

1 **A survey of combat athletes' rapid weight loss practices and evaluation of the**
2 **relationship with concussion symptom recall**

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43 **Abstract**

44 **Objective** – There is a high incidence of concussion and frequent utilization of Rapid Weight Loss
45 (RWL) methods among combat sport athletes, yet the apparent similarity in symptoms experienced as
46 a result of a concussion or RWL has not been investigated. This study surveyed combat sports athletes
47 to investigate the differences in symptom-onset and recovery between combat sports and evaluated the
48 relationships between concussion and RWL symptoms.

49 **Design** – Cross-Sectional Study

50 **Setting** – Data were collected via an online survey.

51 **Participants** – 132 (male 115, female 17) combat sport athletes.

52 **Interventions** – Modified Sport Concussion Assessment Tool (SCAT) symptom checklist and weight-
53 cutting questionnaire.

54 **Main Outcome Measures** – Survey items included combat sport discipline, weight loss, and medical
55 history, weight-cutting questionnaire, and concussion & weight-cutting symptom checklists.

56 **Results** – Strong associations ($r_s = 0.6 - 0.7, p < 0.05$) were observed between concussion and RWL
57 symptoms. The most frequently reported symptom resolution times were 24 - 48 h for a weight-cut
58 (WC; 59%) and 3 - 5 days for a concussion (43%), with 60 - 70% of athletes reporting a deterioration
59 and lengthening of concussion symptoms when undergoing a WC. The majority of athletes (65%) also
60 reported at least one WC in their career to '*not go according to plan*', resulting in a lack of energy
61 (83%) and strength/power (70%).

62 **Conclusions** – RWL and concussion symptoms are strongly associated, with the majority of athletes
63 reporting a deterioration of concussion symptoms during a WC. The results indicate that concussion
64 symptoms should be monitored alongside hydration status to avoid any compound effects of prior RWL
65 on the interpretation of concussion assessments and to avoid potential misdiagnoses among combat
66 athletes.

67 **Keywords:** Traumatic brain injury; martial arts; boxing; wrestling; dehydration

68 **Introduction**

69 Concussions are mild traumatic brain injuries, generally experienced in sport from direct or indirect
70 contact to the head, leading to linear and rotational acceleration of the brain (1). Concussions occur
71 commonly in combat sports, such as Mixed Martial Arts (MMA), boxing, and kickboxing/Muay-Thai
72 (KB/MT) due to head impacts in training and competition (2). Within boxing and MMA, concussion
73 rates range between 16 and 25 per 100 athletic exposures (2, 3, 4), but this may be underestimated due
74 to the absence of medical personnel in a large proportion of training time. With evidence of both short-
75 and long-term health consequences as a result of repetitive head trauma (5, 6, 7), there is an emerging
76 concern for the welfare of combat sport athletes. Therefore, determining the factors that contribute to
77 concussion risk has become a priority.

78 Combat sports are categorized by weight divisions to ensure fair bouts between opponents and reducing
79 potential injuries that might occur as a result of major weight differences (8). Typically, athletes aim to
80 lose body mass (via water) in the shortest time possible, utilizing rapid weight loss (RWL) methods to
81 obtain a perceived advantage of competing against a lighter, or weaker opponent (9). Common forms
82 of RWL are fluid restriction, dehydration by sweating, diuretics, laxatives, and ‘water-loading’ – a
83 method by which large volumes of fluid are consumed to manipulate renal hormones (e.g., aldosterone)
84 and urine output, resulting in further weight loss (10, 11). These strategies can lead to hypo-hydration
85 and, subsequently, alterations to renal function (12), immunoendocrine status (13), brain ventricular
86 volume, and metabolic activity (14).

87 Both cellular dehydration, induced by hypo-hydration or ‘water-cutting’, and concussive events have
88 been reported to impair central nervous system function (1, 14). While the mechanistic basis of these
89 effects is currently uncertain and meaningful links are unestablished, disruption of fluid or ion
90 homeostasis have been commonly reported among hypo-hydrated subjects and those experiencing
91 concussions (14, 15). Hypo-hydration is also reported to lead to cognitive and neuromuscular deficits
92 (16, 17), which could theoretically lead to reduced performance and a heightened risk of concussion.
93 Patel et al. (18) investigated the symptomology of hypo-hydrated, non-concussed subjects, and found
94 an increase in concussion-related symptoms, indicating that hypo-hydration and concussion may elicit

95 similar effects. Indeed, any synergistic effects caused by hypo-hydration or concussive events could
96 exacerbate the reported symptoms. Whether such physiological and physical alterations lead to combat
97 athletes competing or training with a higher risk (or perceived risk) of brain trauma is unknown, though
98 this has been anecdotally reported by mainstream media outlets (19). It is also unclear if certain combat
99 sports place athletes at greater risk, particularly among striking-dominant disciplines or those with
100 stringent weight classifications. Likewise, the clear overlap in the symptoms associated with hypo-
101 hydration and concussion is problematic because diagnostic criteria for both conditions, and apparent
102 severity thereof, are heavily dependent on subjective scoring processes. This increases the risk of
103 concussion misdiagnosis around competition and could jeopardise athlete welfare.

104 Studies investigating concussion symptoms, in isolation, have frequently reported neck pain, fatigue or
105 low energy, trouble falling asleep, and headaches (20), with 60% of MMA athletes returning to sparring
106 within two days or less of their first symptom (21). Symptoms pertaining to heat stress and hypo-
107 hydration are also reported to include headaches, dizziness, and increased perception of fatigue (18,22).
108 Despite the incidence of concussions and abundant use of RWL among combat athletes (10, 23), to
109 date, there has been no study of both self-reported concussion and RWL symptoms in combat athletes
110 or evaluation of their inter-relationships. Therefore, the aims of this survey were to; i) investigate the
111 differences in RWL and concussion symptom-onset and recovery between combat sports and ii)
112 evaluate the relationships between concussion and RWL symptoms among combat athletes who have
113 previously suffered from a concussion and undergone RWL prior to competition.

114

115 **Methods**

116 *Participants*

117 Following institutional ethical approval, participants were recruited via websites and social media, with
118 informed consent obtained in accordance with the Declaration of Helsinki (2013). Participants were
119 required to be over the age of 18 years, competed (at least once) in a combat sport, and had 'cut weight'
120 prior to a competition. A 'weight-cut' (WC) was defined as any method leading to the loss of water,

121 including but not limited to sauna, fluid restriction, diuretics, sweating gels, hot water baths, laxatives,
122 fat burners, vomiting, and ‘water-loading’. A total sample size of 132 (115 male, 17 female) combat
123 athletes (age: 29 ± 8 years, body mass: 77.0 ± 12.9 kg, training experience: 13 ± 6 years) completed the
124 survey. Sporting modalities reported were MMA (31%), KB/MT (20%), boxing (22%), wrestling (5%),
125 Brazilian Jiu-Jitsu (BJJ; 10%), judo (8%) and ‘others’ (6%). Of the total sample, 70% of athletes were
126 actively competitive, with 50% of male athletes and 29% of female athletes competing professionally.

127 *The Survey*

128 The survey combined two validated questionnaires: the Mixed Martial Arts Weight-Cutting
129 Questionnaire (MAWC-Q; 24) and the Sport Concussion Assessment Tool 5 (SCAT-5; 25). Participants
130 were asked preliminary questions regarding demographic, sporting, and medical history, after which
131 the questionnaire was split into three sections, which aimed to address 1) WC practices, 2) WC
132 symptoms, and 3) concussion history and symptoms.

133 The survey was piloted through completion by 15 combat athletes, a wrestling coach, and two experts
134 (current researcher in the field of nutrition and a ringside medic). Written feedback was provided on the
135 suitability and clarity of questions and amendments were made before the finalized version was released
136 online (Joint Information Systems Committee Online surveys).

137 *MAWC-Q*

138 The MAWC-Q consisted of 26 questions, aiming to establish the prevalence and magnitude of RWL
139 methods, specifically amongst MMA athletes. Modifications were made to the MAWC-Q, as follows:
140 a) re-phrasing of questions to ensure appropriateness to all combat athletes, b) omission of questions
141 regarding age of first WC, specific method of weight loss and symptoms, c) addition of questions related
142 to cumulative number of WCs and time in between a WC, and d) the addition of a question, asking if a
143 WC had ‘*not gone according to plan*’ and a series of resultant scenarios. This was to establish the
144 frequency and experiences of worst-case scenarios in weight-cutting practices.

145 *SCAT-5*

146 Symptom profiles for concussion and WCs were assessed using a 22-point symptom checklist from the
147 SCAT-5. Each symptom was assessed using a Likert scale of severity, ranging from 0 (none) to 6
148 (severe +), however modifications were made to the checklist through the addition of two physical
149 symptoms ‘*physically weak*’ and ‘*unable to train*’. This resulted in a ‘symptom score’ of 24 (sum of
150 each selected symptom) and a ‘symptom severity’ of 144 (sum of all Likert scale selections). Thereafter,
151 participants answered six additional ‘Yes or No’ questions (Table 2, Figure 4) related to the relationship
152 between symptom recovery, fluid consumption, and head impacts. The sum of the symptom score and
153 six additional questions led to a third measure: an ‘adjusted symptom score’ of 57.

154 *Statistical Analysis*

155 Statistical analyses were completed using SPSS (v22, IBM Corp., Armonk, NY). Data were presented
156 as means \pm standard deviations (SD), frequency of responses to each item (n), range (where
157 appropriate), or median and interquartile range (IQR) if non-normally distributed. Assumptions of
158 normality and equality of variance were assessed via Shapiro–Wilk and Levene’s tests, respectively.
159 For parametric (WC symptom variables) data, a one-way analysis of variance (ANOVA) was used to
160 assess the difference between each sport (MMA, Boxing, KB/MT, Judo, Wrestling, & BJJ). For non-
161 parametric data, a Kruskal-Wallis test was used to establish differences in concussion symptom
162 variables between each sport. Where there was a significant main effect, pairwise comparisons were
163 examined by a Tukey (parametric) or Dunn-Bonferroni *post-hoc* (non-parametric) to account for the
164 homogeneity of variance. A Spearman’s Rho correlation was used to assess the relationship between
165 concussion and WC symptom variables (symptom severity, symptom score, adjusted symptom score).
166 An alpha level of ≤ 0.05 was set for all analyses.

167

168 **Results**

169 *Modified MAWC-Q*

170 The majority of athletes (83%) reported using a fight preparation camp, with the highest reported WCs
171 being 10 kg (10 days), 8.6 kg (7 days), 7 kg (3 days), and 5 kg (24 h). Median WC was 6.6% of body

172 mass (Table 1A). Most athletes (65%) reported a WC to ‘*not going according to plan*’, with the most
173 frequent consequences being a lack of energy (83%), lack of strength/power (70%), and suboptimal
174 coordination and reaction time (55%) (Table 1B). Responses included in the ‘other’ section were:
175 ‘*collapsed*’ & ‘*cramping*’ ($n = 2$), and ‘*coughing blood and unable to function*’, ‘*projectile vomiting*’,
176 ‘*was asked to keep weight off for an extra 36 hours*’, ‘*felt cold and lips became blue during fight*’,
177 ‘*menopause*’, ‘*fluid ascites*’, and ‘*process was more grueling due to period making me retain more*
178 *water*’ ($n = 1$).

179

180 *****Insert Table 1A & 1B here*****

181

182 *WC and concussion symptom profiles*

183 There was a significant relationship between WC and concussion symptom severity ($r_s = 0.68$, 95%
184 CI [0.54, 0.74], $p < 0.001$), symptom scores ($r_s = 0.60$, 95% CI [0.44, 0.72], $p < 0.001$) and adjusted
185 symptom scores ($r_s = 0.72$, 95% CI [0.59, 0.81], $p < 0.001$) (Figure 1).

186

187 *****Insert Figure 1 here*****

188

189 Mean scores for WC symptom severity, symptom score, and adjusted score were 49 ± 30 out of 144,
190 15 ± 7 out of 24, and 19 ± 9 out of 57, respectively. A significant main effect was observed in WC
191 symptom severity ($F_{(5, 118)} = 5.464$, $p < 0.001$), with differences between MMA and KB/MT (59.2 vs.
192 36.5, $p = 0.01$), MMA and boxing (59.2 vs. 38.0, $p = 0.02$), judo and KB/MT (67.5 vs. 36.5, $p = 0.02$),
193 judo and boxing (67.5 vs. 38.0, $p = 0.03$), judo and BJJ (67.5 vs. 31.9, $p = 0.04$). A significant main
194 effect was also observed in adjusted symptom scores ($F_{(5, 118)} = 3.213$, $p = 0.009$), with a difference
195 between MMA and KB/MT (22.0 vs. 15.6, $p = 0.03$) (Figure 2A & B).

196

197 Median (IQR) scores for concussion symptom severity, symptom score, and adjusted score were 48
198 (57) out of 144, 18 (14) out of 24 and 26 (19) out 57, respectively. A significant main effect was

199 observed in concussion symptom severity ($X^2_{(5)} = 14.142, p = 0.015$), with a difference between MMA
200 and boxing (56.0 vs. 31.9, $p = 0.023$). A main effect was also observed in adjusted symptom scores
201 ($X^2_{(5)} = 13.348, p = 0.02$), with pairwise comparisons showing a significant difference between MMA
202 and boxing (55.5 vs. 32.8, $p = 0.04$) (Figure 2C & D).

203

204 *****Insert Figure 2 here*****

205

206 Of the 132 combat athletes who completed the survey, approximately two-thirds (64%) reported
207 sustaining at least one concussion during their professional career, but only 45% were hospitalized or
208 underwent imaging and 34% were medically diagnosed. The median (IQR) reported time before
209 returning to training after a concussion, was 7 (12) days.

210

211 *****Insert Figure 3 here*****

212

213 The majority of athletes (70%) reported deterioration of concussion symptoms during and after a fight
214 or sparring session, while 37% reported deterioration of WC symptoms. A summary of symptom
215 recovery responses can be found in Table 2.

216

217 *****Insert Figure 4 here*****

218 *****Insert Table 2 here*****

219

220

221 **Discussion**

222 This study surveyed combat sports athletes to investigate the differences in symptom-onset and
223 recovery between combat sports, and evaluated the relationships between concussion and RWL
224 symptoms. There were strong associations between concussion and RWL symptom profiles,
225 particularly for feelings of dizziness, headaches, physical weakness, and fatigue. The majority of
226 athletes (60 - 70%) reported a deterioration and lengthening of concussion symptoms when undergoing
227 a WC, suggesting that prior RWL might affect concussion symptoms.

228 This is the first study to assess the relationship between reported symptoms experienced as a result of
229 previous RWL events and concussions among combat athletes. Our findings indicate a positive
230 relationship between symptoms associated with RWL (via dehydration and leading to hypo-hydration)
231 and concussions, based on both the reported total number and severity of symptoms (Figure 1). Analysis
232 of individual symptoms revealed that the most common WC symptoms were physical weakness,
233 fatigue, dizziness, not feeling 'right', difficulties in concentration and irritability. The most frequently
234 selected concussion symptoms comprised the same responses as WC, in addition to headaches, head
235 pressure, and neck pain (Figure 3). These findings are in accordance with previous literature (18, 29),
236 indicating that RWL via dehydration increases concussion-related symptoms. The possible reasons for
237 feelings of weakness and fatigue could relate to perturbations in ionic balance to restore osmotic
238 equilibrium (30), and subsequent alterations to cell excitability and excitation-contraction coupling
239 capabilities (31, 32). Hypo-hydration also leads to a reduction in total blood volume (hypovolemia),
240 leading to light-headedness and dizziness, while dizziness post-concussion may also be related to
241 vestibular system damage, further increasing headaches, feelings of confusion and concentration
242 difficulty (33). This may explain why the most frequently reported symptom (for both concussed and
243 RWL athletes) after a WC or sparring session was headaches (18) (Figure 3 & 4). Therefore, the
244 implications of less discernible concussion-related symptoms (e.g., dizziness, headaches) in athletes
245 undergoing RWL, might mask or exacerbate the effects of cumulative sub-concussive impacts received
246 throughout the bout. This challenges the accuracy of concussion identification tools, particularly if
247 baseline protocols do not account for hydration status. The extreme practices of WC are likely to
248 introduce a source of external noise to the assessment of concussion symptoms, meaning that

249 knowledge of hydration status is necessary during all protocols to avoid erroneous results. Given that
250 the risks associated with extreme WC could endanger athlete welfare in pursuit of a competitive
251 advantage, further consideration of sporting governing bodies to set limits on weight-cutting is
252 warranted (34).

253 To the best of our knowledge, our study is the first to report the various experiences of combat athletes
254 who felt their WC did not go according to plan, with 70 - 80% of athletes reporting a lack of energy,
255 strength, and power, as well as 40 - 50% reporting a reduction in coordination and feeling more
256 susceptible to concussion (Table 1B). It was also found that 60 - 70% of athletes reported their
257 concussion symptoms to deteriorate and lengthen during a camp where they were weight-cutting, and
258 a fight in which they were dehydrated (Table 2). Furthermore, ~50% of athletes reported increased
259 feelings of being ‘slowed down’, experiencing fatigue, irritability, and physical weakness after fighting
260 in a hypo-hydrated state or cutting weight in camp (Figure 4). These reports could indicate mechanisms
261 by which hypo-hydration exacerbates the physiological responses to a concussion. Indeed, concussions
262 are known to lead to hyper-glycolysis, coupled with relative depletion of energy reserves, in order to
263 restore ionic imbalances (35). The combination of hyper-glycolysis, alongside additional physiological
264 stressors (in a bout) and hypo-hydration, may induce a competing substrate demand, which could be
265 further exacerbated by reduced overall blood volume. In addition, it is possible that damage to neurons
266 (e.g., diffuse axonal or shear injuries) is enhanced secondary to hypo-hydration due to altered membrane
267 stability (32), tissue elasticity (36) and cerebrospinal fluid production (37), leaving the brain more
268 vulnerable to cortical damage from trauma. This could, subsequently, lead to prolonged recovery or
269 further exposure to head trauma, which in chronic cases has been associated with later development of
270 neurodegenerative diseases e.g., dementia pugilistica, chronic traumatic encephalopathy, and
271 Alzheimer’s disease (38, 39, 40).

272 The individual reports of mishaps during WC practices, while anecdotal and possibly related to factors
273 unknown in this study, expose a plethora of additional negative outcomes associated with RWL. In
274 addition, the majority of athletes (65%) stated at least one incident of RWL to “*not go according to*
275 *plan*”, indicating the perceived competitive advantage may often not be achieved by combat athletes

276 (41). It is crucial these reports do not go ignored and athletes seek medical/professional advice with
277 regards to RWL strategies, as many poor outcomes in individual athletes have been documented (42).
278 In addition, MMA athletes presented higher symptom severity and adjusted scores for both concussion
279 and RWL (Figure 2), indicating RWL and concussion symptoms to be more severe in MMA. Symptom
280 severity of RWL in MMA was similar to wrestling, which is also associated with larger and more
281 aggressive RWL magnitudes and methods (23). Interestingly, concussion symptom severity and
282 adjusted scores were not different between sports, except between MMA and boxing. This may be
283 explained by the higher range of weight-classes and lack of indirect head impacts (e.g., takedowns)
284 experienced by boxing athletes in comparison to MMA. Given the differences in symptom severity
285 across various combat sports, we recommend that combat sport organizations aim to incorporate
286 baseline concussion and continual hydration testing protocols to verify the effects of hypo-hydration
287 and concussions independently.

288 To date, this is the first study to report on the resolution of combined RWL and concussion symptoms.
289 Almost all athletes (94%) reported their WC symptoms to improve with fluid replenishment; however,
290 the most frequently reported recovery time (for those with increased symptom scores following a fight)
291 was 24-48 h (Table 2). This indicates that, despite fluid replenishment, over a day was required for said
292 symptoms to resolve. An explanation for this could, in part, be due to a) the method of hydration i.e.,
293 bolus *vs.* tapered drinking strategies (43), b) electrolyte and carbohydrate deficient fluids insufficiently
294 restoring blood osmolality, volume, and glucose (44), or c) concussive/sub-concussive impacts further
295 adding to alterations in cell integrity and ionic imbalances (45, 46). Coaches, athletes and clinicians,
296 should consider the implications of RWL and all aspects of training load (particularly different modes,
297 such as sparring), as this could heavily impact recovery and preparation for a bout (13).

298 One of the main limitations of our study was that we did not account for the additional weight-loss
299 methods used during fight preparation (e.g., food restriction). Furthermore, it is possible that symptoms
300 were misreported due to surpassed time, which could mean that the effects of RWL on concussion-
301 related symptoms have been over- or under-estimated in the current study.

302 **Conclusion**

303 Overall, our findings suggest that RWL symptoms are strongly associated with concussion symptoms,
304 and though these varied between sports, MMA athletes present with the most severe symptoms
305 associated with RWL and concussions. Based on our findings, it is possible that prior WC practices
306 could exacerbate the deleterious effects of a concussion. Indeed, given that WC practices occur before
307 most concussive events and that athletes are unlikely to have recovered from the effects of hypo-
308 hydration by this time, it is possible that WC increases the risk of misdiagnosis. If hydration status is
309 unmonitored during any neurocognitive assessment, such as that performed during baseline concussion
310 assessment protocols or pre-competition, the results are likely to be affected. Where an athlete is safe
311 and able, we recommend that clinicians should monitor hydration status (e.g., point-of-care urine or
312 blood analysis and gross body mass), when performing baseline and post-recovery neurocognitive tests,
313 such as those used to screen for concussion symptoms. More generally, the findings of the current
314 survey suggest that RWL via WC methods should be avoided near to combat training or competition,
315 as it is possible that this could interfere with the decision making of medical professionals' diagnosis
316 of concussion.

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446 Table 1. Participant preparation camp and WC characteristics (average) (A), WC characteristics
447 (frequency) (B).

448 Table 2. Symptom recovery profile, Y = yes.

449 Figure 1. Significant correlations between concussion and WC with 95% confidence intervals. (A)
450 symptom severity ($r_s = 0.68$), (B), symptom scores ($r_s = 0.60$), and (C) adjusted symptom scores, ($r_s =$
451 0.72). (N = 80).

452 Figure 2. Average WC symptom severity (A), adjusted symptom score (B), concussion symptom
453 severity (C) and adjusted symptom score (D) for each combat sport.

454 Figure 3. Percentage of athletes who selected each symptom severity for WC (3A) and concussions
455 (3B).

456 Figure 4. Percentage of athletes who reported symptoms to deteriorate after hypo-hydration or head
457 impact, WC (N = 49), concussion (n = 56).

Table 1. Participant preparation camp and WC characteristics (average) (A), WC characteristics (frequency) (B).

A	Mean \pm SD / Median (IQR)	Range
Average camp length (weeks)	7 \pm 3	4 - 12
Shortest camp length (weeks)	3 \pm 2	1 - 5
General 'walking' weight (kg)	76.3 \pm 13.0	47 - 105
Usual weight cut (kg)	5 (5)	0 - 22
Usual weight regain (kg)	3 (3.5)	0 - 10
Shortest weight cut timing (days)	3 (6)	0 - 15
Weight lost (kg)	5 (4)	0 - 13
Weight loss in 24 h before weigh-in (kg)	2 (2)	0 - 5
Total no. of weight cuts in career	15 (20)	0 - 147

B	n	%
Time between weigh-in and bout (h)		
24 – 36	75	56.8
12 – 23	14	10.6
6 – 12	10	7.6
2 – 5	20	15.2
< 2	6	4.5
Time between each weight cut (months)		
< 1	76	57.6
1 – 2	31	23.5
3 – 4	18	13.6
\geq 5	7	5.3
Weight-cut not according to plan (Y/N)	Y = 86	65.1
<i>Felt a lack of energy</i>	71	82.6
<i>Felt a lack of strength/power</i>	60	69.8
<i>Coordination & reaction time felt suboptimal</i>	47	54.7
<i>Felt dehydrated during the fight</i>	41	47.7
<i>Felt easier to get 'rocked' during the fight</i>	33	38.4
<i>Initially failed to make weight</i>	30	34.9
<i>Fell ill in the lead up to the fight</i>	27	31.4
<i>Felt too bloated going into the fight</i>	20	23.3
<i>Other*</i>	11	12.8

Table 2. Symptom recovery profile, Y = yes.

Symptom recovery related questions	WC		Concussion	
	% (n)	Total n	% (n)	Total n
Do you feel that these symptoms became worse during/after the fight (or sparring session) within which you were dehydrated? (Y)			70 (56)	80
Do you feel that these symptoms improved when you were able to consume fluids again? (Y)	94 (124)	132	30 (17)	56
Do you feel that these symptoms lasted longer in comparison to a camp/session when you were not cutting weight? (Y)	61 (81)	132	60 (48)	80
Do you feel that you experienced less of these symptoms in a camp/session when you were not cutting weight? (Y)	89 (117)	132	70 (56)	80
Do you feel that these symptoms became worse during/after the fight (or sparring session)? (Y)	37 (49)	132		
How long did these symptoms tend to last for?		49		56
Less than 24 h	22 (11)		15 (12)	
24-48 h	59 (29)		28 (23)	
3-5 days	10 (5)		43 (34)	
6-13 days	2 (1)		8 (6)	
14-28 days	6 (3)		4 (3)	
Over 28 days	0		3 (2)	

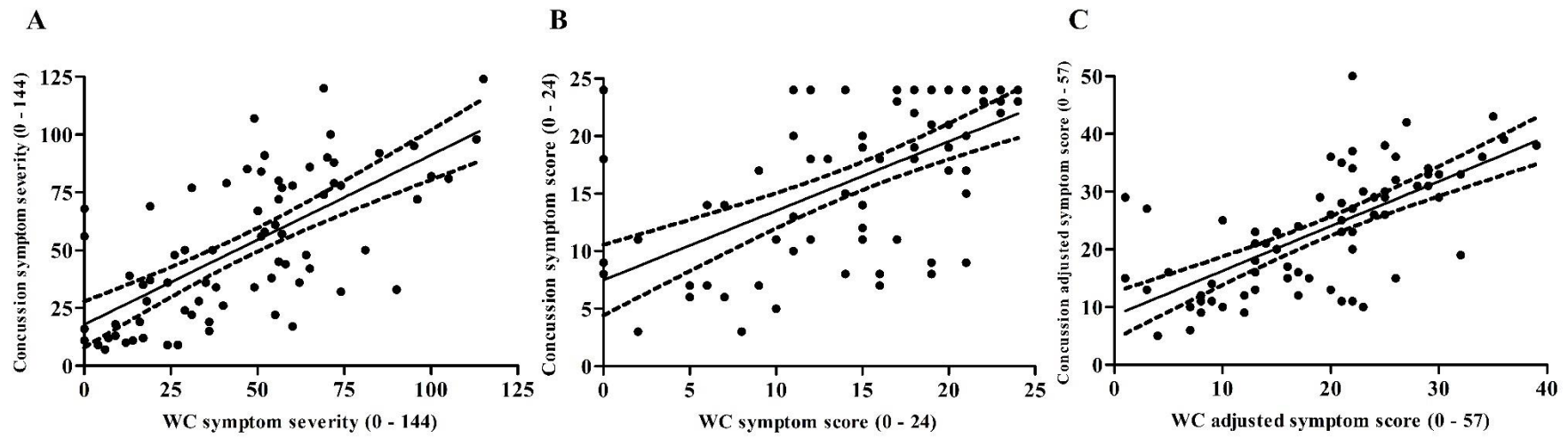


Figure 1. Significant correlations between concussion and WC with 95% confidence intervals. (A) symptom severity ($r_s = 0.68$), (B) symptom scores ($r_s = 0.60$) and (C) adjusted symptom scores, ($r_s = 0.72$). (N = 80).

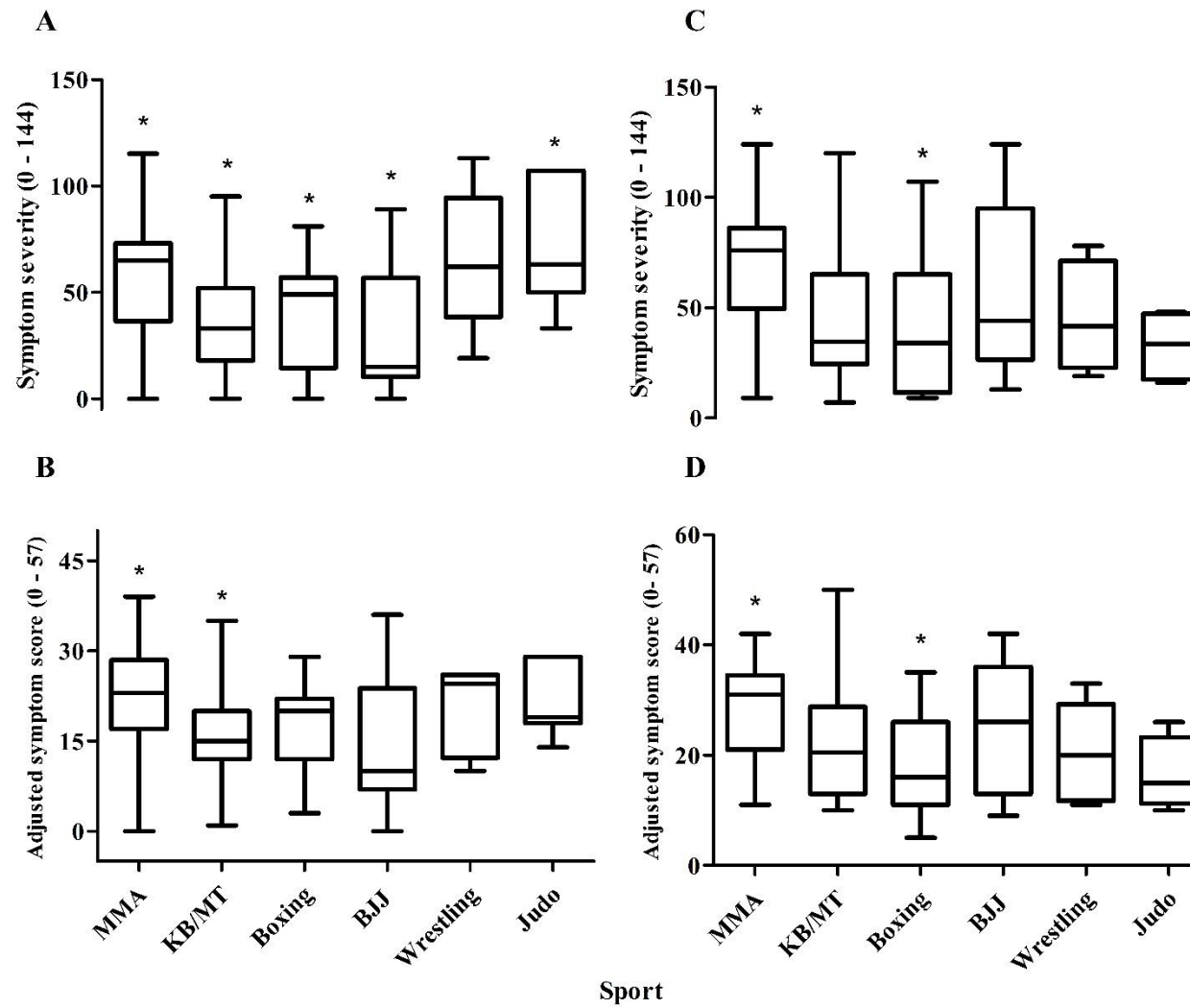


Figure 2. Average WC symptom severity (A), adjusted symptom score (B), concussion symptom severity (C) and adjusted symptom score (D) for each combat sport.

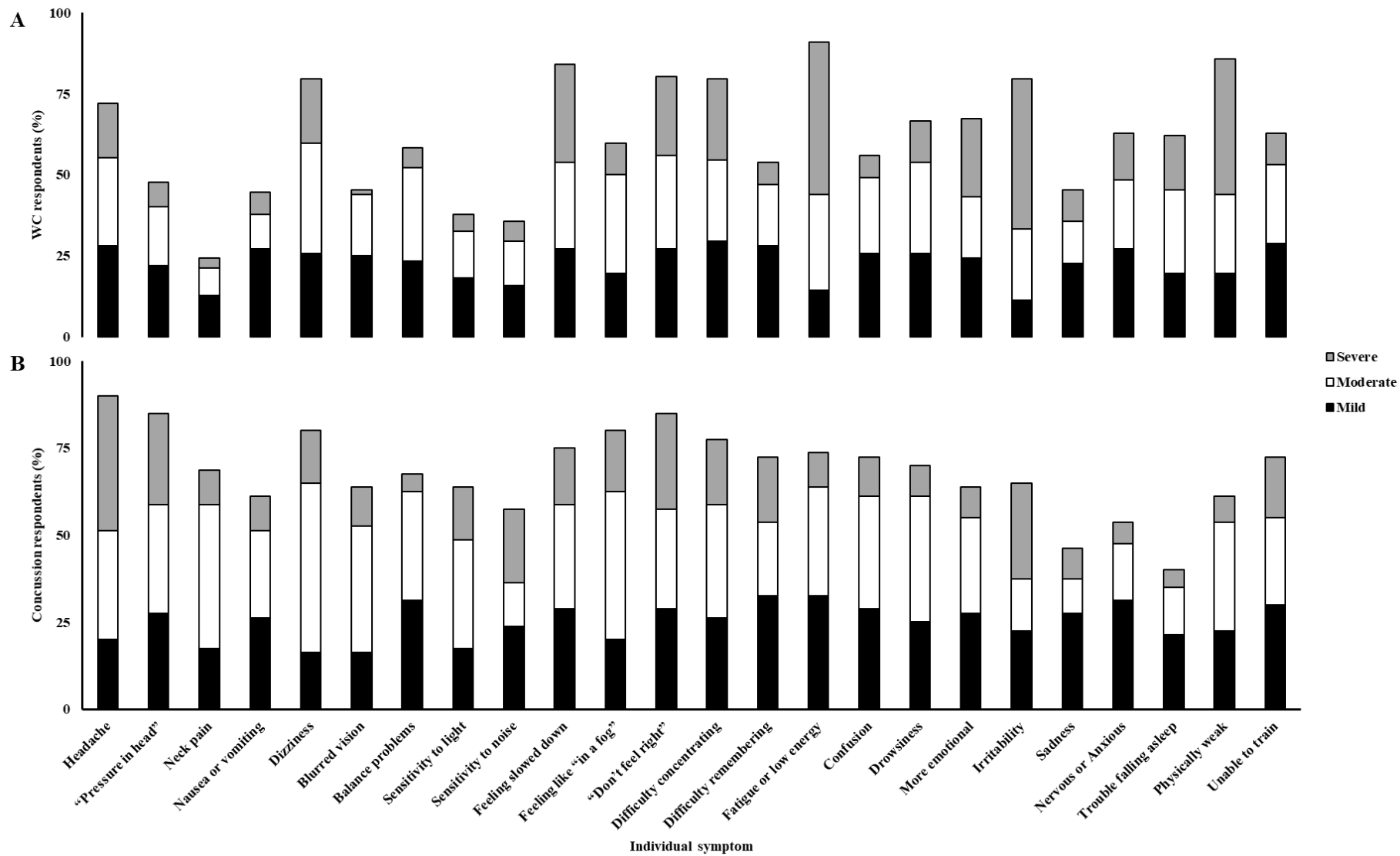


Figure 3. Percentage of athletes who selected each symptom severity for WC (3A) and concussions (3B).

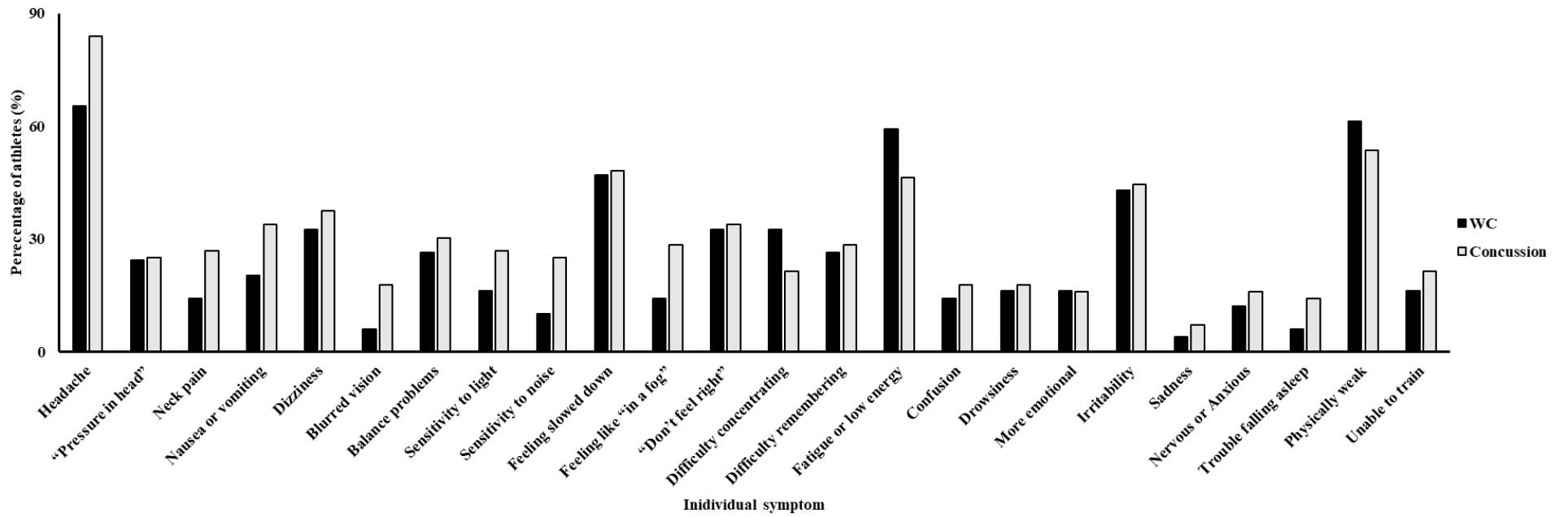


Figure 4. Percentage of athletes who reported symptoms to deteriorate after hypo-hydration or head impact, WC (n = 49), concussion (n = 56).