,27-30} However, the effects of such weight loss on both
385 short-term and long-term health requires further research. It is
386 possible that the high magnitudes of weight loss could result in
387 a number of health complications including cardiovascular
388 problems and increased insulin sensitivity,¹⁷ alongside an
389 increased risk of brain damage during competition.^{6,31,32} As such,
390 there have been calls to ban the practice of weight cutting³³
391 however, this is not likely to occur and the effectiveness of such
392 a ban would be questionable. Furthermore, while it is plausible
393 that the aggressive weight loss magnitude and strategies
394 observed in this study may cause risk to the athletes and impair
395 performance^{6,12,17} there is a paucity of systematic supporting
396 evidence. Clearly further research is needed in this area.
397 Regardless, the results of this study are important as they allow
398 for a greater understanding of the reported weight loss practices
399 currently used within combat sports and individuals perceived to
400 influence such strategies. Such information will aid in better
401 informing strategies aimed at maximising athlete safety and
402 performance, as well as, informing research methodology aimed
403 at examining the effects of such weight loss on performance and
404 health.

405

406 *Practical applications*

407 The present study provides comprehensive data on the weight
408 loss strategies employed in different combat sports. Whilst this
409 relies on self-reported data, a sufficiently large total athlete
410 sample was recruited and a highly validated combat sports
411 survey was used in an attempt to mitigate this confounder. A
412 wide range of weight loss methods were used throughout the
413 combat sports assessed but the especially high magnitude of
414 weight lost and the high prevalence of methods such as water
415 loading, using a sauna and using rubber/plastic suits in MMA
416 outlines a concerning weight loss culture in MMA.
417 Understanding the strategies in different combat sports will
418 allow more accurate best practice guidelines to be developed for
419 each combat sport and improve regulations which attempt to
420 reduce the negative influences of weight cutting. Alongside
421 providing useful information for regulatory bodies the
422 information in this study is also useful for coaches and
423 competitors to better understand their practices in the context of
424 other competitors and other combat sports.

425

426 *Conclusions*

427 Manipulating body mass to be within a prescribed limit is
428 commonplace in most combat sports, ranging from striking to
429 grappling or mixed style sports. Athletes will commonly use
430 several strategies that serve as a risk to their personal wellbeing
431 and a potential catalyst for impaired performance. Whilst
432 similarities exist between combat sports, the results of this study
433 indicate important differences regarding the magnitude of
434 weight loss and strategies used. In particular, a greater
435 magnitude of weight lost and prevalence of acute dehydration
436 strategies was observed in MMA which was a novel finding of
437 this study. Better understanding these practices is essential for
438 developing meaningful regulations regarding weight loss in
439 combat sports and informing coaches and competitors to make
440 informed decisions for an athlete's future and competitive
441 success.

442

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Table 1. Descriptive statistics of athlete details and competitive history in the combat sports of Brazilian jiu jitsu (BJJ), boxing, judo, mixed martial arts (MMA), muay Thai/kickboxing (MT/K), taekwondo (TKD) and wrestling

	BJJ	Boxing	Judo	MMA	MT/K	TKD	Wrestling
Age	29±7 ^{b,f,g}	25±6 ^{a,g}	28±8 ^{f,g}	27±6 ^g	27±6 ^g	23±6 ^{a,c}	21±7 ^{a,b,c,d,e}
Height	1.77±0.09 ^f	1.79±0.09 ^f	1.77±0.08 ^f	1.78±0.09 ^f	1.78±0.1 ^f	1.71±0.11 ^{a,b,c,d,e}	1.75±0.09
Sex (% Male)	90% ^{f,g}	85% ^{f,g}	89% ^{f,g}	96% ^f	95% ^f	44% ^{a,b,c,d,e,g}	98% ^{a,b,c,f}
Age began competing	22±7 ^{c,d,f,g}	20±6 ^{c,f,g}	14±8 ^{a,b,d,e}	17±5 ^{a,c,e,f,g}	21±5 ^{c,d,f,g}	13±6 ^{a,b,d,e}	13±3 ^{a,b,d,e}
Times competed over past 12 months	3±3 ^g	4±4 ^g	5±8 ^g	2±2 ^g	2±3 ^g	5±5 ^g	17±18 ^{a,b,c,d,e,f}
Times competed for championship over past 12 months	1±1.6 ^{f,g}	0.8±1.2 ^f	1.9±2.4	0.4±0.7 ^{f,g}	0.4±1.2 ^{f,g}	3±3.7 ^{a,b,d,e}	2.2±4.7 ^{a,d,e}
Times lost weight for a competition over past 2 years	3±3 ^g	6±60 ^g	5±5 ^g	4±2 ^g	3±4 ^g	7±5 ^g	16±18 ^{a,b,c,d,e,f}
Athletes who changed weight class over past 2 years (% yes)	52%	47%	38% ^g	45%	54%	63%	67% ^c
3 most frequently occurring country of birth	USA(50%) AU(17%) CA(10%)	USA(28%) AU(21%) CA,UK(15%)	AU(38%) USA(26%) UK(8%)	USA(36%) UK(8%) AU(7%)	USA(36%) AU(17%) CA(15%)	AU(76%) USA(12%) NZ(5%)	USA(86%) UK(6%) CA(5%)

^a = $P < 0.05$ when compared with BJJ. ^b = $P < 0.05$ when compared with Boxing. ^c = $P < 0.05$ when compared with Judo.

^d = $P < 0.05$ when compared with MMA. ^e = $P < 0.05$ when compared with muay Thai/ Kickboxing. ^f = $P < 0.05$ when compared with Taekwondo. ^g = $P < 0.05$ when compared with Wrestling

N/A = Not applicable as no main effects were observed

Table 2. Level of competitive experience of combat sport athletes competing in Brazilian jiu jitsu (BJJ), boxing, judo, mixed martial arts (MMA), muay Thai/kickboxing (MT/K), taekwondo (TKD) and wrestling

Level of competition	BJJ	Boxing	Judo	MMA	MT/K	TKD	Wrestling
Regional/State	81% ^e	76%	89% ^e	80%	60% ^{a,c,f,g}	97% ^e	92% ^e
National/International	47% ^{c,f,g}	41% ^{c,f}	72% ^{a,b,e,g}	51% ^f	28% ^{c,f}	90% ^{a,b,d,e,g}	39% ^{a,c,f}
Amateur	74% ^{d,e}	95% ^g	82% ^e	93% ^{a,g}	99% ^{a,c,g}	85%	68% ^{b,d,e}
Semi-Professional	15% ^{d,e,f}	19%	25%	34% ^{a,g}	35% ^{a,g}	41% ^{a,g}	13% ^{d,e,f}
Professional	10% ^{d,f}	5% ^d	10% ^d	38% ^{a,b,c,e,g}	12% ^d	31% ^{a,g}	5% ^{d,f}

^a = $P < 0.05$ when compared with BJJ. ^b = $P < 0.05$ when compared with Boxing. ^c = $P < 0.05$ when compared with Judo.

^d = $P < 0.05$ when compared with MMA. ^e = $P < 0.05$ when compared with muay Thai/ Kickboxing. ^f = $P < 0.05$ when compared with Taekwondo. ^g = $P < 0.05$ when compared with Wrestling

N/A = Not applicable as no main effects were observed

Table 3. Weight loss history and magnitude of weight loss in the combat sports of Brazilian jiu jitsu (BJJ), boxing, judo, mixed martial arts (MMA), muay Thai/kickboxing (MT/K), taekwondo (TKD) and wrestling

	BJJ	Boxing	Judo	MMA	MT/K	TKD	Wrestling
Weight without a competition coming up (kg)	80.9±19.3 ^{f,g}	77.5±13.9 ^f	81.2±13.1 ^{f,g}	82.8±12.6 ^{f,g}	75.2±13.7 ^f	65.3±13 ^{a,b,c,d,e,g}	74.3±13.9 ^{a,c,d,f}
Current weight class (kg)	76.6±13.9 ^{e,f,g}	71.6±10.6 ^f	80.2±14 ^{d,e,f,g}	71.5±14.6 ^{c,f}	70.6±12 ^{a,c,f}	61.6±13.2 ^{a,b,c,e,g}	69.9±13.4 ^{a,c,f}
Participants that have lost weight to compete (% yes)	88%	93%	86%	95%	94%	85%	97%
Most amount of weight lost for a competition (kg)	6.7±4.6 ^d	8.5±4.8	8.1±8.2	10.4±4.2 ^{a,e,f,g}	6.9±3.5 ^d	6.5±3.3 ^d	7.1±4.2 ^d
How much weight usually lost for a competition (kg)	4.2±2.6 ^d	5.3±2.9 ^d	3.8±2.1 ^d	9.8±7.9 ^{a,b,c,e,f,g}	5.9±3.5 ^d	4±3 ^d	4.4±3.7 ^d
How many days weight is usually lost over	18±19 ^g	26±26 ^g	14±16 ^g	27±24 ^g	21±20 ^g	28±48 ^g	7±9 ^{a,b,c,d,e,f,g}
Weight typically lost within 2 weeks of weigh-in	3.1±2.3 ^d	3.7±2.7	2.4±2.1 ^d	5.6±3.1 ^{a,c,e,f,g}	2.6±1.7 ^d	3.4±3.2 ^d	3.4±3.2 ^d
Weight typically lost within 24 h of weigh-in	1.4±1.4 ^{d,g}	1.8±2.1 ^d	1.5±1.1 ^d	3.4±1.9 ^{a,b,c,e,f,g}	2±1.2 ^d	1.6±1.4 ^d	2.3±1.5 ^{a,d}
Weight typically regained between weigh-in and competition	1.3±1.4 ^{d,e,g}	2±2.2 ^d	2±1.3 ^{d,e}	5.3±2.9 ^{a,b,c,e,f,g}	3.5±3.7 ^{a,c,d,g}	2.2±1.3 ^d	2.2±1.4 ^{a,e,d}
Time between weigh-in and competition (h)	6±8 ^{d,e,f}	7±7 ^{d,e,f}	11±8 ^{d,e,f}	24±11 ^{a,b,c,g}	18±9 ^{a,b,c,g}	19±5 ^{a,b,c,g}	7±15 ^{d,e,f}
Weight regained 7 days following competition	3.2±2.3 ^{d,e,g}	4±2.5 ^d	3.1±2 ^d	7.8±3.7 ^{a,b,c,e,f,g}	4.6±3 ^{a,d}	3.6±3 ^d	4.4±2.4 ^{a,d}

^a = $P < 0.05$ when compared with BJJ. ^b = $P < 0.05$ when compared with Boxing. ^c = $P < 0.05$ when compared with Judo.

^d = $P < 0.05$ when compared with MMA. ^e = $P < 0.05$ when compared with muay Thai/ Kickboxing. ^f = $P < 0.05$ when compared with Taekwondo. ^g = $P < 0.05$ when compared with Wrestling

N/A = Not applicable as no main effects were observed

Table 4. Ranking of the influence each individual had on weight loss practices followed by athletes competing in Brazilian jiu jitsu (BJJ), boxing, judo, mixed martial arts (MMA), muay Thai/kickboxing (MT/K), taekwondo (TKD) and wrestling

Individual	BJJ	Boxing	Judo	MMA	MT/K	TKD	Wrestling	Average over all sports
Training partner	2 (41%)	2 (36%)	2 (41%)	2 (33%)	2 (36%)	1 (36%)	2 (39%)	2±1
	1 (36%)	4 (27%)	1 (23%)	4 (30%)	1 (20%)	3 (32%)	1 (25%)	
	3 (13%)	1,3 (14%)	3 (20%)	1,3 (17%)	3 (20%)	2,5,6 (8%)	3 (24%)	
Coach	2 (35%)	1 (59%)	1 (43%)	1 (46%)	1 (56%)	2 (52%)	1 (47%)	2±1
	1 (25%)	2 (27%)	2 (27%)	2 (28%)	2 (31%)	1 (36%)	2 (28%)	
	3 (24%) ^e	3 (14%)	3 (20%)	3 (11%)	3,4 (7%) ^a	4 (8%)	3 (18%)	
Opponent	1 (31%)	3 (32%)	3 (25%)	1 (22%)	4 (22%)	3 (32%)	3 (28%)	3±2
	3 (31%)	1 (23%)	1 (23%)	6 (20%)	3 (18%)	2 (16%)	1 (23%)	
	2,4 (9%)	5 (14%)	2 (20%)	3 (17%)	2 (13%)	1,8 (12%)	2 (18%)	
Parents	4 (28%)	8 (45%)	8 (36%)	8 (48%)	8 (49%)	4 (20%)	4 (29%)	6±2
	8 (27%)	7 (14%)	4 (30%)	7 (24%)	7 (20%)	5 (16%)	8 (17%)	
	5 (17%)	4 (14%)	4 (9%) ^d	6 (11%) ^{c,f,g}	4 (18%) ^{f,g}	6,8 (16%) ^{d,e}	3 (13%) ^{d,e}	
Physician/Doctor (N/A)	5 (29%)	6 (32%)	5 (27%)	7 (41%)	7 (29%)	5 (32%)	5 (33%)	6±1
	7 (27%)	7 (32%)	7 (27%)	5 (20%)	5 (22%)	7 (20%)	6 (24%)	
	6 (18%)	8 (18%)	6 (18%)	8 (15%)	6 (20%)	6 (16%)	8 (17%)	
Dietician	6 (37%)	6 (32%)	6 (32%)	6 (30%)	6 (44%)	7 (32%)	6 (31%)	6±2
	7 (19%)	7 (23%)	5 (16%)	4 (15%)	5 (22%)	5 (20%)	7 (31%)	
	5 (17%) ^d	8 (23%) ^d	7,8 (14%)	2 (13%) ^{a,b,f,g}	7 (11%)	6,8 (16%) ^d	8 (15%) ^d	
Physical trainer (N/A)	7 (21%)	3 (32%)	7 (30%)	5 (33%)	3 (24%)	4 (28%)	5 (25%)	5±2
	5 (20%)	5 (27%)	6 (23%)	3 (20%)	5 (24%)	7 (20%)	7 (22%)	
	6 (17%)	7 (14%)	4 (18%)	4,5 (15%)	6 (18%)	2,3 (16%)	4 (19%)	
Matchmaker	8 (41%)	4 (32%)	8 (32%)	5 (22%)	3 (22%)	8 (36%)	8 (40%)	6±2
	7 (15%)	5 (23%)	7 (23%)	3 (15%)	7 (16%)	6 (24%)	4 (16%)	
	4 (14%) ^{b,d,e}	2 (18%) ^{a,c,f,g}	6 (16%) ^{b,d,e}	8 (15%) ^{a,c,f,g}	8 (16%) ^{a,c,f,g}	7 (20%) ^{b,c,d,e}	7 (13%) ^{b,d,e}	

Data shows the 3 most frequently occurring ranks chosen by athletes and is displayed as percentage of athletes in group who chose the rank.

^a = $P < 0.05$ when compared with BJJ. ^b = $P < 0.05$ when compared with Boxing. ^c = $P < 0.05$ when compared with Judo. ^d = $P < 0.05$ when compared with MMA.

^e = $P < 0.05$ when compared with muay Thai/ Kickboxing. ^f = $P < 0.05$ when compared with Taekwondo. ^g = $P < 0.05$ when compared with Wrestling

N/A = Not applicable as no main effects were observed

Table 5. Prevalence of weight loss practices in the combat sports of Brazilian jiu jitsu (BJJ), boxing, judo, mixed martial arts (MMA), muay Thai/kickboxing (MT/K), taekwondo (TKD) and wrestling

Individual	BJJ	Boxing	Judo	MMA	MT/K	TKD	Wrestling	All sports
Gradual dieting	92% ^g	86%	66% ^d	93% ^{c,g}	87%	92%	67% ^{a,d}	83%
Skipping 1 or 2 meals	53% ^{f,g}	36% ^{f,g}	66%	57% ^g	49% ^{f,g}	84% ^{a,b,e}	84% ^{a,b,d,e}	61%
Fasting (not eating all day)	33% ^{f,g}	36%	54%	48%	44%	68% ^a	57% ^a	49%
Restricting fluid ingestion	68% ^g	68%	84%	76%	76%	84%	94% ^a	79%
Increased exercise	86%	86%	82%	78%	82%	88%	95%	85%
Training in heated rooms	38% ^{d,g}	45% ^g	43% ^g	63% ^a	44% ^g	40% ^g	83% ^{a,b,c,e,f}	51%
Sauna	36% ^{d,g}	50%	43% ^d	76% ^{a,c}	51%	48%	50% ^a	51%
Training in rubber/plastic suits	16% ^{d,g}	50%	23% ^d	63% ^{a,c,f,g}	40%	28% ^d	83% ^{a,d}	43%
Use winter or plastic suits for the whole day (without exercising)	6% ^{d,g}	18%	7%	20% ^a	4%	8%	17% ^a	11%
Spitting	4% ^g	23% ^g	18% ^g	30% ^g	20% ^g	20%	47% ^{a,b,c,d,e}	23%
Laxatives (N/A)	9%	9%	9%	0%	9%	16%	12%	9%
Diuretics (N/A)	8%	9%	5%	7%	9%	12%	12%	9%
Diet Pills (N/A)	1%	5%	2%	7%	7%	8%	6%	5%
Vomiting (N/A)	1%	0%	5%	2%	0%	4%	5%	2%
Excessive fluid consumption (water loading)	50% ^d	64%	41% ^d	67% ^{a,c,g}	62%	48%	37% ^d	53%

Data is presented as percentage of athletes that selected always or sometimes

^a = $P < 0.05$ when compared with BJJ. ^b = $P < 0.05$ when compared with Boxing. ^c = $P < 0.05$ when compared with Judo. ^d = $P < 0.05$ when compared with MMA.

^e = $P < 0.05$ when compared with muay Thai/ Kickboxing. ^f = $P < 0.05$ when compared with Taekwondo. ^g = $P < 0.05$ when compared with Wrestling

N/A = Not applicable as no main effects were observed