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Section: Case Study

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Case Study: Extreme weight making causes relative energy deficiency, dehydration and acute kidney injury in a male mixed martial arts athlete

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Abstract

The aim of the present case study was to quantify the physiological and metabolic impact of extreme weight cutting by an elite male MMA athlete. Throughout an 8-week period, we obtained regular assessments of body composition, resting metabolic rate (RMR), $\text{VO}_{2\text{peak}}$ and blood clinical chemistry to assess endocrine status, lipid profiles, hydration and kidney function. The athlete adhered to a “phased” weight loss plan consisting of 7 weeks of reduced energy (ranging from 1300 – 1900 kcal.d⁻¹) intake (phase 1), 5 days of water loading with 8 L per day for 4 days followed by 250 ml on day 5 (phase 2), 20 h fasting and dehydration (phase 3) and 32 h of rehydration and refuelling prior to competition (phase 4). Body mass declined by 18.1 % (80.2 to 65.7 kg) corresponding to changes of 4.4, 2.8 and 7.3 kg in phase 1, 2 and 3, respectively. We observed clear indices of relative energy deficiency, as evidenced by reduced RMR (-331 kcal), inability to complete performance tests, alterations to endocrine hormones (testosterone: <3 nmol.L⁻¹) and hypercholesterolemia (>6 mmol.L⁻¹). Moreover, severe dehydration (reducing body mass by 9.3%) in the final 24 hours prior to weigh-in induced hypernatremia (plasma sodium: 148 mmol.L⁻¹) and acute kidney injury (serum creatinine: 177 $\mu\text{mol.L}^{-1}$). These data therefore support publicised reports of the harmful (and potentially fatal) effects of extreme weight cutting in MMA athletes and represent a call for action to governing bodies to safeguard the welfare of MMA athletes.

Keywords: rapid weight loss, RED-S, testosterone, dehydration

Mixed martial arts (MMA) is a full contact combat sport often referred to as *cage fighting* or *ultimate fighting*. When compared with other combat sports (Alderman 2004; Davis *et al.*, 2001; Kinningham & Gorenflo, 2001; Kordi *et al.*, 2011; Morton *et al.*, 2010; Oppliger, Steen & Scott, 2003), the magnitude of weight loss reported by MMA athletes (e.g. 10% in the 24 h prior to weigh-in) (Matthews & Nicholas, 2017) has been identified as a cause for concern in both the literature (Crighton, Close & Morton, 2016) and televised media (Ralph, 2017). The sport has experienced two weight-cutting induced fatalities (Barrabi, 2013; Okamoto, 2017) as well as health problems (e.g. kidney failure) and substance abuse (e.g. diuretics) (Beacham, 2017; Drahota, 2017; Hiergesell, 2018; MMA Junkie Staff, 2017). As such, the California State Athletic Commission have recently introduced a 10-point strategic plan to protect against dangers of extreme weight cutting, notably a 10% maximal weight regain allowance following weigh in, introduction of four new weight classes, “check weigh-ins” and regular hydration testing (Okamoto, 2018).

Athlete Overview

A professional male MMA athlete (age: 22 years; body mass: 80.2 kg; height 1.80 m) volunteered to take part after providing informed written consent and permission to publish. The athlete had been competing professionally since age 17 with a professional record of 13

Athlete Assessments

The athlete was assessed at regular periods before and after the contest for body composition via skinfold assessment (according to ISAK standards; Stewart & Marfell-Jones, 2011) and DXA (QDR Series Horizon, Hologic Inc., Bedford, MA, USA) using the DXA Best Practice Protocol (Nana *et al.*, 2015). RMR was assessed via indirect calorimetry (GEM Open Circuit Indirect Calorimeter, GEMNutrition Ltd. UK) using the protocol described by Bone and Burke (2017). Peak oxygen uptake ($\text{VO}_{2\text{peak}}$) was assessed on a motorised treadmill (h/p/cosmos, Pulsar, Nussdorf-Trainstein, DE) using an online gas analysis system (CPX Ultima Series Medgraphics, MN, USA) and the exercise protocol described by Bartlett *et al.*,

Overview of Time-Course and Magnitude of Required Weight Loss

Phase 1: Energy restriction (-8 weeks to -1 week from weigh-in)

The athlete adhered to a “low carbohydrate” diet for the duration of the 8 weeks. At -8 weeks until -4 weeks, the athlete reported consuming daily energy intakes ranges from 1500 – 1900 kcal per day (1.5-2.5 g/kg CHO, 1.6-1.8 g/kg protein, 0.8-1 g/kg fat) and fluid was consumed *ad libitum*. From -4 weeks to -1 week, energy intake was reduced to 1300-1500 kcal, as occurring by a reduction in protein intake to approximately 1 g/kg body mass. All food was purchased from an external company (Goodness Grill and Juice Bar, Liverpool, UK) who provided pre-packaged meals in known portion sizes and macronutrient intakes. An overview of the athlete’s reported energy intake (as reported by the meal preparation company) during phase 1 is presented in Figure 1. From -8 weeks until -4 weeks, protein intake was typically distributed across breakfast, lunch and dinner as three 25-30 g portions comprising animal protein sources such as eggs, fish, chicken, red meat as well as 25-30 g whey protein (Nutrition X, Gloucestershire, UK) after each training session. From -4 weeks until -1 week, daily protein intake was reduced by removal of the whey protein and reducing portion sizes in the main meals. Estimation of energy intake was provided by the meal preparation company. In addition, the research team also performed dietary analysis on 6 occasions (4 days within phase 1 and 2 days within phase 2) to estimate sodium and fibre content (using the Nutritics dietary

Phase 2: Water loading (-1 week to -1 day)

Phase 3: Acute weight cut strategy (-1 day to weigh-in)

At 1800 h on the day prior to weigh-in, the athlete commenced a 20 h acute weight cut period where no food or fluid was consumed. The athlete engaged in a series of continuous cycles of sweating at -20 h (1 bath + 1 wrap; 72.3-72. kg), -19 h (3 baths + 3 wraps; 70.4 kg), -6 h (3 baths + 3 wraps; 67.9 kg) and -3 h (2 baths + 2 wraps; 67.0 kg). Cycles consisted of being covered in a wax-oil rub (Sweet Sweat, San Pedro, CA) and submerging distally from the neck in hot water baths (20 min) followed by the athlete wrapping himself in layers of blankets and towels (resembling an Egyptian Mummy) (20 min).

In the 32 h period between the weigh-in and contest, the athlete rehydrated *ad libitum* and consumed a high carbohydrate diet (15 g/kg CHO, 3.2 g/kg protein, 2.6 g/kg fat; as quantified from dietary recall performed by author one). As such, the athlete's body mass increased to 77.0 kg at 5 hours prior to competition (the last time the athlete recorded his body mass). In Phase 4, estimated fibre and sodium intake was 63.0 and 8.5 grams respectively in total. CHO provided by fluid sources corresponded to 175 grams and 3 Litres (through milk, fruit juices and sports drinks) though no formal assessment was made of additional fluids consumed. The majority of carbohydrate (9 g/kg CHO, 40 g fibre, 5.3 g sodium) was consumed in the period after weigh-in between 2 pm and 11 pm. Approximately 6 g/kg CHO, 23 g fibre, and 3.2 g sodium was consumed on contest day between 9 am and 6 pm. The athlete reported that his last form of energy intake was consumed at 3 hours (2.1 g/kg CHO, 9.2 g fibre, 1.4 g sodium) before the contest (i.e. 6 pm) though fluid intake was consumed *ad libitum* (and not recorded) up until the beginning of the contest. The athlete's post-weigh-in energy intake and fluid intake appears to agree with recent combat sport recovery guidelines proposed by Reale et al. (2017b) in terms of CHO content post-weigh-in and also the pre-contest meal. Nonetheless, fibre intake could be considered high given the habitual low fibre intake that the athlete was consuming previously.

In the 2 weeks after the contest, the athlete resumed his habitual diet and returned to the laboratory at 2 weeks after weigh-in for final assessments. In this period, the athlete engaged in no formal training or structured physical activity and consumed both food and fluid *ad libitum*. No form of dietary assessment or estimation of energy intake was made during this period as the athlete did not engage in any assessments during this time.

On the basis of initial assessment of body composition (see Figure 2A-F), it was apparent the target weight would have to be achieved via a combination of reductions in fat mass (i.e. adipose tissue) and fat free mass (i.e. muscle protein, muscle glycogen stores and water). The athlete reported adhering to daily energy intake of approximately 1300-1900 kcal/d for the first 7 weeks (i.e. phase 1), largely achieved via macronutrients intake of approximately 1.5-2.5, 1.6-1.8, and 0.8-1.0 g/kg of CHO, protein and fat respectively. When considered with previous literature, such data suggest that the combination of strength training and daily protein intake equivalent to 2 X RDA is sufficient to maintain (or increase) fat free mass (see Figure 2B and 2C), even when in an energy deficient state (Pasiakos et al. 2013; Morton et al. 2018; Longland *et al.*, 2016; Wilson *et al.*, 2013; Wilson *et al.*, 2015). Nonetheless, we acknowledge the potential under-reporting associated with the dietary assessment measures utilised here (i.e. self-reporting of daily energy intake from pre-prepared meal packages).

Whilst we also acknowledge our inability to assess energy availability (owing to the lack of assessments of daily energy expenditure and exercise energy expenditure), we observed that the athlete exhibited clear symptoms of the relative energy deficiency in sport syndrome (RED-S) (Mountjoy et al. 2014). In addition to reductions in resting metabolic rate and the inability to complete the maximal oxygen uptake test (see Figure 2G and 2H, respectively), we observed perturbations to endocrine status and hypercholesterolemia (see Figure 3). The observations of reduced testosterone in MMA athletes who also undertook RWL of 10% body mass in a 24 h period was also documented by Coswig et al. (2015). Nonetheless, the present paper reports the time-course of changes to endocrine markers across the entire 8-week period, as opposed to the cross-sectional study of MMA athletes who did or did not partake in RWL associated with making weight. Interestingly, the time-course of changes to both endocrine (e.g. reduced testosterone and IGF-1 etc) and lipid profiles is similar to that observed in US

Despite a body mass loss of 4.4 kg during phase 1, the athlete was still required to lose 9.6 kg in the next 7-days. In phase 2 of the athlete's strategy, he subsequently underwent a 5-day water loading protocol where 8 L was consumed daily for 4 days (corresponding to approximately 100 ml/kg) followed by 250 ml only for 1 day. Such alterations to fluid intake were done so in conjunction with a further reduction in energy intake to 500-1000 kcal/d that was also comprised of low-residue foods. It is, of course, difficult to ascertain the precise contribution of water loading and/or further reductions in energy availability (note that testosterone concentration declined to $<3 \text{ nmol.L}^{-1}$) in modulating the additional 2.8 kg lost during phase 2. Nonetheless, it is noteworthy that a comparable water loading protocol (100 ml/kg for 3 days followed by 15 ml/kg for 1 day) has recently been confirmed to enhance body mass loss (3.2 v 2.4%) when compared with a matched subject group who consumed a lower daily water intake of 40 ml/kg (Reale *et al.*, 2017a). Interestingly, we report similar magnitudes of change in body mass (i.e. 3.7%), daily urine output (e.g. an increase of 150% from 4 L to 6 L) and plasma sodium concentrations (maintained within the range of 136-140 mmol.L^{-1}) to that observed by the previous authors. When taken together, such data suggest that the water-loading protocol reported here and studied under experimental conditions (Reale *et al.*, 2017a) may be an effective method to enhance acute weight loss without causing clinical meaningful changes to blood biochemistry.

The excessive dehydration experienced in phase 3 (i.e. absolute weight loss of 7.3 kg) induced a significant stress response (e.g. 3-fold increases in plasma cortisol to approximately 1500 nmol.L⁻¹, see Figure 3B) and is evidenced by the elevations in serum proteins (see Figure 4D), plasma osmolality (see Figure 4H) and sodium concentration to 148 mmol.L⁻¹ (see Figure 4G). This absolute and relative magnitude of weight loss (i.e. 10%) has been previously

Following the 32 h rehydration and refuelling strategy, the athlete gained 10.6 kg in absolute mass. Unfortunately, we were unable to obtain an additional blood sample immediately prior to competition and hence cannot ascertain if the alterations in clinical chemistry discussed above had yet returned to normal. Nonetheless, at 2 weeks after competition resting metabolic rate, markers of endocrine status, lipid profile, hydration status and kidney function all returned towards or within normative ranges. It is noteworthy, that upon final assessment of body composition the athlete presented with an increased body mass (+3.3

Conclusions

Post-Script

Acknowledgements

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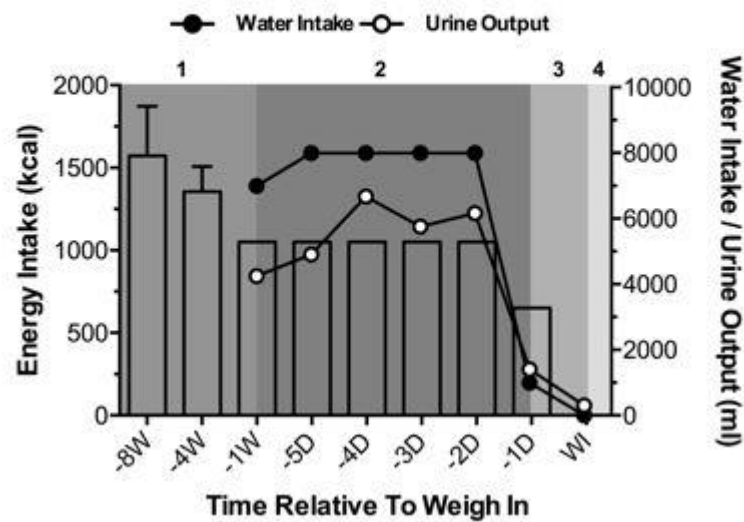


Figure 1. Reported energy intake during the 8 weeks prior to weigh-in (represented by **bars**), and water intake and urine output (represented by **lines**) during the final 7 days (D) prior to weigh-in. Error bars on -8 weeks (W) and -4W represent the mean (SD) of energy intake, as reported by the meal preparation company during the week of assessment.



assessment point (**Black Bars**).

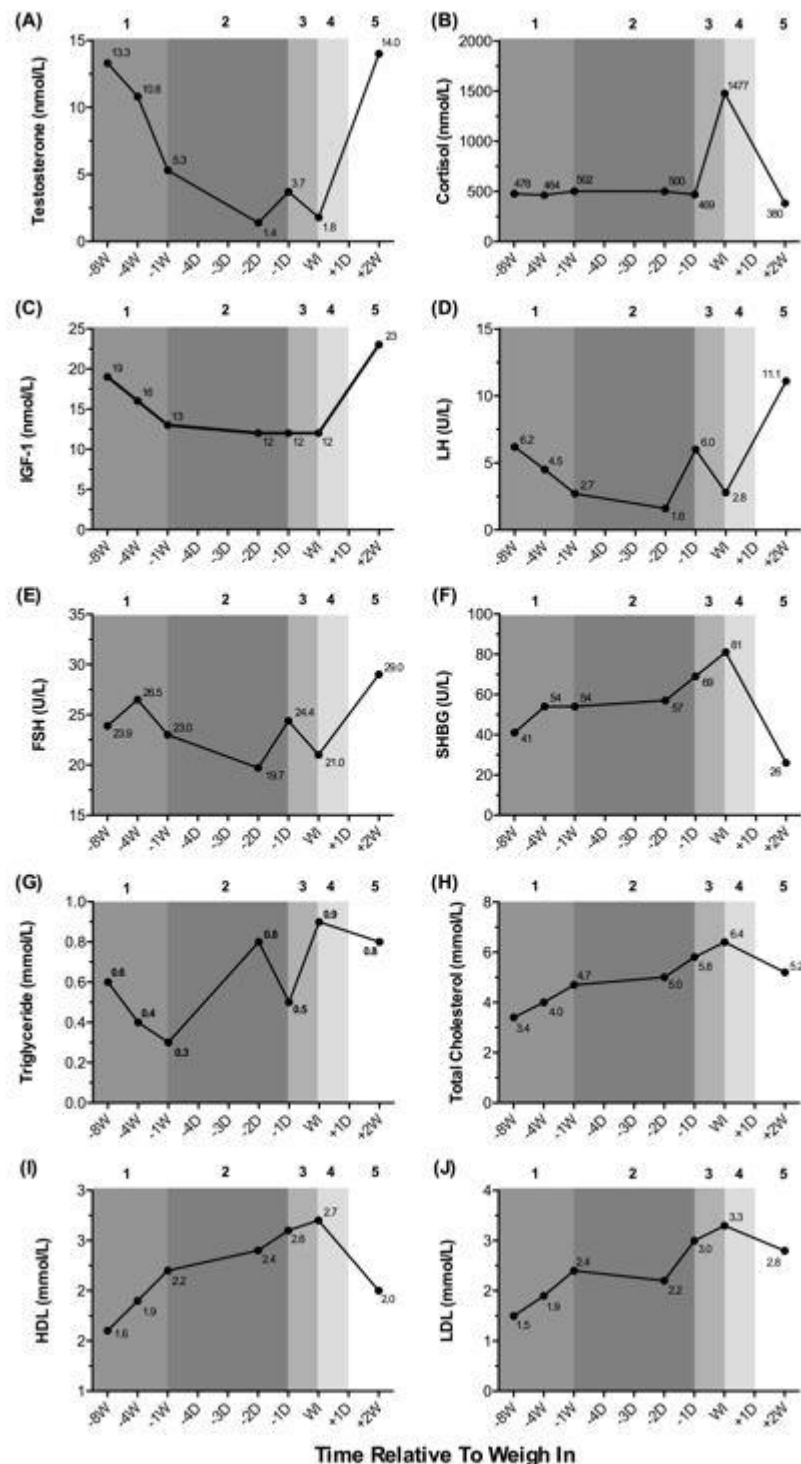


Figure 3. Endocrine and lipid biomarker profile changes: Testosterone (**A**), cortisol (**B**), insulin-like growth factor 1 (IGF-I) (**C**), luteinizing hormone (LH) (**D**), follicle-stimulating hormone (FSH) (**E**), sex hormone binding globulin (SHBG) (**F**), triglyceride (**G**), total cholesterol (**H**), high density lipid (HDL) (**I**), and low density lipid (LDL) (**J**).

