Acute Weight Loss Strategies for Combat Sports and Applications to Olympic Success

Link to publication record in USC Research Bank:
http://research.usc.edu.au/vital/access/manager/Repository/21748

Document Version:
Author accepted manuscript (postprint)

Citation for published version:

Copyright Statement:
Copyright © 2016 Human Kinetics. Reproduced here in accordance with the publisher’s copyright policy.

General Rights:
Copyright for the publications made accessible via the USC Research Bank is retained by the author(s) and / or the copyright owners and it is a condition of accessing these publications that users recognize and abide by the legal requirements associated with these rights.

Take down policy
The University of the Sunshine Coast has made every reasonable effort to ensure that USC Research Bank content complies with copyright legislation. If you believe that the public display of this file breaches copyright please contact research-repository@usc.edu.au providing details, and we will remove the work immediately and investigate your claim.
1. Title page

Title: Acute weight loss strategies for combat sports and applications to Olympic success

Submission Type: Invited brief review

Authors: Reid Reale¹,², Louise M Burke¹,³, Gary Slater²
1 Australian Institute of Sport, Canberra, Australian Capital Territory, Australia
2 University of Sunshine Coast, Sippy Downs, Queensland, Australia
3 Australian Catholic University, Melbourne, Victoria, Australia

Address for correspondence:
Reid Reale
Australian Institute of Sport
Telephone: +61 422 831 719
E-mail: reid.reale@ausport.gov.au

Running Head: Acute weight loss in combat sports

Abstract/summary Word Count: 147 words
Text-Only Word Count: 5496
Number of Figures and Tables: 1 figure 2 tables
2. Abstract / summary

It is common for athletes in weight category sports to try to gain a theoretical advantage by competing in weight divisions which are lower than their day-to-day body mass (BM). Weight loss is achieved not only through chronic strategies (body fat losses) but also through acute manipulations prior to weigh-in (“making weight”). Both have performance implications. In this review we focus on Olympic combat sports, noting that the varied nature of regulations surrounding the weigh-in procedures, weight requirements and recovery opportunities among these sports provide opportunity for a wider discussion of factors that can be applied to other weight category sports. We summarise previous literature which has examined the performance effects of “weight making” practices before investigating the physiological nature of these BM losses. Practical recommendations in the form of a decision tree are provided to guide the achievement of acute BM loss while minimising performance decrements.
3. Contents

Section 1.
Introduction
  - Weight categories and weight loss
  - Methods, prevalence and magnitude of acute weight loss
  - Performance implications of acute weight loss
  - Recovery from acute weight loss

Section 2.
Understanding the physiology of acute weight loss
  - Body water and acute weight loss overview
  - Respiration and water loss
  - Urination and water loss
  - Sweating and water loss
  - Sodium intake and water loss
  - Glycogen, bound water and acute weight loss
  - Gut contents and acute weight loss

Section 3.
Conclusions and practical applications
4. Text

Section 1.

Introduction

In a number of sports, athletes compete in defined weight divisions designed to match competitors according to body mass (BM) as a proxy for body size. This regulation creates a number of unique challenges and practices related to the manipulation of BM around competition which must be integrated into sports nutrition goals and performance considerations. It is beyond the scope of this review to provide an in-depth commentary on the specific issues in all such sports; however, weight category sports on the Olympic Games Program are of interest. These sports, which feature only at the Summer Games, include rowing, weight lifting and the majority of combat sports (i.e. boxing, taekwondo, judo, freestyle wrestling and Greco-Roman wrestling). Indeed at the 2016 Rio Olympic Games, combat sports will make up 53 of the 306 available gold medals; consequently empirically based guidelines focusing on this population will benefit a large cohort of athletes and support staff. The aim of this paper, therefore, is to investigate the specific features of weight-making in Olympic combat sports. We note that the varied nature of regulations surrounding the weigh-in procedures, weight requirements and recovery opportunities among these sports will provide opportunity for a wide discussion of factors that can be applied to other weight category sports.

Weight categories and weight loss

Weight divisions have been established to create ‘an even playing field’ in which competitors are matched for physical size (BM). Official ‘weigh-ins’ are held prior to a competitive event, and also on subsequent days in multi day competitions, to certify that athletes have met the requirements of their intended competition division (known as ‘making weight’). The duration of the period between weigh-in and competition varies according to the rules of sport, and dictates the opportunity to undertake strategies to recover from acute weight loss (AWL) practices often implemented to achieve the BM target. In the case of boxing, which instigates a morning weigh-in, recovery time can range from three hours for athletes who fight in the first bouts of the day to twelve hours for competitors in the later bouts. In judo, wrestling and taekwondo, weigh-ins held the evening prior to competition may provide an interval of 24 hours. These time frames contrast with conditions in the other Olympic weight category sports (lightweight rowing and weightlifting) in which there is a fixed period of two hours between weigh-in and competition. Despite the original intention of matching opponents by size, athletes recognise the opportunities provided by the weigh-in format: it is common for fighters to reduce BM using both chronic and acute techniques to qualify for a weight division that is lighter than their ‘natural’ or day-to-day BM, thus gaining a theoretical advantage in size/strength/leverage over smaller opponents. Furthermore, in the Olympic combat sports, where the intervals between the lighter weight divisions are smaller in absolute terms (Table 1), there is a potential ‘temptation’ for smaller athletes to engage in larger relative AWL. Indeed, there is evidence that those competing in the lighter weight divisions achieve weight loss of greater magnitude (kg) than those in heavier weight divisions \(^1,2\), indicating that many athletes intend to compete in the lightest weight division possible.

Table 1.

Professionals who work with these athletes should gain an understanding of current BM manipulation practices, the physiological attributes and consequences of chronic and AWL,
as well as the weigh-in procedures and competition format of Olympic combat sports (Table 2).

**Table 2.**

Thorough reviews of the research of weight loss practices and the effects on health and performance outcomes for athletes have been published in the past, examining chronic and acute strategies in the wider athlete population as well as the specific issue of AWL practices in combat sport athletes. It is clear is that both chronic and AWL practices are associated with negative outcomes. In terms of chronic practices, the International Olympic Committee recently released a consensus statement detailing the issue of chronic energy deficits in athletes attempting to chronically manage BM and the potential detrimental effects on; lean mass maintenance, immune function, bone health, metabolic rate and hormonal processes. Although this statement is applicable to a wide variety of athletes who manipulate their BM and composition to improve power to weight ratios, the unique feature of combat sports (and other weight category sports) is the superimposition of the AWL phase around competition.

Acute weight loss or ‘weight cutting/making’ is an ingrained practice in combat sports. Indeed, one study has reported that its prevalence is twice as high as the use of gradual weight loss strategies. Combat athletes report that coaches and team mates, as well as their personal desire to win, are the biggest influences on their decisions regarding weight loss efforts. From their perspective, weight making provides more than a physical advantage over an opponent. Qualitative research indicates that athletes derive a sense of ‘sport identity’ and the feeling of being ‘a real athlete’ from the weight making process. Furthermore, it may serve as a coping strategy and create an increased sense of focus and commitment.

In contrast to the real and/or perceived competitive benefits, many negative consequences may arise from AWL. In November 1997 three America wrestlers died while “making weight” via food and fluid restriction, the use of vapour impermeable suits and exercise in a hot and humid environment. This prompted rule changes in the national competition, including reducing the recovery time post weigh-in as well as identifying a ‘minimum wrestling weight’ (MWW) based on pre-season body composition measurements, which have been associated with a decline in extreme AWL practices in this cohort. Position statements from the American College of Sports Medicine, The Association of Ringside Physicians and the National Athletic Trainers Association warn against extreme practices and recommend rule changes to discourage specific weight loss techniques and large magnitudes of AWL as well as recommending minimum body fat levels of 5% and 12% in males and females respectively. However these are yet to influence Olympic competitions; with many athletes who change their weight loss practices to suit the new rules for national competitions reverting to previous extreme practices when the rules permit this as is the case for international style competitions including the Olympic Games.

**Methods, prevalence and magnitude of acute weight loss**

Various methods are used by combat sport athletes to achieve AWL, with the most popular methods across all Olympic combat sports being an increase in exercise and restriction of fluid/food intake. Dietary changes include restricted intakes of fluid, carbohydrate, fat and/or fibre intake with reductions in total energy intake ranging from a 35% decrease...
during the week before weigh-in to total food restriction on weigh-in day 17-21. Furthermore, it has been demonstrated that athletes who lack a good understanding of nutrition are more likely to resort to extreme fasting and dehydration to achieve weight loss, than those with a better understanding 22. The magnitude of AWL before weigh-in is commonly reported at around 5% of BM across all combat athletes 4, 6, 18, 20; however differences exist amongst sports in the ranges, time spans over which the weight is lost, and how frequently they occur.

Performance implications of acute weight loss

The potential for performance impairment in response to AWL techniques appears obvious, yet the impact of these practices on sport performance remains somewhat an issue of conjecture. While activities that demand high power and strength outputs are less likely to be influenced by AWL 23, performance in activities that require significant contributions of aerobic and anaerobic metabolism to energy yield are typically compromised 3. Several mechanisms have been proposed to explain the implications of AWL on performance. Hypohydration or lowered plasma volume coupled with depletion of muscle glycogen stores has been proposed to underlie the performance decrement associated with AWL 24. However, hypohydration is generally induced in combination with thermal and metabolic stress and the impact of these confounding variables on performance cannot be discounted. Other mechanisms considered in the literature include changes in enzyme activity, modified sarcoplasmic reticulum function 25 and structural changes to muscles 26. In addition, the body’s acid/base environment may change in response to a significant reduction in dietary carbohydrate intake 27. Furthermore, psychological performance is adversely influenced by body water deficits 28 although the impact of this alone on sports specific performance remains to be addressed. It has also been proposed that hypohydration alters central nervous system function 29, perhaps because of the association between hyperthermia and central fatigue 30. The increase in training load common among athletes attempting to acutely decrease BM may not be without performance implications.

It is crucial to note, however, that much of the general research on AWL and performance outcomes lacks context validity for weight making sports. A key shortcoming is the failure to include a recovery period and its associated nutrition practices following the weight loss period to mimic the interval between weigh-in and the exercise bout in real-world combat sports. Indeed, in studies in which ample time and appropriate recovery strategies have followed the “weigh-in”, the negative effects of the AWL have been found to be reversible 31.

Another ‘real world’ aspect of the effect of AWL on performance in combat sports is the recognition that performance is measured relative to other competitors rather than an individual’s absolute best. Thus it may not be important if AWL reduces an athlete’s performance as long as it remains better than that of an opponent’. Several studies have attempted to provide insight into how BM reduction may affect competitive success. In an investigation of high school wrestling 10, where a MMW corresponding to 5% body fat was determined as a voluntary identification of the lowest weight an athlete should compete at, those competing below MMW were more likely to place in state championship qualifying tournaments than those who didn’t.

Another protocol used to examine the “real life” relationship between AWL and performance in is to compare the magnitude of the gain in BM between weigh-in and competition and competitive success. This regain of BM has been used as a surrogate for the magnitude of AWL needed to make weight. However studies which have undertaken this protocol have produced mixed results 1, 2, 11. For example, it has been reported that large BM regains
correlated with competitive advantage in high school wrestlers, but not in collegiate wrestlers at a national championship. Here it is acknowledged that success in wrestling is determined by multiple factors including aerobic and anaerobic fitness, strength, power, psychological and emotional state and perhaps most importantly skill and technical proficiency. Among high school athletes, where many of these areas are not well developed, BM may contribute more to an athlete’s overall attributes than in more experienced athletes. However, in the highly selective sporting competition of college wrestlers, it is likely that the cohort consisted of a more homogenous group of already successful athletes. Furthermore BM regain for winners and losers were substantially higher (5.3±2.0% vs 5.3±2.4% respectively), compared to the high school wrestlers (2.4±1.8% vs 1.9±1.6%).

In contrast, no association was found between BM re-gain and competitive success in teenage taekwondo athletes and raises physical differences in the activities involved in combat sports as a potential confounder in the importance of BM manipulations. Grappling activities, which underpin the sport of wrestling (and judo), involve the manipulation of an opponent’s BM whereas striking sports (e.g. taekwondo/boxing) are potentially more dependent on the tactical movements of one’s own BM. Indeed, it has been suggested that height plays a more pivotal role than BM in striking sports and that athletes should be separated by height rather than BM to equalise competition matchups. Unfortunately, there are no studies on the effect of post-weigh-in BM regain on competitive success in judo or boxing.

In summary, the final effect of AWL on combat sports performance involves a complex interaction of factors, including the method/s of AWL, the intensity, type and duration of the performance effort, environmental conditions and an individual’s fitness capacity. Furthermore, the rules of the sport, including the period of time between weigh-in and competition allows an opportunity for athletes to restore fluid deficits and replace carbohydrate stores which may have been manipulated prior to weigh-in and thus recalibrate the final performance effect. This will now be explored.

**Recovery practices following acute weight loss**

Although combat sport athletes recognise the importance of replacing fuel stores and restoring fluid deficits post weigh-in, many do not appear to follow best practice guidelines. The optimal recovery strategies will depend on the methods of AWL which have been used. Recovery from the dehydration associated with AWL is possible depending on the degree of fluid loss and the recovery time available. In the lab setting dehydration of 2.8% and changes in plasma volume are reversible following three hours of aggressive nutritional recovery. However in one example during an actual wrestling competition, plasma volume and body water changes associated with dehydration of 6% BM were not completely reversed even 15 hours post weigh-in. Indeed, hydration assessment undertaken just before competition revealed significant levels of hypohydration in more than 80% and 95% of combat sport athletes who participated in events with weigh-ins scheduled for the evening before and the morning of the event respectively.

In terms of restoration or preparation of glycogen stores before competition, an assessment of the dietary practices of wrestlers following a weigh-in on the evening before competition found that reported carbohydrate intake was in general agreement with guidelines for optimal glycogen storage. A different study using muscle glycogen measurement via biopsy techniques confirmed the general success of athletes in preparing adequate fuel stores for competition when overnight recovery is available. It is unclear whether athletes who
undergo weigh-in the morning of a competition can fully normalise or supercompensate muscle glycogen levels, however such targets may not be necessary for optimal performance. Indeed, four hours of refuelling has been shown to be adequate for judo related performance 40 and glycogen stores have not been found to be limiting for performance when ad libitum intake of carbohydrate between bouts is allowed 39. Thus aggressive refuelling strategies involving the intake of large amounts of carbohydrate between weigh-in and competition may not be warranted.

Taken together, the apparent post-weigh-in fluid and food intake practices of combat athletes and the theoretical timelines of glycogen storage and rehydration suggest that for combat sports which implement weigh-ins the evening before competition day, there is opportunity for adequate restoration of fluid and fuel status; furthermore, although this is probably achieved in the case of glycogen preparation, many athletes do not attain euhydration 34, 37, 39. In contrast, shorter recovery periods, as occur when weigh-in occurs on the morning of competition do not provide enough time for athletes to rehydrate when they have employed dehydration to the degree commonly practiced 3, 4, 37, 41. Furthermore, while theoretically providing enough time for sufficient (not full) glycogen restoration 39, the period between a morning weigh-in and competition time may not be well utilised by athletes 34. All of these findings highlight the importance of appropriate nutrition education for both coaches and athletes. Providing detailed recommendations is beyond the scope of this review, thus readers are directed towards published reviews on rehydration 42 and glycogen restoration 43.

Section 2.
Understanding the physiology of acute weight loss

During the process of AWL, BM is lost from various compartments of the body with measurement artefacts sometimes obscuring the real shifts and losses involved. A small amount of body fat is lost as a result of several days of energy restriction 44, 45, but significant reductions in measurements of lean mass are also observed 34, 46. Since changes in lean mass measurements associated with restriction of energy, carbohydrate and fluid appear to be essentially reversed after post-weigh-in recovery or post-competition, it suggests they are associated with loss of muscle water and substrates (e.g. glycogen) rather than loss of contractile proteins. This theory is supported by evidence of reductions in total body water with weight making 46 and a halving of biopsy-derived values of muscle glycogen during a 72 hour AWL protocol in which there was a loss of 5% BM 39. A significant reduction in the intake of dietary fibre and total food mass associated with food restriction 19, 34, 47 is also likely to cause a loss of BM as a consequence of reduced gastrointestinal contents and fluid in the intestinal lumen bound to dietary fibre 48. This section will address each of these potential areas of BM change during AWL, with the intent of understanding how they can be best manipulated to minimise health risks and optimise performance.

Body water and acute weight loss overview

Water makes up about 60% of the human body 49; this varies within and between different population types and is likely to be higher in combat sport athletes due to their relatively high levels of lean mass 32. Given the size of this body compartment and the rapid speed in which it can be manipulated in comparison to other contributors to BM, it is logical that it is a primary focus of the AWL strategies of combat sport athletes.
There are three separate strategies that can be used to achieve an acute reduction in body water content: the consumption of less fluid (fluid restriction) in relation to normal daily losses; the ‘unlocking’ of bound body fluid, which will in turn be excreted; and the promotion of additional fluid loss. Fluid restriction is an obvious means to reduce total body water and plays a well-documented role in the AWL practices of combat athletes 17-21. Reductions in fluid compartments in the body can be derived from losses from both intracellular and extracellular stores, and include ‘free water’ or ‘bound water’. Bound water, which has the potential to be eliminated, includes that in glycogen stores and also that drawn into the intestinal space due to the presence of food matter with absorptive properties, such as fibre containing foods. The excretion of water from the body is accomplished via respiration, urination and perspiration (sweating).

**Respiration and water loss**

Respiratory water losses are affected by pulmonary ventilation, plus the temperature and humidity of inspired air. In temperate environments, these losses are approximately equal to the amount of water generated through aerobic metabolism; roughly 250-350mL per day, increasing with respiratory rate as exercise intensity increases 49. While altitude doesn’t significantly alter respiratory water losses 50, large decreases in humidity (from 80% to 20%) can dramatically affect respiratory water losses, particularly during exercise where losses increase from 0.8 to 2.7ml/min 51. Oral exhalation increases net respiratory water losses by up to 46% compared to nasal exhalation 52.

It should be noted that some bound water is released during aerobic metabolism and expelled via respiration 49; however the ability to acutely manipulate this type of bound water is minimal, and the minor amount (relative to other paths of fluid loss) can essentially be disregarded in the context of AWL. Total daily respiratory water losses range from 400mL/day in sedentary individuals in temperate environments up to 1500mL/day during times of exercise in low humidity 51. In terms of AWL strategies, exposure to a low humidity environment in the day(s) prior to weigh-in provides a passive method to significantly increase water losses, while exercising in this environment allows the addition of increased insensible loss to sweat losses.

**Urination and water loss**

Urine production is the body’s primary method of regulating fluid balance. This process is tightly controlled by the renal system, with aldosterone and antidiuretic hormone triggering renal responses to conserve or release fluid and sodium, thus maintaining body water and plasma sodium concentration. Depending on other contributions to body fluid balance, typical daily urine losses are in the range of 1-2L per day 49, 51 however are significantly decreased as dehydration progresses 53. Obligatory rates of urine production to allow the elimination of body waste products are 0.5L/d and thus set the low level of the range of daily losses, while fluid intakes greater than the maximal rate of urine production of 18/L can lead to hyponatremia/water intoxication 54, 55. Encouraging polyuria against the tide of hydration status presents another strategy of AWL, with protocols including, including sleeping or laying with the head tilted downward 56 and acute intake of high doses of vitamin C 57. Mechanisms underpinning the increased urine production in the former relating to disturbances in fluid and sodium homeostatic regulators caused by prompt increases in central blood volume 56.
Combat sport athletes have been reported to use pharmacological diuretics to promote greater urine loss in spite of their inclusion on the World Anti-Doping Agency’s List of Prohibited Substances. Herbal diuretics which have been shown to be effective in facilitating polyuria may also be used, although this activity is morally questionable with respect to doping and may result in performance decrements due to preferential plasma volume losses, as is the case for their pharmacological counterparts.

One novel but largely untested method reported by combat sport athletes to increase urine production/losses is the process of ‘water loading’. Anecdotally, it is claimed that excessive water intake over a few days promotes polyuria which persists beyond the period of increased fluid intake and thus achieves a net decrease in body water. This remains to be confirmed through scientific investigation, however if successful could provide an effective means of fluid loss albeit with the potential side-effect of promoting the potentially dangerous outcome of hyponatremia via water intoxication.

**Sweating and water loss**

Although urination may account for the majority of fluid losses in the general population in temperate environments, in hot/humid environments, perspiration (or loss of sweat) associated with thermoregulatory activities accounts for the majority of fluid losses. Furthermore, in all environments, the thermal challenge provided by exercise increases sweat losses, with a range of sweat rates being observed across individuals, exercise protocols and environmental conditions.

The facilitation of body fluid loss via sweating can include active (exercise induced) or passive (exposure to hot environment) strategies and is the most common method of acute BM manipulation undertaken by combat sport athletes. This observation is not surprising since sweat rates of up to 2 L/h can be achieved and represent a rapid way to achieve relative large BM losses.

Body sweat response is driven by a number of factors including core temperature and skin temperature. The onset of sweating can be altered by changes in plasma electrolyte concentration, plasma volume and total body water content; however, these cannot be manipulated to enhance sweat losses without the introduction of more fluid into the body, which is counterproductive to the goal of AWL. However, heat acclimation, adaption to exercise training and increased skin temperature are useful in increasing sweat losses. It should be noted however that females produce less sweat than males and are less responsive to the effects of training adaption on sweat rate and sweat temperature threshold. This has been attributed to peripheral vasodilation and hormonal differences.

It is important to note the differences in physiological response to passive versus active sweating. Passive sweating prior to exercise decreases plasma volume, sweat rate and stroke volume during exercise, contributing to an increase in serum osmolality, heart rate and body heat storage. These physiological changes occur to a lesser extent when hypohydration develops only during exercise. Thus a combination of fluid restriction and active dehydration (preferably accompanying any existing training an athlete is engaged in during the hours or day prior to weigh-in) may be the most practical way to induce dehydration in order to acutely reduce BM while minimising performance decrements. Further passive sweating should be used only when necessary and when ample time is available for recovery. If utilising saunas as means to facilitate perspiration, dry heat saunas should be used in preference to steam saunas as it has been demonstrated that fluid loss for a given period of time is greater (up to double the rate of loss) and results in less physiological strain.
**Sodium intake and water loss**

The human body tightly regulates the osmotic pressure of body fluids through renal excretion and retention of electrolytes and fluid. It is commonly accepted that the increased intake of sodium leads to increased retention of fluid, and that the reverse is true also. This explains the common health guideline to lower sodium intake in order to lower blood volume, and thus blood pressure. In one study, hypertensive subjects lost 1-2% BM following a low sodium diet (<500mg) for five days, although no interim measures were taken to establish the time frame of weight. While a reduction in salt intake has been shown to significantly reduce blood pressure in hypertensive people and to a lesser extent in normotensive people, indicating a decrease in intravascular fluid retention, this may not translate to alterations in BM in all people. Nevertheless, it has become a practice among some combat sport athletes to reduce sodium below habitual intakes during the weight cutting period. While this may not influence total body water per se, when used in combination with other fluid manipulation strategies it may ‘release’ more body water and allow a reduction in BM. This remains to be confirmed by empirical research.

**Glycogen, bound water and acute weight loss**

Dietary carbohydrate is stored in skeletal muscle and liver tissue as glycogen and acts as an energy reserve which can be quickly mobilized when there is a need for glucose. Glycogen is a branched bio-polymer of glucose which has been noted to bind to water at a ratio of 1: 2.7 (water: glycogen). Furthermore glycogen storage may contribute up to 8% of liver weight and 1-2% of skeletal muscle weight. Thus, based on calculation of the male body being 60-65% muscle mass with an average liver weight of 1.56 kg, a 75 kg male may potentially store 462 g and 1665-3610 g of glycogen and bound water in the liver and skeletal muscle, respectively. Of course the validity of these estimations are limited by the accuracy of measurements of glycogen:water ratios, and the stability of this ratio in different tissues and across different glycogen concentrations. Nevertheless, manipulation of the glycogen stores provides another strategy to achieve AWL by athletes. Two methods are available to achieve this: to consume a low carbohydrate diet to prevent the restoration of muscle glycogen stores following their depletion via the normal training program and to perform additional exercise in order to deplete glycogen reserves more rapidly. Issues determining the benefits/disadvantages of each approach include the effects of additional exercise in the period just prior to the weigh-in/event, versus the effect of a more chronic period of carbohydrate depletion on programmed training leading into the competition.

Data from the available literature show that 7 days of a low carbohydrate diet, combined with training and a slight reduction in energy (<10%) can achieve a BM reduction of ~2% while maintaining performance of strength/power measures as well as a 30 s Wingate test. Similar findings have been demonstrated by others following 2 weeks of a low carbohydrate diet, however 6 weeks of a low carbohydrate diet was associated with increased RPE during exercise and decrements in power and endurance, which the authors attributed to losses in lean mass. Together these findings have several implications for combat sport athletes: 1. The adoption of a low carbohydrate diet is an effective means to decrease BM in order to make weight (via the loss of glycogen and bound water); 2. It may not be crucial to replenish glycogen stores when the recovery period between weigh-in and competition is minimal, and 3. A viable weight making strategy for sports with multiple weigh-ins across consecutive days (i.e. amateur boxing) may involve the reduction of BM via a low
carbohydrate diet prior to the first weigh-in, with the maintenance of this strategy over the course of competition period and opportunities for acute rehydration and intake of adequate carbohydrate for each bout. The magnitude of possible BM loss and the strategies needed to achieve it (i.e. the level of carbohydrate restriction and the time frame required to produce maximal BM loss) will depend on glycogen status and training load prior to commencement of the strategy. Restricting carbohydrate intake to less than 50 g per day (combined with a small reduction in energy) should be enough to facilitate 1-2% BM loss based on existing research \(^\text{73}\) and the reported carbohydrate intakes of combat sport athletes \(^\text{19, 47}\).

**Gut contents and acute weight loss**

Many fighters have been reported to reduce portion sizes and total food volume prior to weigh-in in order to reduce mass of intestinal contents and contribute to total loss of BM \(^\text{17-21}\). The use of bowel preparations or laxatives is commonly reported amongst weight category sport athletes, presumably to facilitate in the expulsion of intestinal contents and promotion of AWL, possibly equating to 1 kg \(^\text{76}\). While this method is effective in cleansing the colon and removing intestinal bulk, the use of bowel preparation formulas has been shown to reduce exercise capacity \(^\text{76}\). Therefore, dietary strategies to reduce total food volume may be a preferable way to manipulate the mass of intestinal contents while maintaining performance goals. This might include a switch to consumption of foods that are energy-dense in the hours and days prior to weigh-in to maintain energy and macronutrients intakes with a smaller food mass. This would be particularly important for those whose weigh-in times are within several hours of competition time and thus have limited potential to effectively rehydrate and refuel between weigh-in and competition.

Dietary fibre can both slow transit time of foods through the bowel as well as draw water into the intestinal space, adding bulk to stools. Different foods possess different faecal bulking properties \(^\text{48}\) but it is assumed that if a person reduces their habitual consumption of ‘bulking’ fibre-rich foods’, it will reduce the mass of undigested plant matter, the amount of water drawn into the intestinal space and faecal bulk, favourably lowering BM. Indeed, a linear relationship exists between fibre intake and bowel cleanliness in pre colonoscopy patients \(^\text{77}\), and the adoption of a low residue (low fibre) diet for even two days helps to cleanse the bowel \(^\text{77}\) with seven days of less than 10g fibre per day being equally as effective as a bowel preparation formula \(^\text{78}\). Additionally low fibre diets result in less physiological stress and symptoms than a bowel preparation formula \(^\text{78}\). For combat sport athletes, the ability to continue to train throughout the bowel emptying process is an important consideration.

Despite the available research on the bowel emptying effects of low fibre diets, and the evidence that many fighters adopt low fibre diets during the final days before weigh-in \(^\text{19}\), there are no specific investigations on the success of this approach on the outcomes of weight-making and the magnitude of the weight change it might achieve. Additionally, since whole gut transit times vary widely between individuals from 10-96 hours \(^\text{79}\), precise guidelines for the use of fibre restriction for AWL cannot be determined at this stage. Further investigation in the application of low residue formulas to weight making is warranted, including the potential for weight loss, as well as health and performance implications.

**Section 3.**

**Conclusion and practical applications**
Athletes currently engage in varying degrees of fluid deprivation, food restriction and increased exercise during protocols aimed at achieving AWL. In light of the information discussed throughout this review, recommendations can be devised to refine weight making practices of combat sport athletes. While some form of dietary restriction is generally necessary to facilitate AWL, the most effective strategy to achieve an AWL while allowing restoration of performance after the weigh-in is to consume strategic amounts of energy from low weight/low fibre foods while inducing a mild fluid deficit. Greater fluid deficits and depletion of glycogen stores provide an additional strategy for those requiring greater weight losses. Optimal post-weigh-in recovery strategies are influenced by method(s) used to achieve AWL. Figure 1 provides a decision tree to help coaches and athletes plan an appropriate weight making strategy.

**Figure 1.**

It is important to note that circumstances will vary between sports and individuals. By monitoring day-to-day and within day fluctuations in BM, athletes and coaches can better understand the acute management of BM. Athletes should trial their weight making and recovery practices prior to important competitions, record their experiences and continually reflect on the process from one weigh-in to the next.
5. Acknowledgments, authorships, declarations of funding sources and conflicts of interest

This manuscript was jointly designed and produced by Reid Reale, Gary Slater and Louise Burke. All authors approved the final version of the paper.

This project did not receive any funding.

All the authors declare that they have no conflict of interest derived from the outcomes of this manuscript.
6. References


7. Figures and tables

Figure 1. ‘Weight making’ plan decision tree

*Duration of carbohydrate restriction required to maximally reduce glycogen mass will vary depending on current glycogen status and training volume and intensity in the 7 days prior to weigh-in. For athletes engaged in greater training loads, fewer days of carbohydrate restriction will be required to deplete glycogen stores.

**Duration of fibre restriction required to maximally reduce gut contents will vary depending on individual whole gut transit time, athletes should note individual responses to low fibre intakes.
<table>
<thead>
<tr>
<th>Freestyle Wrestling</th>
<th>Greco-Roman Wrestling</th>
<th>Judo</th>
<th>Boxing</th>
<th>Taekwondo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men’s Weight</td>
<td>Women’s Weight</td>
<td>Men’s Weight</td>
<td>Women’s Weight</td>
<td>Men’s Weight</td>
</tr>
<tr>
<td>&lt;48</td>
<td>&lt;58</td>
<td>&lt;48</td>
<td>&lt;48</td>
<td>46-49</td>
</tr>
<tr>
<td>&lt;57</td>
<td>&lt;58</td>
<td>&lt;57</td>
<td>&lt;57</td>
<td>52-56</td>
</tr>
<tr>
<td>&lt;65</td>
<td>&lt;63</td>
<td>&lt;63</td>
<td>&lt;63</td>
<td>64-69</td>
</tr>
<tr>
<td>&lt;74</td>
<td>&lt;75</td>
<td>&lt;63</td>
<td>&lt;70</td>
<td>69-75</td>
</tr>
<tr>
<td>&lt;86</td>
<td>&lt;85</td>
<td>&lt;73</td>
<td>&lt;78</td>
<td>75-81</td>
</tr>
<tr>
<td>&lt;97</td>
<td>&lt;98</td>
<td>&lt;81</td>
<td>&gt;78</td>
<td>81-91</td>
</tr>
<tr>
<td>&lt;125</td>
<td>&lt;130</td>
<td></td>
<td></td>
<td>&gt;100</td>
</tr>
<tr>
<td>Sport</td>
<td>Weigh-in procedures</td>
<td>Competition format</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freestyle Wrestling</td>
<td>Once, evening before competition</td>
<td>All contests for one weight division in single day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Best of 3 x 2 min rounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winner by immobilisation of opponent on back (pin) or by judges decision via points once time has elapsed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greco-Roman Wrestling</td>
<td>Once, evening before competition</td>
<td>All contests for one weight division in single day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Best of 3 x 2 min rounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winner by immobilisation of opponent on back (pin) or by judges decision via points once time has elapsed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Judo</td>
<td>Once, evening before competition</td>
<td>All contests for one weight division in single day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 x 5 min match</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winner by ippon (throwing opponent on back with strength and speed, forcing opponent to submit with arm lock or stranglehold, immobilisation of opponent on back) or by judges decision via points once time has elapsed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boxing</td>
<td>Morning on the first day of competition and morning of every contest day</td>
<td>Successive contests on separate days</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No less than 3 hours between weigh-in and contest</td>
<td>2 x 3 min rounds (men)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 x 2 min rounds (women)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winner by knockout, technical knockout, referees stoppage or by judges decision via points at end of bout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taekwondo</td>
<td>Once, evening before competition</td>
<td>All contests for one weight division in single day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 x 2 min rounds</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electronic sensor scoring system</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winner by knockout, reaching 12 point difference at completion of second round or via superior score at end of bout</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>