TITLE
Physiological and perceptual responses to a five-week pre-event taper in professional mixed martial arts athletes

AUTHOR
Uddin, Nasir; Tallent, Jamie; Waldron, Mark

JOURNAL
The Journal of Sport and Exercise Science

DATE DEPOSITED
24 August 2020

Physiological and perceptual responses to a five-week pre-event taper in professional mixed martial arts athletes

Nasir UDDIN [1, 2] *, Jamie TALLENT [1], Mark WALDRON [3, 4]

[1]School of Sport, Health and Applied Science, St Mary's University, Twickenham, UK; [2]Centre for Applied Sciences, City & Islington College, London, UK; [3]College of Engineering, Swansea University, Swansea, UK; [4]School of Science and Technology, University of New England, NSW, Australia.

*Corresponding author: Nasir Uddin, St Marys University. Waldegrave Road, London. TW1 4SX, Nasir.uddin@candi.ac.uk

ABSTRACT

BACKGROUND: The purpose of this study was to evaluate changes in markers of endocrine, immune and mood status among Mixed Martial Arts (MMA) athletes during different stages of fight preparation camps.

METHODS: Six professional MMA athletes were observed across the final five weeks (W4 – W0); including the final seven days (D6 – D0) of fight camp, and were tested for salivary immunoglobin-A (sIgA), salivary cortisol (SC), creatine kinase (CK), urine osmolality (UO), body mass (BM), training load (TL), reported fluid intake and profile of mood state (POMS) scores.

RESULTS: Magnitude-based decisions revealed *large*, *very likely* decreases in sIgA concentrations in W1 relative to all previous weeks, and *large*, *very likely* reductions in CK concentrations within W0 in relation to W2 and W4. POMS scores were reduced in W0 and W1 compared to W4 (*moderate, very likely*), despite a reduction in training load in W0 relative to all previous weeks (*large, very likely*). In W0, reported fluid intake decreased as UO increased at D1 and D2, in comparison to all previous days (*large, very likely*). Elevated POMS and SC (*moderate to large*, *very likely*) were also observed at D1, in comparison to D2 to D6. While 8% of BM was lost over the 5-week period, 5% was lost within the final 4 days.

CONCLUSIONS: Across a 5-week fight camp, mood states are negatively affected, alongside increased markers of muscle damage and immune status, which can be partially offset with a pre-event taper. Owing to the weight cutting practices of these professional MMA athletes, ~ 5% of BM is lost in the final 4 days, which coincides with poorer mood states and increased stress-hormone responses in the final few days of the fight camp. Coaches should consider the implications of taper length and RWL strategies in the recovery process of MMA athletes.

Key words: dehydration, fatigue, overtraining, MMA, rapid weight loss

Introduction

Mixed Martial Arts (MMA) is a combat sport, which combines various fighting techniques found in traditional martial arts, such as kickboxing, boxing, muay-thai, wrestling and Brazilian Jiu-Jitsu. Athletes within MMA are generally deemed to be in an 'off-camp' or 'fight-camp' phase, the latter of which is used to target specific adaptations in the final 4-10 weeks prior to a competitive event (UFCPI, 2018). As a result of training for multiple disciplines and in the event of agreeing a bout at short notice (< 4 weeks), training load can often be mismanaged within the fight camp, contributing to inadequate recovery and suboptimal performance (Amtmann, 2004). High training loads may lead to excessive muscle damage, kidney dysfunction (via rhabdomyolysis) and fluid or electrolyte imbalances (Mashiko et al., 2004), leading to chronic states of overreaching and subsequent development of over-training syndrome (Coutts et al 2007).

After repeated, strenuous bouts of prolonged training sessions, a window of 3-72 h of reduced immunity has been observed, referred to as the 'open window' (Walsh et al., 2011), leaving athletes at a greater risk to infections, particularly those of the upper respiratory tract (URTIs) (Budgett, 1998). Salivary proteins, such as IgA (sIgA) play an integral role in mucosal immunity and can serve as an indicator of URTI risk (Mackninnon, Ginn & Seymour, 1993). Indeed, reductions in sIgA secretion during prolonged training camps have been reported, and sIgA secretion is inversely related to URTI risk (Gleeson et al., 1995). In addition, higher cortisol, mood disturbances and muscle soreness are associated with decreased mucosal immunity, which can be elicited during a period of increased training loads (Papacosta, Nassis & Gleeson, 2016).

Progressive reductions in training load (tapers) are typically incorporated into pre-competition training programmes to minimise training-induced fatigue, maximize physiological adaptations and optimise performance (Mujika, 2010). Pre-competition tapering is more complicated in combat sports (in comparison to non-weight classification sports), owing to the potential use of rapid weight loss (RWL) strategies in the days leading up to a competitive event. Such strategies aim to reduce body mass (primarily water mass) within the final days preceding an event and are used in order to gain a competitive advantage (against a lighter athlete). During intensive training, this may be detrimental to the athlete's health, compromising immune function and reducing salivary flow rate (Ford et al., 1997; Tsai et al., 2009). Therefore, it is suggested that the practices of MMA fighters towards the end of a fight camp may compromise their health status, in turn, leading to suboptimal performance.

Athletes dehydrating for the purpose of RWL typically have inadequate time to rehydrate before MMA events e.g. restoring 5% of body mass within 24 hours (Jetton et al., 2013). With inadequate fluid intake and physical recovery, athletes are more susceptible to renal injury, due to the high levels of plasma creatine kinase concentrations observed in MMA fighters and reductions in myoglobin solubility (Weichmann et al., 2016). The resulting hypo-hydration and severe energy restrictions from RWL have also been reported to lead to an increased perception of fatigue, tension, anxiety and impaired short-term memory (Steen & Brownell, 1990; Choma, Sforzo & Keller, 1998). Furthermore, hypo-hydration has been reported to impair muscle excitability and reduce muscular endurance, irrespective of fluid replacement (Bigard et al, 2001; Bowtell et al., 2013). Therefore, hypo-hydration is likely to contribute to neuromuscular fatigue before and during competition.

It is likely that the cumulative demands of pre-competition preparation for combat sports athletes induce physical and mental fatigue, which can lead to chronic overreaching and subequently over-training syndrome, unless adequate recovery is provided (Urhausen & Kindermann, 2002). Those with OTS report disrupted mood, sleep and behaviour (Meeusen et alk 2013), as well as neuroendocrine dysregulation (Cadegiani & Kater, 2017). Indeed, some hormones secreted from the hypothalamic pituitary adrenal axis have been related to immunosuppression (Ford et al., 1997) and could be used to monitor the health status of combat sports athletes. Presently, there has been no investigation of combat athletes' well-being and endocrine response to an MMA fight camp. It is therefore necessary to evaluate the fight preparation period of professional MMA athletes, as this information could be used to inform future preparations.

The purpose of the study was to evaluate the change in physiological (hydration, endocrine and immune) and perceptual markers (mood state) of professional MMA athletes within the final 5-weeks (minimum fight camp time frame + period of RWL) of an uninterrupted fight camp.

Materials and methods

Participants provided written informed consent to participate in a prospective observational study across five weeks. Institutional ethical approval was given for this study, which was conducted in accordance with the 1964 Helsinki declaration. Prior to initial testing, participants arrived at the laboratory, completed a physical activity readiness questionnaire (PAR-Q) and were familiarised with methods for obtaining and storing urine and saliva samples. In addition, they were familiarised to the Profile of Mood State (POMS) questionnaire.

On each testing day, participants were instructed to obtain urine and saliva samples at home within 30-min of waking up. Upon arrival at the laboratory in the morning (~0900 h) in a fasted state before training, they were requested to empty their bladders, followed by measurements of body mass, POMS and capillary blood samples (from the ear) to assess plasma creatine kinase (Figure 1). Each testing day was identical except for the final week (excluding fight day), wherein daily measurements of POMS, urine, saliva and body mass were taken. Weeks and days are expressed as n where n = number of weeks/days from fight day (Figure 1).

Insert Figure 1 here

Participants

Six male (age: 27 ± 7 years, stature: 1.71 ± 0.08 m, body mass: 78.1 ± 10.3 kg, training age: 6 ± 4 years, counter-movement jump height: 0.39 ± 0.10 m) professional MMA athletes with no underlying health conditions, consented to take part in this study. Inclusion criterion necessitated that the athletes were injury free and competing within a regulated MMA organization.

Methods

Body mass

Following, urination and prior to any fluid and energy intake the mean of three nude body mass measurements were taken using a portable scale (MPMS-230, Marsden Weighing Group, Oxfordshire, UK).

Urine Osmolality

Participants were instructed to collect midstream samples of first urine (within 30-min of waking up) (50 ml collection pots)) and return them to the laboratory on each testing day. Pre-fight (weigh-in) day urine was assessed in the final 30-min prior to stepping on the scale at the event. Fight day urine was assessed ~ 6-h prior to the bout, before consumption of a lunch meal and a minimum of 1-h post water consumption. Urine osmolality (mOsml·kg^{-1}H_2O) was measured using a thermally compensated refractometer (Osmocheck refractometer, Vitech Scientific Ltd, West Sussex, UK) with a manufacturer's reported testing accuracy of ± 20 mOsml·kg^{-1}H_2O and a between run coefficient of variation (CV) of 0.3%. Participants were asked to report fluid intake (L) on a daily basis in the final week.

Whole-blood Creatine Kinase concentration

Approximately 300 µl of capillary whole-blood (from the ear) was collected (Microcuvette®CB300, Sarstedt, Numbrecht, Germany), placed in a refrigerated centrifuge (Mikro 220R D-78532, Tuttlingen, Germany) and spun at 3500 rev/min for 6-min at 4 ◦C. All samples were then stored and analysed using an automated analyser (Clinical Analyser Rx Daytona – Randox Teoranta, Co. Donegal, Republic of Ireland) with a between run CV of 2.0 %.

Saliva Variables (sIgA & Cortisol)

An IPRO Lateral Flow Device reader (IPRO Interactive Ltd, Wallingford, UK) was used to analyse salivary cortisol and sIgA. Saliva swab testing kits with instructions were administered for participants to obtain morning saliva within the first 30 min of waking up, prior to arrival at the laboratory. Approximately 0.5 ml of saliva was collected via an oral swab and placed into a buffer solution. Two drops of the buffer/saliva mixture were then placed on to a lateral flow indicator test strip, allowing the mixture to flow laterally across the conjugated pad and the nitrocellulose membrane. Test strips were left for a 15-min incubation period before analysis. Between run mean CV were 8.5 % and 6.8 % for sIgA and cortisol respectively.

Training Load

Participants were asked to provide a rate of perceived exertion (RPE) using a 10-point rating scale. The intensity of all training sessions (technique drilling, grading, sparring, strength and conditioning) were recorded within 30-min of completion. A typical weekly training schedule is shown in Table 1.

*** Insert Table 1 here ***

The RPE value was multiplied by training time to calculate session RPE (sRPE) as a measure of training load (Lambert & Borresen, 2010). Intended taper length was also requested to indicate when and how training load reduction was expected. Athletes within this study underwent a taper length between six and ten days, which was preceded by a final 'maximal' sparring session and utilizing the days within the taper to reduce load via mobility, conditioning and 'drilling' sessions.

Profile of Mood States Questionnaire (POMS)

POMS was administered to assess transient disturbances in 6 different moods: anger, confusion, tension, fatigue, depression and vigour. The questionnaire consisted of 65 questions assessed through a 5-point likert scale ranging between 'not at all' and 'extremely' and resulted in an overall mood disturbance score. Participants were asked to complete an online version of the POMS questionnaire while isolated in a quiet area of the laboratory at the start of each testing day (~ 9 am) (Morgan et al., 1987).

Statistical analysis

Magnitude-based decisions (MBD) were used to determine whether observed effects were unlikely or likely, allowing practical inferences to be drawn from the approach described by Batterham & Hopkins (Batterham & Hopkins, 2006). Effect sizes (ES) and MBD identified likelihood of effects of time on each dependent variable (BM, UO, sIgA, CK, SC, TL, POMS overall score and sub-scores) across the final five weeks. ES were defined as; *trivial* = 0.2; *small* = 0.21 – 0.6; *moderate* = 0.61 – 1.2; *large* = 1.21 – 1.99; *very large* > 2.0. Raw data were log-transformed to account for uniformity of effects. Threshold probabilities for a substantial effect based on the 90% confidence limits were: <0.5% *most unlikely*, 0.5 – 5% *very unlikely*, 5.1 – 25% *unlikely*, 25.1 – 75% *possibly*, 75.1 – 95% *likely*, 95.1 – 99.5% *very likely*, > 99.5% *most likely*. Thresholds for the magnitude of the observed change in the dependant variables were determined as the within-participant standard deviation x 0.2 (*small*), 0.6 (*moderate*) and 1.2 (*large*). Effects with confidence limits across a *likely, small* positive or negative change were classified as unclear. The uncertainty of effects were based on 90% confidence limits for all variables. A custom spreadsheet designed for cross-over trials was used to perform all of the calculations (http://www.sportsci.org/).

Results

Changes across final five weeks

Large, very likely reductions in TL were observed between week 0 and all other weeks. There were *large*, *very likely* reductions in sIgA between week 1 and weeks 2, 3 & 4.

CK reductions were *large, very* or *most likely* between week 0 and weeks 1, 2 & 4, and also between weeks 1 & 3.

POMS depression score reductions were *large*, *very likely* between week 4 and weeks 3 & 2 while POMS confusion score reductions were *large*, *very* or *most likely* between week 4 and weeks 2 & 1. (Table 2)

*** Insert Table 2 here ***

Changes across final seven days

There were *large*, *very* or *most likely* reductions in UO and increases in fluid intake between all days (Table 3).

There were *large*, *very likely* increases in POMS scores between day 1 and days 4, 5 & 6, and reductions between day 4 and days 0 & 2. *Large*, *very likely* increases in POMS depression scores were found between day 1 and days 2, 3 & 4. *Large*, *very* or *most likely* increases in POMS confusion scores were found between day 1 and days 3, 4, 5 & 6. *Large*, *very likely* reductions in POMS fatigue scores were found between day 1 and days 4, 5 & 6. There were also *large*, *very likely* reductions in POMS vigour scores between day 1 and days 4, 5 & 6. (Table 4)

*** Insert Table 3 here ***

*** Insert Table 4 here ***

Discussion

The aim of this study was to evaluate changes in physiological and mood state across the final five weeks of a fight camp amongst professional MMA fighters. The main observations within this study include a reduction in BM of ~ 8% within the final five weeks, with ~ 5% occurring within the final four days of the weight cut. Mood state worsened across the five weeks, particularly due to the increase in POMS sub-scores of confusion, depression and tension. *Very large* plasma CK reductions were observed in the final week relative to all weeks, however a *large* reduction in sIgA secretion was observed within the penultimate week. Though sIgA also improved with TL reduction (taper), it did not return to baseline concentrations. Finally, a *large* increase in SC was observed within the final two days (weigh-in and fight day), yet overall change was *trivial* across the five weeks. Collectively, the results provide novel evidence of the undesirable changes in immunoendocrine and mood status in professional MMA athletes across the final five weeks of a fight preparation camp.

Participants within the present study achieved a total BM loss of ~10.0% across the final four weeks, with 4.7-5.7% of BM reduction occurring within the final week. A similar magnitude of change across time has been observed in MMA (Jetton et al., 2013; Kasper et al., 2018), judo (Pallares et al., 2016), wrestling (Roemmich & Sinning, 1997) and boxing (Reljic, Hassler & Jost, 2013). However, athletes within the current study decreased BM by 1.8 kg within the final 24-h, which is lower than previously reported losses of 3.4 and 9.8 kg within 24-h and 27 days respectively (Barley, Chapman & Abbiss, 2017). Five of the six athletes were hyper-hydrated before gradually dehydrating to a hypo-hydrated state during weigh-in day. With reported fluid intake as high as 8.5 L at D6 but as low as 0.2 L at D1, patterns follow a typical weight-cutting method reported amongst MMA athletes, known as ‘water-loading’ (Reale et al., 2018). It is possible that methods of water loading within this study differed from others, as most did not reach a state of severe hypo-hydration (> 1200 $mOsml \cdot kg^{-1} H_2O$) that has been reported (Kasper et al., 2018). Though final UO was not measured immediately prior to the fight (~ 6-h), the current findings confirm that fluid balance is manipulated by MMA athletes to control body mass losses but suggest that magnitude/method of water loading may vary between individuals. It is also possible that the changes in BM were influenced by calorie restriction; however, this was not monitored and is a limitation of the study.

TL was *largely* reduced in W0 to facilitate at least a one week taper, in order to minimise training induced fatigue and maximise physiological adaptations prior to the fight. However, irrespective of TL periodisation strategies, a reduction in sIgA secretion and increase in mood scores remained evident in the final two weeks of the preparation camp. Acute reductions in TL have been strongly associated with improved mood state (Saw, Main & Gastin, 2016), yet peak disturbances in overall mood scores were observed in the penultimate day (weigh-in) and penultimate week within this study, indicating that the athletes' psychological state was not solely dependent on load reduction and may have been attributed to fluid restriction levels. This has been observed in participants regardless of whether fluid restriction was involuntary (Ely et al., 2013) or voluntary and when sleep, diet and caffeine were controlled (Mundel, Hill & Legg, 2015). With increased POMS sub-scores of confusion, depression, anger alongside decreased plasma CK and sIgA concentration, it is possible that mood disturbances were also reflective of pre-fight stressors, along with the recovery process from training-induced fatigue. This suggests that POMS provides a useful global indicator of mood state but may not consistently coincide with adjustments in TL, due to a multitude of factors involved in subjective scoring.

Plasma CK concentrations increased across the pre-competition fight camp, with peak values occurring within W1. However, this was reduced in W0, in accordance with a programmed decrease in TL. CK concentrations were larger than anticipated in the current sample, with fight day concentrations almost resembling CK values 24-h post-fight and 3 times the observed values pre-event (Weichmann et al., 2016). The reasons for this are unclear but could be related to muscle damage induced by MMA bouts, which include repetitive eccentric contractions (e.g. kicking decelerations) and blunt trauma associated with strikes (Baird et al., 2012; Weichmann et al., 2016), which were not specifically monitored during the fight camp. Nevertheless, these data indicate a progression in indirect muscle damage markers during fight camp, which suggests that the participants in this study may have entered their fights with a higher level of muscle damage than previously reported (Weichmann et al., 2016), further highlighting the importance of TL management to optimise recovery within the correct time frame.

SC and sIgA concentrations were monitored across the 5-week tapering period, as an indication of the hypothalamic pituitary axis stress response and mucosal immunity, respectively. Peak reduction of sIgA concentrations were observed in W1, indicating potential increased URTI risk due to a reduced mucosal immunity[5]. It was speculated that this steep decline in sIgA concentration is representative of the ‘open window’ phenomenon, whereby athletes have been reported to have lower salivary immunoglobins and peripheral blood immune cells following prolonged and intensified training (Walsh et al., 2011). Similarly, the athletes examined here were recovering from training-induced fatigue, following a period of high TL. Interestingly, there was a *moderate* reduction in sIgA concentration in W0 (compared to W3 & W2), which occurred alongside reductions in TL and plasma CK concentration, indicating a partially successful tapering strategy. sIgA concentrations observed in the initial weeks were not restored in the final stages of the taper, suggesting higher risk of illness and infection near to the day of the fight. In addition to physical exertion, cortisol secretion can be induced by non-physical stimuli, such as anxiety and psychological stress (Kunz-Ebrecht et al., 2003). This is supported by similar trends observed in overall mood and sub-scores of confusion and depression reported in the current study. These findings indicate that some professional MMA athletes might experience higher levels of anticipatory psychological stress or arousal particularly at weigh-in and fight days. Further research is required to understand the way in which this can be managed to facilitate optimal performance.

Changes in sub sections of mood state may have also been associated with factors other than SC. For example, in the final week of the taper, scores of confusion, depression and anger increased as BM reduced, but decreased again as BM increased within the final day. Such a trend suggests that the mood state of an MMA athlete may be influenced by the magnitude or method of BM reduction within the final week of fight preparation. Hypo-hydration has been reported to impair visuomotor performance (Wittbrodt et al., 2018), short-term memory (Choma, Sforzo & Keller, 1998) and brain metabolism (Kempton et al., 2011), suggesting acute altered brain function. As cortisol is a glucocorticoid, which can be elevated due to euphorigenic or neuro-stimulatory causes (Kunz-Ebrecht et al, 2003), it is hypothesised that rises in cortisol, tension and fatigue may also be attributed to neuroendocrine and corticospinal responses to hypo-hydration. It is also important to note that though participants returned to baseline BM, UO did not, suggesting blood volume may have not increased and reached baseline values. The reduction in blood volume and increase in UO results in a shift of sodium uptake, leading to altered excitation-contraction capabilities (Hackney et al., 2012; Bowtell et al., 2013). As a result, though athletes may have achieved initial BM, this may not be reflective of restored performance, tolerance to fatigue and sarcolemmal breakdown (within bouts), as has been reported previously (Bigard et al., 2001) and could have major implications upon brain morphology (e.g. ventricular enlargement) (Wittbrodt et al., 2018), increased oxygen metabolism (Kempton et al., 2011) and neuromuscular function (e.g. time to fatigue in skeletal muscle) (Bigard et al., 2001; Hackney et al., 2012; Bowtell et al., 2013)..

Data presented here suggest MMA athletes may enter competitive events with significant muscle damage due to sub-optimal tapering strategies, which should be monitored in accordance to individual load and type of session. Rehydration strategies should be considered (i.e. bolus vs metered drinking, % of BM lost vs total litres of fluid ingested, electrolyte and glucose content) for effective recovery of blood volume and BM. Furthermore, it is recommended that coaches look towards alternative and additional methods of subjective mood/stress scoring, specific to overreaching and/or discriminating between psychosocial stressors and TL.

The authors acknowledge that a larger sample size with a wider weight-class range are needed to further examine the immunoendocrine and mood status of MMA athletes undergoing a fight preparation camp. It is possible that heavyweight athletes may not engage in RWL strategies and therefore present a different physiological and mood profile during a fight preparation camp.

Conclusions

The mood state of professional fighters appears to deteriorate across the five-week fight camp, leading to increased feelings of confusion, depression and tension. Indirect markers of muscle damage and mucosal immunity are also negatively affected during the five-weeks, but can partially recover with a de-loading taper strategy in the pre-fight period. Professional MMA athletes practice pre-fight fluid restriction as a method of RWL, which appears to coincide with negative mood states. Increased cortisol in the final few days of the fight camp may also be related to increased pre-fight stress/anxiety, while salivary IgA decreased >70% 1 week out from fight day, potentially increasing risk of MMA athletes to URTIs towards or after competition date. Practitioners and coaches within MMA should consider refining methods related to the monitoring of load management and mood states while looking to optimise the rehydration process for their athletes during fight preparation camps.

REFERENCES

[1] UFCPI. A Cross-Sectional Performance Analysis and Projection of the UFC Athlete. 2018.

[2] Amtmann JA. Self-reported training methods of mixed martial artists at a regional reality fighting event. J Strength Cond Res 2004;18:194–6.

[3] Mashiko T, Umeda T, Nakaji S, Sugawara K. Effects of exercise on the physical condition of college rugby players during summer training camp. Br J Sports Med 2004;38:186-90.

[4] Coutts A, Reaburn P, Piva TJ, Murphy A. Changes in selected biochemical, muscular strength, power, and endurance measures during deliberate overreaching and tapering in rugby league players. Int J Sports Med 2007;28:116-24.

[5] Walsh NP, Gleeson M, Shephard RJ, Gleeson M, Woods JA, Bishop N et al. Position statement part one: immune function and exercise. Exerc Immunol Rev 2011;17:6-63.

[6] Budgett R. Fatigue and underperformance in athletes: the overtraining syndrome. Br J Sports Med 1998;32:107-10.

[7] Mackinnon LT, Ginn E. Seymour GJ. Temporal relationship between exercise-induced decreases in salivary IgA and sub- sequent appearance of upper respiratory tract infection in elite athletes. Aust J Sci Med Sport 1993;25:94-99,.

[8] Gleeson M, McDonald WA, Cripps AW, Pyne DB, Clancy RL, Fricker PA. The effect on immunity of long-term intensive training in elite swimmers. Clin Exp Immun 1995;102:210-6.

[9] Papacosta E, Nassis GP, Gleeson M. Salivary hormones and anxiety in winners and losers of an international judo competition. J Sport Sci 2016;34:1281-7.

[10] Mujika I. Intense training: the key to optimal performance before and during the taper. Scand J Med Sci Sport 2010;20:24-31.

[11] Ford J, Trevatt CA, Dix A, Fallowfield JL. The effect of fluid replacement and heat on salivary flow rate and optical density at 280 nm in response to exercise. J Sports Sci 1997;15:49–50.

[12] Tsai ML, Chou KM, Chang CK, Fang SH. Changes of mucosal immunity and anti-oxidation activity in elite male Taiwanese Taekwondo athletes associated with intensive training and rapid weight loss. Br J Sports Med 2009.

[13] Jetton AM, Lawrence MM, Meucci M, Haines TL, Collier SR, Morris DM et al. Dehydration and acute weight gain in mixed martial arts fighters before competition. J Strength Cond Res 2013;27:1322-6.

[14] Wiechmann GJ, Saygili E, Zilkens C, Krauspe R, Behringer M. Evaluation of muscle damage marker after mixed martial arts matches. Orthop Rev 2016;8.

[15] Steen SN, Brownell KD. Patterns of weight loss and regain in wrestlers: has the tradition changed? Med Sci Sport Exc 1990;22:762-8.

[16] Choma CW, Sforzo GA, & Keller BA. Impact of rapid weight loss on cognitive function in collegiate wrestlers. Med Sci Sport Exc 1998:30:746-749.

[17] Bowtell JL, Avenell G, Hunter SP, Mileva KN. Effect of hypohydration on peripheral and corticospinal excitability and voluntary activation. PLoS One 2013:8.

[18] Bigard AX, Sanchez H, Claveyrolas G, Martin S, Thimonier B, Arnaud MJ. Effects of dehydration and rehydration on EMG changes during fatiguing contractions. Med Sci Sport Ex 2001;33:1694-700.

[19] Urhausen A, Kindermann W. Diagnosis of overtraining. Sports Med 2002;32:95-102.

[20] Meeusen R, Duclos M, Foster C, Fry A, Gleeson M, Nieman D et al. Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. Med Sci Sport Exc 2013;45:186-205,.

[21] Cadegiani FA, Kater CE. Hypothalamic-pituitary-adrenal (HPA) axis functioning in overtraining syndrome: findings from endocrine and metabolic responses on overtraining syndrome (EROS)—EROS-HPA Axis. Sport med 2017;3:45.

[22] Lambert MI, Borresen J. Measuring training load in sports. Int J Sports Physiol Perf 2010;5:406-11.

[23] Morgan W, Brown D, Raglin J, O'Connor P, Ellickson K. Psychological monitoring of overtraining and staleness. Br J Sports Med 1987;21:107-114.

[24] Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. Int J Sports Physiol Perform 2006;1:50–57.

[25] Kasper AM, Crighton B, Langan-Evans C, Riley P, Sharma A, Close GL, Morton JP. Case Study: Extreme Weight Making Causes Relative Energy Deficiency, Dehydration and Acute Kidney Injury in a Male Mixed Martial Arts Athlete. Int J Sport Nutr Exerc Metab 2018;1-20,

[26] Pallarés JG, Martínez-Abellán A, López-Gullón JM, Morán-Navarro R, De la Cruz-Sánchez E, Mora-Rodríguez R. Muscle contraction velocity, strength and power output changes following different degrees of hypohydration in competitive olympic combat sports. J Int Soc Sports Nutr 2016;13:10.

[27] Roemmich JN, Sinning WE. Weight loss and wrestling training: effects on nutrition, growth, maturation, body composition, and strength. J Appl Physiol 1997;82:1751-9.

[28] Reljic D, Hässler E, Jost J, Friedmann-Bette B. Rapid weight loss and the body fluid balance and hemoglobin mass of elite amateur boxers. J Athl Train 2013;48:109-17.

[29] Barley OR, Chapman DW, Abbiss CR. Weight Loss Strategies in Combat Sports and Concerning Habits in Mixed Martial Arts. Int J Sports Physiol Perf 2017;1-24.

[30] Reale R, Slater G, Cox GR, Dunican IC, & Burke LM. The effect of water loading on acute weight loss following fluid restriction in combat sports athletes. Int J of Sport Nutr Ex Metab 2018;28:565-573.

[31] Saw AE, Main LC, Gastin PB. Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review. Br J Sports Med 2016;50:281-91.

[32] Ely BR, Sollanek KJ, Cheuvront SN, Lieberman HR, Kenefick RW. Hypohydration and acute thermal stress affect mood state but not cognition or dynamic postural balance. Euro J App Physiol 2013;113:1027-34.

[33] Mündel T, Hill S, Legg S. Hypohydration per se affects mood states and executive cognitive processing: results from a face-valid model for studying some consequences of' voluntary dehydration'. Extrem physiol med 2015;4:A97.

[34] Baird MF, Graham SM, Baker JS, Bickerstaff GF. Creatine-kinase and exercise-related muscle damage implications for muscle performance and recovery. J Nutr Metab 2012.

[35] Kunz-Ebrecht SR, Mohamed-Ali V, Feldman PJ, Kirschbaum C, Steptoe A. Cortisol responses to mild psychological stress are inversely associated with proinflammatory cytokines. Brain Behav Immun 2003;17:373-83.

[36] Wittbrodt MT, Sawka MN, Mizelle JC, Wheaton LA, Millard-Stafford ML. Exercise-heat stress with and without water replacement alters brain structures and impairs visuomotor performance. Physiol Rep 2018;6:e13805.

[37] Kempton MJ, Ettinger U, Foster R, Williams SC, Calvert GA, Hampshire A, Zelaya FO, O'Gorman RL, McMorris T, Owen AM, Smith MS. Dehydration affects brain structure and function in healthy adolescents. Hum Brain Mapp 2011;32:71-9.

[38] Hackney KJ, Cook SB, Fairchild TJ, Ploutz-Snyder LL Skeletal muscle volume following dehydration induced by exercise in heat. Extr Physiol Med 2012;1:3.

Acknowledgements.— The authors would like to acknowledge the professional fighters (and coaches) that took part, allowed insight and access to their fight preparation camps and official events.

TABLES

Table 1.— Typical weekly training schedule of a single MMA fighter. MA – martial arts, MMA – mixed martial arts, S&C – strength & condition, D&S – drills and sparring, S – sparring.

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
AM	MA specific – D&S (120 min)	Rest	MMA – S (90 min)	MA specific – D&S (120 min)	Rest	MMA – S (90 min)	MA specific – D&S (150 min)
PM	S&C (90 min)	MA specific – D&S (120 min)	S&C (90 min)	MA specific – D&S (120 min)	Rest	S&C (60 min)	Rest

Table 2.— Magnitude-based decisions for dependant variables across week 4 to 0.

	Week from fight					Direction and qualitative inference [ES] (log transformed ± 90 % CL)
Variable	**4**	**3**	**2**	**1**	**0**	
BM (kg)	77.12 ± 7.61	76.42 ± 7.44	76.2 ± 8.55	75.48 ± 8.21	75.6 ± 8.19	**P + :** 4 v 1 [0.19] (± 0.13), 4 v 0 [0.18] (± 0.15)
TL (AI)	3852 ± 738	4028 ± 817	4635 ± 1067	3969 ± 1097	2871 ± 433	**L +** : 4 v 3 [0.86] (± 0.97), 4 v 1 [1.05] (± 1.22) **VL +** : 3 v 0 [1.83] (± 0.94), 1 v 0 [1.63] (± 1.28) **ML +** : 4 v 0 [2.68] (± 0.70), 2 v 0 [2.6] (± 1.03)
CK (u/L)	1473 ± 453	1171 ± 487	1285 ± 738	1489 ± 1288	713 ± 667	**L +** : 4 v 3 [0.56] (± 0.40) **VL +** : 4 v 0 [3.24] (± 1.95), 3 v 0 [2.69] (± 1.92), 2 v 0 [2.69] (± 1.28) **ML +** : 1 v 0 [2.44] (± 0.53)
SC (ug/ml)	14.61 ± 4.49	15.7 ± 4.91	18.97 ± 9.11	16.76 ± 9.16	20.76 ± 13.48	**P - :** 4 v 3 [0.13] (± 0.24)
sIgA (ug/ml)	474 ± 202	532 ± 180	499 ± 110	240 ± 164	364 ± 157	**L + :** 2 v 0 [0.64] (± 0.63) **VL +** : 4 v 1 [1.39] (± 1.08), 3 v 1 [1.66] (± 1.21), 3 v 0 [0.71] (± 0.48), 2 v 1 [1.59] (± 0.89)
POMS (Overall)	16.2 ± 10.6	31.3 ± 15.5	33.8 ± 18.1	45.5 ± 22.0	35.3 ± 17.2	**P - :** 2 v 1 [0.32] (± 0.45) **L -** : 4 v 2 [0.85] (± 0.76), 3 v 1 [0.53] (± 0.68) **VL -** : 4 v 1 [1.17] (± 0.88), 4 v 0 [0.93] (± 0.71)
Depression	2.0 ± 1.0	3.1 ± 2.6	2.0 ± 1.8	8.0 ± 11.2	7.7 ± 6.3	**VL - :** 4 v 3 [1.57] (± 1.11), 4 v 1 [2.87] (± 2.51) **L +** : 3 v 2 [0.85] (± 0.70) **VL +** : 1 v 0 [0.7] (± 0.37)
Confusion	3.3 ± 1.0	5 ± 2.4	7.7 ± 1.9	7.6 ± 1.9	6.2 ± 4.8	**VL - :** 4 v 3 [0.86] (± 0.60), 4 v 2 [2.02] (± 1.13), 3 v 1 [1.16] (± 0.56) **ML -** : 4 v 1 [2.02] (± 0.74) **L -** : 3 v 2 [1.16] (± 1.16)
Tension	6.3 ± 5.4	8.3 ± 3.2	8.8 ± 4.9	13 ± 6.8	13.5 ± 5.5	**L - :** 4 v 2 [0.47] (± 0.39), 4 v 1 [0.82] (± 0.92), 3 v 1 [0.36] (± 0.41) **P +** : 1 v 0 [0.35] (± 0.47)
Fatigue	11 ± 7.9	13 ± 2.4	14.2 ± 5.1	10.7 ± 2.0	8.5 ± 5.5	**P + :** 3 v 0 [0.27] (± 0.32), 2 v 1 [0.22] (± 0.41)
Anger	8.3 ± 4.5	13.7 ± 8.5	10.8 ± 7.1	13.8 ± 5.7	10.7 ± 2.7	**L - :** 4 v 1 [0.7] (± 0.58), 4 v 0 [0.49] (± 0.53), 2 v 1 [0.63] (± 0.74)
Vigour	15.2 ± 5.4	12 ± 6.9	9.7 ± 6.3	9.7 ± 4.6	11.7 ± 7.5	**L + :** 4 v 2 [0.77] (± 0.67), 4 v 1 [1.01] (± 0.91)

Qualtitative inferences: L = Likely; VL = Very likely; ML = Most likely; P = Possibly; + = Increase; - = Decrease.

Table 3.— Magnitude-based decisions for dependant variables across final seven days.

	Day from fight							Direction and qualitative inference [ES] (log transformed ± 90 % CL)
Variable	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
BM (kg)	75.6 ± 9	75.8 ± 8	75.6 ± 8	74.9 ± 8	73.4 ± 7	71.8 ± 6	75.6 ± 8	**VL + :** 5 v 1 [0.38] (± 0.17), 4 v 1 [0.36] (± 0.16) **P -** : 2 v 0 [0.21] (± 0.13) **P +** : 5 v 2 [0.22] (± 0.13) **L +** : 6 v 1 [0.36] (± 0.17) **VL -** : 1 v 0 [0.37] (± 0.16)
UO (mOsml·kg-1H2O)	252 ± 133	153 ± 147	215 ± 148	524 ± 129	733 ± 158	1024 ± 176	506 ± 388	**VL - :** 6 v 3 [1.01] (± 0.52), 6 v 2 [1.4] (± 0.66), 5 v 0 [1.19] (± 0.81), 2 v 1 [0.39] (± 0.12) **ML -** : 6 v 1 [1.78] (± 0.70), 5 v 3 [1.65] (± 0.50), 5 v 2 [2.03] (± 0.65), 5 v 1 [2.42] (± 0.58), 4 v 3 [1.21] (± 0.45), 4 v 2 [1.6] (± 0.54), 4 v 1 [1.99] (± 0.82), 3 v 1 [0.77] (± 0.21) **L +** : 6 v 5 [0.64] (± 0.68), 2 v 0 [0.84] (± 1.01), 1 v 0 [1.23] (± 1.03) **L -** : 6 v 0 [0.56] (± 0.42), 5 v 4 [0.43] (± 0.52), 4 v 0 [0.76] (± 0.82), 3 v 2 [0.39] (± 0.24)
Fluid intake (L)	5.2 ± 2.4	5.8 ± 1.7	5.2 ± 1.4	2.5 ± 0.5	1.8 ± 0.7	0.6 ± 0.3	3.4 ± 1.3	**VL + :** 6 v 0 [0.78] (± 0.43), 4 v 0 [0.87] (± 0.39) **VL - :** 2 v 0 [1.15] (± 0.72) **ML - :** 1 v 0 [3.4] (± 1.03) **ML + :** 6 v 3 [1.26] (± 0.48), 6 v 2 [1.92] (± 0.61), 6 v 1 [4.18] (± 0.97), 5 v 3 [1.55] (± 0.39), 5 v 2 [2.21] (± 0.78), 5 v 1 [4.46] (± 0.87), 5 v 0 [1.06] (± 0.41), 4 v 3 [1.35] (± 0.39), 4 v 2 [2.01] (± 0.59), 4 v 1 [4.27] (± 0.72), 3 v 1 [2.92] (± 0.92), 2 v 1 [2.25] (± 0.76) **L + :** 3 v 2 [0.66] (± 0.6) **L - :** 3 v 0 [0.48] (± 0.53)
SC (ug/ml)	15 ± 7	11 ± 5	11 ± 4	10 ± 3	12 ± 5	23 ± 12	21 ± 13	**VL + :** 6 v 5 [0.47] (± 0.15) **VL -** : 4 v 1 [0.93] (± 0.38), 2 v 1 [0.91] (± 0.50) **ML -** : 5 v 1 [0.99] (± 0.38), 3 v 1 [1.1] (± 0.34) **L +** : 6 v 4 [0.41] (± 0.29), 6 v 3 [0.57] (± 0.38), 6 v 2 [0.39] (± 0.22) **L -** : 6 v 1 [0.52] (± 0.22)
sIgA (ug/ml)	555 ± 221	476 ± 298	507 ± 162	400 ± 142	324 ± 192	400 ± 294	364 ± 157	**L + :** 6 v 3 [0.46] (± 0.37), 6 v 2 [0.87] (± 0.71), 6 v 1 [0.87] (± 0.98), 4 v 3 [0.37] (± 0.25), 4 v 1 [0.78] (± 0.95), 3 v 2 [0.41] (± 0.41) **VL +** : 4 v 2 [0.78] (± 0.52)

Qualitative inferences: L = Likely; VL = Very likely; ML = Most likely; P = Possibly; + = Increase; - = Decrease..

Table 4.— Magnitude-based decisions for POMS and sub-scores across final seven days.

	Day from fight							Direction and qualitative inference [ES] (log transformed ± 90 % CL)
Variable	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
POMS (Overall)	22.8 ± 7.5	23.3 ± 7.1	20.2 ± 11.6	32.5 ± 21.5	40.8 ± 18.1	51.8 ± 12.4	35 ± 16.7	**L +** : 1 v 0 [0.87] (± 0.72) **VL -** : 6 v 1 [1.63] (± 0.75), 5 v 1 [1.55] (± 0.60), 4 v 2 [1.61] (± 1.26), 4 v 1 [2.21] (± 1.34), 4 v 0 [1.35] (± 1.04) **L -** : 6 v 2 [1.02] (± 0.88), 6 v 0 [0.77] (± 0.65), 5 v 2 [0.94] (± 0.89), 5 v 0 [0.68] (± 0.63), 3 v 2 [0.8] (± 0.79), 3 v 1 [1.41] (± 1.27), 2 v 1 [0.61] (± 0.57)
Depression	5.5 ± 3.2	5.5 ± 2.8	5 ± 3.4	6.3 ± 5.9	8.5 ± 7.3	12.3 ± 7.5	8.2 ± 6.3	**L - :** 6 v 1 [1.63] (± 1.81), 5 v 1 [1.56] (± 1.67) , 3 v 2 [0.45] (± 0.43) , 5 v 1 [1.56] (± 1.67) **VL -** : 4 v 1 [2.06] (± 1.35), 3 v 1 [1.97] (± 1.09), 2 v 1 [1.65] (± 1.16) **VL +** : 1 v 0 [1.53] (± 1.16)
Confusion	3.5 ± 0.8	4.2 ± 1.7	4.7 ± 1.9	7 ± 2.7	8.5 ± 4.6	10.2 ± 3.8	6.2 ± 4.8	**L - :** 6 v 4 [0.75] (± 0.69), 3 v 2 [0.4] (± 0.40), 2 v 1 [0.73] (± 0.63) **VL -** : 6 v 3 [1.94] (± 1.29), 6 v 2 [2.34] (± 1.52), 5 v 3 [1.72] (± 1.47), 5 v 2 [2.12] (± 1.63), 5 v 1 [2.86] (± 1.62), 4 v 3 [1.19] (± 0.93), 4 v 2 [1.59] (± 1.05) **ML -** : 6 v 1 [3.08] (± 1.09), 4 v 1 [2.32] (± 0.88), 3 v 1 [1.13] (± 0.44) **VL +** : 1 v 0 [2.23] (± 1.55) **L +** : 2 v 0 [1.49] (± 1.29)
Tension	9.2 ± 3.3	10.3 ± 2.1	11.2 ± 3.1	10.8 ± 3.1	11.5 ± 3.0	12.5 ± 4.2	13.5 ± 5.5	**L - :** 6 v 5 [0.37] (± 0.36), 6 v 3 [0.41] (± 0.57), 6 v 2 [0.6] (± 0.53), 6 v 0 [0.84] (± 0.81), 3 v 0 [0.43] (± 0.58) **VL -** : 6 v 4 [0.53] (± 0.32)
Fatigue	7.5 ± 2.0	6.8 ± 1.9	5.2 ± 2.9	10.7 ± 5.3	9.8 ± 3.7	11.5 ± 2.7	8.5 ± 5.5	**VL - :** 6 v 1 [1.25] (± 0.91), 6 v 0 [0.93] (± 0.62), 5 v 1 [1.54] (± 0.86), 5 v 0 [1.2] (± 0.71), 4 v 1 [2.81] (± 1.79), 4 v 0 [2.57] (± 1.65) **P +** : 6 v 5 [0.28] (± 0.28) **L +** : 5 v 4 [1.28] (± 1.39) **VL +** : 6 v 4 [1.56] (± 1.35)
Anger	9.5 ± 5.1	9 ± 4.5	9 ± 4.8	8.5 ± 6.3	10.8 ± 6.0	12.5 ± 6.8	10.7 ± 2.7	**P - :** 3 v 2 [0.3] (± 0.37)
Vigour	12.3 ± 3.1	12.5 ± 3.0	7.5 ± 1.9	7.9 ± 2.7	8.1 ± 4.5	8.8 ± 3.8	7.7 ± 4.8	**L - : 6** v 4 [0.47] (± 0.63), 5 v 4 [0.42] (± 0.57) **VL -** : 1 v 0 [1.66] (± 1.34) **L +** : 5 v 3 [0.64] (± 0.73) **VL +** : 6 v 2 [1.57] (± 1.21), 6 v 1 [2.41] (± 2.01), 5 v 2 [1.61] (± 1.28), 5 v 1 [2.45] (± 2.03), 4 v 3 [1.06] (± 0.6), 4 v 2 [2.04] (± 1.38), 4 v 1 [2.88] (± 1.61)

Qualitative inferences: L = Likely; VL = Very likely; ML = Most likely; P = Possibly; + = Increase; - = Decrease.

FIGURES

Week	W4	W3	W2	W1	W0					
Day from fight day	D28	D21	D14	D7	D6	D5	D4	D3	D2	D1	D0
Variables	BM sIgA SC CK TL POMS	BM sIgA SC CK TL POMS	BM sIgA SC CK TL POMS	BM sIgA SC CK TL POMS	BM UO sIgA SC TL POMS	BM UO sIgA SC TL POMS	BM UO sIgA SC TL POMS	BM UO sIgA SC TL POMS	BM UO sIgA SC TL POMS	BM UO sIgA SC TL POMS	BM UO sIgA SC CK TL POMS

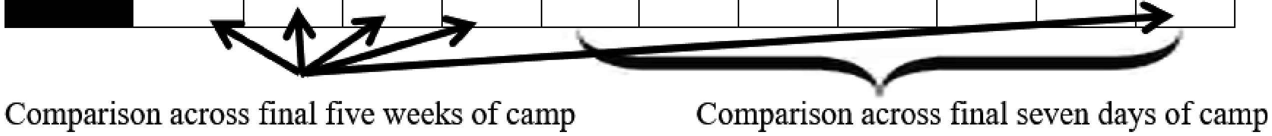

Figure 1.— Research Design – 11 testing points across 5 weeks. Body Mass (BM), Urine Osmolality (UO), Salivary Immunoglobin-A (sIgA), Salivary Cortisol (SC), Creatine Kinase (CK), Training Load (TL), Profile of Moods State (POMS).