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The Effect of Water Loading for Acute Weight Loss Following Fluid Restriction on Sleep Quality and Quantity in Combat Sports Athletes

Original Research

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Abstract
Introduction: Combat sport athletes commonly engage in established and novel acute weight-loss strategies to achieve weight division targets. The effect of such practices on sleep is unknown.
Methods: Twenty-two combat sports athletes wore wrist actigraphy devices for nine nights during a training camp and completed questionnaires assessing daytime sleepiness, insomnia, sleep apnoea and chronotype. Athletes were assigned to a control (CG) or water loading group (WLG). Both followed a low residue diet for 96h, and restricted fluid for 24h before weigh-in. Prior to restriction, the CG consumed 40ml/kg and WLG consumed 100ml/kg fluid daily.
Results: Four athletes responded positively for the potential prevalence of sleep apnoea (2 CG/WLG), reporting subthreshold insomnia 8±4, athletes were assessed as having an "intermediate chronotype". Sleep latency estimates in CG were longer on days 4/6 relative to 3 ($p<0.05$). There was a between-group difference for sleep latency on day 6, with CG taking 35 mins longer (95% CI 5-64mins, $p=0.022$) to fall asleep.
Conclusion: Acute weight loss by means of a low residue diet, both with and without water loading before the fluid restriction is a safe and effective means of manipulating body mass to in the context of sleep.

Key Words: Weight-Cutting, Body Composition, Athlete Monitoring

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Introduction

Combat sports include those such as Boxing, Taekwondo, Karate, Muay Thai, Judo, Wrestling, Brazilian Jiu-Jitsu (BJJ), Sambo and Mixed Martial Arts (MMA) in which athletes compete against one another with the general goal of disabling or outscoring their opponent. Many combat sports are weight category sports, meaning that athletes must compete within a pre-determined specified weight class that has been established to create 'an even playing field' in which no competitor has a significant size or strength advantage. In order to enforce the class regulations, athletes must attend an 'official weigh-in' at some point before a competition (commonly ranging from 0-24 h before a competition) to have their weight verified.

It is common for athletes to compete in a weight class lower than their day-to-day training/walking-around weight to gain an advantage over smaller opponents during the competition. Athletes achieve this via both chronic and acute weight-loss strategies in the lead up to the competition. A chronic weight loss strategy involves dietary calorie reduction with increased physical activity (typically starting 4-6 weeks from competition) and is followed by a more acute approach consisting of various forms of food restriction, increased exercise, and dehydration (several days before the competitive event). These and other measures result in reductions in overall body weight, body water (including that bound to glycogen), and gut content [1]. This practice is commonly known as *"cutting weight"*. Following the official weigh-in and before a competition, athletes usually recover to their previous weight via rehydration and refuelling strategies.

After acute weight loss, athletes are advised to individualise their body composition management based on personal experience, the requirements of their sport and time available for post-weigh-in recovery. Acute weight loss efforts need to be balanced against performance decrements and health concerns. A detailed discussion of acute weight loss physiology is beyond the scope of this manuscript. However, evidenced-based best-practice methods include the adoption of a low fibre/low residue diet in the 2-3 days prior to weigh-in, and mild to moderate body water losses in the 24h prior to weigh-in, with more aggressive techniques being used as a 'last resort' and only when sufficient recovery time is available [2]. One of the more aggressive strategies that have garnered attention in recent years is the practice of 'water loading'. This process of fluid manipulation has been used as an effective method to reduce body mass in the seven days before a competition [2]. One empirically-proven fluid manipulation strategy requires the athlete to consume excess water based on their body mass (BM) for 3-5 days (100mL per kg BM) followed by a period of water restriction (15mL per kg BM) [3].

A potential consequence of the process of water loading is nocturia, waking to urinate during the sleep period. If occurring regularly, such awakenings could cause fragmentation of an athlete's standard sleep patterns and result in them spending more time awake during the sleep period. Given the importance of sleep for athletic performance [4], particularly in the days leading up to a competition, it is possible that water loading and the associated nocturia could potentially negatively affect performance [5,6]. To date, little is known about the effects of acute weight loss, including protocols that incorporate water loading, on sleep quantity or quality [4], anything that disrupts pre-competition sleep is contraindicated [6].

Therefore, this study aimed to examine the effects of best practice pre-competition acute weight loss protocols with and without water loading on sleep quality and quantity. The primary hypothesis of this study was that athletes engaging in water loading as part of an acute weight loss protocol would have decreased sleep quality and quantity compared to athletes who engage in protocols that do not involve water loading.

Methods

Participants

Twenty-two trained combat sports athletes from grappling disciplines of either Judo, Wrestling, BJJ and or MMA based in Australia, volunteered to take part in the study at the Australian Institute of Sport (AIS), Canberra, Australia. Athletes were invited from any of these grappling disciplines who regularly trained, 3-4 times a week regardless of status (professional or amateur). Approval for the study was obtained from the Human Research Ethics Offices of The University of the Sunshine Coast, the AIS and the University of Western Australia. Written informed consent was obtained from all athletes before their participation.

Protocol

This study was conducted at the AIS Combat Centre over nine days, with eight nights of sleep monitoring. Athletes were randomised to two different groups; Control Group (CG) and the Water Loading Group (WLG). All athletes for this study slept within a segregated accommodation block at the AIS athlete village and were assigned to their room. At the commencement of the study (day 1), athletes completed an online survey instrument that included questions relating to sleep, sleep disorders, caffeine and alcohol consumption. Athletes wore wrist-activity monitors to collect objective measures of sleep. This particular study was part of a broader study that investigated the effect of water loading on acute weight loss in combat sport athletes and collected and analysed measures relating to blood pressure, heart rate, gastrointestinal symptoms, hormone analysis, urine collection and analysis, body mass changes and physical performance [2].

Figure 1. The 9-day study was conducted in three phases

FAMILIARISATION PHASE			EXPERIMENTAL PHASE					END OF STUDY
Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**
Arrival at AIS	Baseline testing	Baseline testing	**Water loading phase**	**Water loading phase**	**Water loading phase**	**Water restriction**	**Water restriction/ rehydration**	**Rehydration**
(n=22)	WLG (n=12) Control (n=10)	WLG (n=12) Control (n=10)	WLG (n=12) Control (n=10)	WLG (n=11) * Control (n=10)	WLG (n=11) * Control (n=10)	WLG (n=11) * Control (n=10)	WLG (n=11) * Control (n=10)	Final day (n=21)
Assigned to groups	Physical testing familiarisation	Pre-Study physical testing	Grappling training (10:00-12:00 & 15:00-17:00)	Grappling training (10:00-12:00 & 15:00-17:00)	Grappling training (10:00-12:00 & 15:00-17:00)	Grappling training (15:00-17:00)	Final weight cut (09:00-12:00)	Post-Study physical testing
Issue wrist-activity monitors to measure sleep Administer the sleep survey instrument 19:00-21:00	Blood Pressure & Heart Rate (07:00-08:30) & (17:00-18:30)	Blood Pressure & Heart Rate (07:00-08:30) & (17:00-18:30)	Blood Pressure & Heart Rate (07:00-08:30 & 17:00-18:30)	Blood Pressure & Heart Rate (07:00-08:30 & 17:00-18:30)	Blood Pressure & Heart Rate (07:00-08:30 & 17:00-18:30)	Blood Pressure & Heart Rate (07:00-08:30 & 17:00-18:30)	Blood Pressure & Heart Rate (07:00-08:30 & 17:00-18:30)	Blood Pressure & Heart Rate (07:00-08:30)
Measures of sleep from wrist-activity monitors	Measures of sleep from wrist-activity monitors	Measures of sleep from wrist-activity monitors	Measures of sleep from wrist-activity monitors	Measures of sleep from wrist-activity monitors	Measures of sleep from wrist-activity monitors	Measures of sleep from wrist-activity monitors	Measures of sleep from wrist-activity monitors	

Figure 1: Experimental overview
*One athlete removed due to a potential concussion.

Familiarisation phase (days 1-3): On day 1, athletes were assigned to either a control group (CG) that consisted of following a low-residue diet or an experimental group (WLG) that consisted of following a low-residue diet plus water loading. Each athlete's sleep was objectively measured via a wrist actigraphy device throughout the nine days. Athletes also completed an online survey instrument that included questions relating to sleep, sleep disorders, sleep medication, health status and alcohol consumption to collect baseline data.

Experimental phase (days 4-8): On days 4-7, athletes attended a morning (10:00-12:00) and afternoon training session (15:30-17:30) in the discipline of either Judo, Wrestling or BJJ. On day 8 athletes completed no training (simulating the typical pre-competition weigh-in day).

All participants in the CG and the WLG were administered a standardised diet throughout the experimental phase of the study (days 4-8). In this phase, the standardised diets provided an energy content of 125 kJ/kg FFM^{-1} to meet resting requirements, plus additional energy to account for exercise-induced thermogenesis, representing a mild energy restriction, maintaining moderate energy availability protein 2.2-2.5g/kg FFM^{-1}, carbohydrate 5-6g/kg FFM^{-1} and fat 1-2 g/kg FFM^{-1}. Sodium prescription was 300mgMj^{-1} and fibre 10-13g, representing a low residue diet.

On days 4-6 of the study; the WLG consumed 100mL/kg body mass (BM) of fluid (water). This is defined as the "Water Loading Phase", with the CG consuming 40mL/kg BM of fluid. On day 7, both groups followed the same fluid restriction, reducing consumption to 15mL/kg BM of fluid. On day 8, no fluid was consumed until after the morning laboratory data collection, after which both groups followed the same recovery fluid prescription. This was calculated as 30mL/kg BM +150% of the body mass loss from the start of the fluid restriction (morning of day 4) until the present point. Participants were provided with instructions throughout the day (a millilitre per hour target) to disperse the fluid consumption evenly throughout the day to rehydrate.

End of study (day 9): Wrist-activity monitors were collected at this time. The study concluded at 13:00 on day 9.

Specific measurements
Anthropometric and physiological measurements
Measurements of each athlete's height (cm), weight (kg), neck circumference (cm) and Body Mass Index (BMI), calculated from weight/height^2 (kg/m^2) were obtained on day 2 of the study.

Sleep disorder questionnaires

Insomnia was assessed using the validated Insomnia Severity Index (ISI). The ISI consists of five separate questions that ask the participant to self-rate their own experience with insomnia, each with a scale of 0-4. The questions relate to severity, satisfaction, noticeability and worry or distress associated with their insomnia. Scores were aggregated and assessed against a criterion. A score >15 indicates clinical insomnia [7].

Daytime sleepiness was assessed using the Epworth Sleepiness Scale (ESS). The ESS is a self-reported scale that asks how likely an individual is to doze off or fall asleep in everyday daytime situations. Scores >9 indicate excessive daytime sleepiness [8].

Obstructive Sleep Apnoea (OSA) risk was assessed using the Berlin questionnaire [9], which assigns the risk of OSA based on the presence and frequency of snoring behaviour; wake time sleepiness or fatigue and a history of obesity and hypertension. A positive response to two or more of these categories indicates risk for OSA.

Morning-Eveningness Questionnaire (MEQ) is a self-reported questionnaire which assesses chronotype [10]. It consists of 19 questions regarding the time of day, alertness, and sleepiness, with answers ranging from 0-4 to 0-6 depending on the specific question. Scores between; 16-30 indicate a definite evening type; 31-41 indicates evening type; 42-58 intermediate; 56-69 moderate morning; 70-86 indicates definite morning type.

Sleep-wrist activity monitors

A wrist-activity monitor, the Readiband™ (v3, analysed using Readiband Sync™) (Fatigue Science Inc., Canada) was issued to each athlete at 20:00 on day 1. The wrist-activity monitor was worn on the non-dominant wrist throughout the 9-days, including during training sessions. These devices have been shown to compare favourably both to in-laboratory gold standard polysomnography (PSG) and another widely used and validated wrist-activity monitor, the ActiGraph™ [11]. The Readiband has been shown to have an epoch-to-epoch sleep/wake scoring accuracy of 82%, a sensitivity of 88% and a specificity of 55% in comparison to the gold standard in-laboratory PSG [12]. The Readiband has been used in numerous sports-related research studies [13,14] and has been approved by the Federal Drug Administration [15] for the measurement of physical activity and sleep.

The wrist-activity monitors (Readiband) were downloaded and analysed using the automated Readiband Sync™ software and its proprietary algorithm. Sleep measures derived included: time in bed (the total time spent in bed, from lights out to time at wake); time at sleep onset (the time the person initiated sleep); sleep latency (time between lights out and sleep onset); sleep duration (time between sleep onset and wake, minus any time awake during this period); fragmentation index (number of awakenings after sleep onset until time at wake); wake after sleep onset (WASO) (time spent awake after sleep onset and before final waking time); time at wake (time of final waking, not followed by any additional sleep) and sleep efficiency (percentage of time spent asleep whilst in bed: sleep duration/time in bed minus sleep latency and WASO).

Statistical Analysis

A linear mixed model approach was used to examine the impact of day and treatment group (WLG or CG) on the sleep responses, bodyweight, neck and leg circumference data. In instances where measures were taken in the morning and afternoon, an average of these was taken for analyses purposes. Fixed effects of day, treatment and their corresponding interaction were used along with random individual effects, and an appropriate correlation structure was investigated and used. Between-group comparisons are made on each day, and within-group comparisons, to either day 3 or some other relevant reference point are made. Raw data are presented as mean ± standard deviation (SD) for each group and modelling results are expressed as least square means and standard errors for treatment by day combinations or differences and least-square means and 95% confidence intervals. An unpaired t-test was used to compare the response of sleep disorder questionnaire data between groups. Analyses were undertaken using SAS Software version 9.4 and all graphics produced using the R environment for statistical computing.

Results

Twenty-two athletes were initially enrolled, due to a potential concussion during an afternoon training session on day 5, one athlete was removed from the WLG based upon a medical doctor's advice. Thus, for analysis 11 participants were included in the CG and 10 were included in the WLG.

Anthropometric and athlete data

Overall (n=21), athletes had an average weight of 78±9kg, height 177±1cm, and age of 27±4years. The WLG (n=10) had an average weight of 79±8kg, height 176±1cm, and age of 28±4years and the CG (n=11) had an average weight 78±9kg, height 178±1cm, and an age of 25±4years **(Table 1)**. All athletes were experienced in grappling, with experience ranging from 2-10 years. Alcohol use and sleep medication use were all within normal ranges. Athletes self-reported their health status from good to excellent and rated sleep as extremely important or important. There were no statistical differences between the groups for any of the anthropometric and athlete data.

Table 1: Baseline descriptive characteristics

	Overall n=21	CG n=11	WLG n=10
Demographic information			
Age (years)	27±4	25±4	28±4
Weight (kg)	78±9	78±9	79±8
Height (cm)	177±1	178±1	176±1
Body Mass Index (BMI)	25±2	25±2	25±2
Grappling experience (years)	6±3	5±2	6±4
Alcohol (score)	4±3	4±2	3±3
Health status (count)			
Excellent	6	3	3
Very Good	9	3	6
Good	6	3	3
How would you rate the importance of sleep on your recovery (count)			
Not important at all	-	-	-
Somewhat important	2	2	-
Important	7	2	5
Extremely important	12	6	6
Sleep medication to get to or stay asleep (count)			
Nearly every day	2	1	1
3-4 times per week	1	-	1
1-2 times per week	-	-	-
1-2 times per month	1	1	-
Never	17	8	9
Sleep disorders			
Berlin questionnaire (positive response)		2	2
Epworth Sleepiness Scale (ESS)		5±3	6±3
Insomnia Severity Index (ISI)	8±4	8±2	9±3
Morning-Eveningness Questionnaire (MEQ)	46±6	46±4	45±8

Table 1: Depicts the descriptive data as collected from the paper-based survey instrument. Data presented as Means with Standard Deviations (SD)
±SD of the mean. There were no statistical differences found between groups. **CG:** Control Group, **WLG:** Water Loading Group.

Sleep-related questionnaires

Athletes in both groups reported sub-threshold *insomnia* (ISI score 8-14) **(Table 1)** with no *excessive daytime sleepiness* (ESS score >10) reported. Two athletes in each group (WLG and CG were identified as being at risk for *OSA* (Berlin questionnaire positive in ≥2 categories). Athletes in both groups indicated an intermediate chronotype from the *MEQ* with an overall average score of 46 (42-58 indicates intermediate chronotype). There were no statistical differences between the groups.

Sleep-wrist activity monitor data

Overall, nightly **sleep latency** (Time to fall asleep) was on average, 34±32 mins per night. On the night of day 4, sleep latency was estimated to be the longest for the CG at 58mins (95% CI 37-80 mins) and was the longest for the WLG on the night of day 7 at 46 mins (95% CI 26-67) **(Figure 2).** For the WLG there were no differences within the groups compared to the night of day 3 (end of the familiarisation phase), however, for the control group days, 4 and 6 showed higher sleep latency estimates compared to day 3 (both $p<0.05$). On the night of day 6, there was a statistical difference between the groups for sleep latency, with the CG taking on average 35 mins (95% CI 5-64mins, $p=0.022$) longer to fall asleep compared to the WLG.

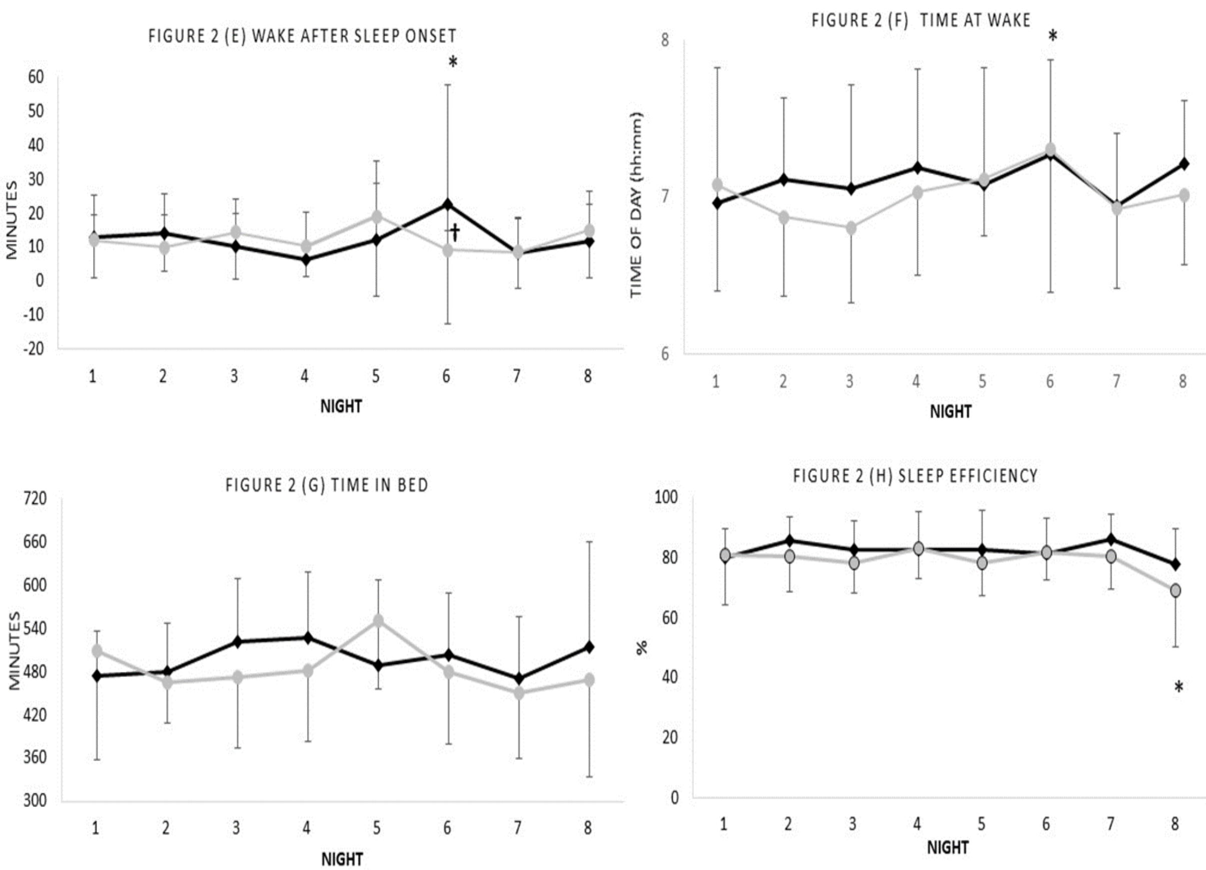

Figure 2 (a-h): Measures of sleep on Nights 1-8. *Control-Group* (solid black line) and the *Water Loading Group* (grey line). Data presented as mean ±SD, * $P<0.05$ v night 3, †$p<0.05$ difference between groups.

Overall the time at sleep onset (the time they fell asleep) was on average 23:30±1:22 hh:mm per night. On the night of day 8 (the last night); both groups had their latest time at sleep onset during the study at 00:37 hh:mm respectively with the CG had a later time at sleep onset by 121 mins (95% CI 61-180, $p<0.001$) and the WLG by 74 mins (95% CI 18-156, $p=0.011$) compared to day 3. There were no statistical differences between groups on any night.

Overall, sleep duration was on average 389±90 mins per night, with the WLG achieving 373 ±95 mins and the CG achieving 408±82 mins. There were no significant differences between groups for sleep duration and the only differences within groups compared to day 3 was observed for the CG on day 8 who achieved on average 73 mins more sleep (95% CI 17-128, p=0.011). Note the WLG achieved on average 52 mins more sleep on day 8 compared to day 3 (p=0.056).

Overall, the fragmentation index (number of awakenings during sleep) was on average 3±2 times per night for both groups, respectively. The only significant difference between the groups occurred on day 6 when the fragmentation index was an average of 2 units (95% CI 0-4, p=0.037) higher in the WLG compared to the CG.

Overall, WASO (duration of awake time overnight) was on average, 12±13 mins per night (Figure 3). On the night of day 6, the CG spent an estimated 13mins (95% CI 1.8-25mins, p=0.024) longer awake than the WLG. Comparing within groups, only day 6 in the CG was statistically significantly different to day 3 (estimated difference 12 minutes, 95% CI 1-23 mins, p=0.031).

Overall, the time at wake (the time they woke up in the morning) was on average 06:34±45 hh:mm each day with the WLG awakening on average at 06:31±33 hh:mm and the CG awakening on average at 06:36±37 hh: mm. There were no statistical differences between groups on any night and within groups, only the WLG on day 6 was significantly different to day 3 (estimated difference 0.50 hours, 95% CI 0.03 to 0.97 hours, p=0.039).

Overall, time in bed was on average 490±99 mins per night with the WLG spending 485±103 mins and the CG spending 485±103 mins on average per night in bed. There were no statistical differences between or within groups on any night.

Overall, sleep efficiency (a measure of sleep quality) was on average 81±12% with the WLG achieving an average of 79±12% and the CG achieving an average 82±11%. There were no statistical differences between and within groups, only the WLG on day 8 was statistically significantly different to day 3 (estimated difference 10.1, 95% CI 2.2-18.0, p=0.012).

Discussion

This is the first investigation to assess the sleep of combat-sport athletes during acute weight loss and to compare differences in two weight-loss strategies. The main findings were (1) acute weight loss did not affect sleep, and (2) the different methods of acute weight loss examined in this study did not differentially affect sleep. Therefore, at least regarding the pre-competition dietary strategies investigated here, losing weight via low-residue diets either with or without water loading appears unlikely to exert a sleep-loss-related performance reduction in combat athletes.

While the sleep duration of athletes in this study was quite low compared to the recommendations by the Sleep Health Foundation (7-9 h) [16] with 6 h 13 mins for the WLG and 6 h 48 mins for the CG; these values are similar to those reported in other grappling athletes (6-7 h) [13]. A potential explanation for these less-than-optimal sleep quantities may involve the athletes' chronotypes and the time at which they were required to awaken each morning. The athletes in the present investigation had a chronotype classified as "intermediate" as assessed by the MEQ. A chronotype of "intermediate" means a person will generally wake between 07:30-09:30. In this study, the athletes were required to be awake at 06:30 each morning to attend the physiology laboratory for testing between 06:30-07:00. These observed early morning "time at wake" values are earlier than their assessed chronotype and may explain the relatively low values of sleep duration of 6.5 h per night. Such early morning "time at wake" reduces the opportunity for sleep duration. To facilitate an increase in sleep duration (7-9 h) a delay in morning wake times to 07:30 would be required at home or in other training environments.

Of greater interest than overall sleep duration are the findings regarding the effects of the two different weight-loss strategies. Although it was hypothesised that excessive water consumption associated with the water-loading strategy might lead to nocturia by way of sleep onset or maintenance insomnia, no such evidence was found either in the self-reported measures of insomnia from the ISI and or measures of WASO and fragmentation index as assessed by the Readiband. Whilst there was a statistical difference in the number of awakenings on night 6 by two events, this change is not clinically relevant. In addition, the duration of these awakenings was not reflected in the duration of WASO. In contrast, the CG spent more time awake throughout the time in bed than the WLG.

Sleep latency was high overall for both groups and was greater than the clinical normative values of 10-20 mins, with sleep latency ranging from 17-53 mins throughout the study. It is of interest that the CG had extremely high values of sleep latency with large standard deviations on the 1st night of the experimental phase (day 4) and on the 3rd night of the experimental phase compared to the WLG (day 6) although not statistically significant between groups. This may be in part due to the low fibre diet in the CG, which is associated with an increase in the time to fall asleep (sleep latency) [17]. Another potential factor contributing to these relatively high values of sleep latency may be the Readiband device. The Readiband device has been shown to overestimate sleep latency, as such measures of sleep latency should be interpreted with caution [11].

It is interesting that water loading did not have adverse effects on sleep since the sheer volume of fluid consumed by those in the water-loading group would have increased the probability of nocturia. Nocturia has been identified as a significant cause of disturbed sleep, and in fact, a study of older adults (55-84 years old) indicated that 53% of respondents experienced nocturia-related sleep disturbances nearly every night [18]. Perhaps, the younger age of the participants in the present investigation (27 years old) was at least in part responsible for our failure to corroborate the earlier findings.

Beyond the nocturia-related concerns, we also observed that being dehydrated (following fluid restriction) did not affect any measures of sleep. This supports a recent PSG study which revealed no significant differences in any indices of sleep quality and quantity between a dehydration and euhydration scenario similar to those in the present study, strengthening the claim that dehydration (at least to the degree in this study) does not affect sleep [19.]

Limitations

A significant limitation of this study was the inability to replicate the actual week leading up to a competitive fight. Generally during this week athletes would not only have to reduce body weight but in the case of professional or Olympic athletes, they may have media engagements such as press conferences, radio, podcasts and television to promote the fight. However, the strength of this study was to remove these variables to study the effects of acute weight loss alone and the effect on measures of sleep quantity and quality.

Conclusion

This study highlights that sleep latency may be as a result of the low residue diet in the CG, this may be further affected in a real-life context leading up to a competition and as such non-pharmacological strategies to promote sleep should be considered. Also, early morning time at wake for testing and or training should be delayed creating an opportunity to increase sleep duration. In conclusion, the process of making weight using a low residue diet, both with and without water loading before the fluid restriction is a safe and effective means of manipulating body mass in the context of sleep.

Media-Friendly Summary

Acute weight loss (weight cutting) has received a lot of attention in recent years with several athletes suffering the adverse effects of acute weight loss in the week prior to a fight. Whilst research and our understanding of acute weight loss techniques is increasing; we still don't know how combat sport athletes sleep. Sleep is the number one free recovery tool, however many combat sport athletes report that they don't sleep well due to a number of factors such as; increase in training load, time of day of training, media commitments, acute weight loss and nerves in the week before a fight. In this study, we observed two methods that are commonly used (1) low fibre diet and (2) water loading. Whilst it was thought that the water loading might lead to more awakenings to go to the bathroom, it did not. What we did find is that combat sport athletes don't sleep very well, with all athletes only achieving 6.5 hrs. of sleep per night.

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