ACSM Expert Consensus Statement on Weight Loss in Weight-Category Sports

Louise M Burke, Joseph Matthews, Gary Slater, Carl Langan-Evans, Craig A. Horswill

Contact information for authors:

Louise M Burke, PhD, BSc (nut) G Dip Diet
Exercise and Nutrition Research Program, Mary MacKillop Institute for Health Research, Australian Catholic University
215 Spring St Melbourne, Vic 3000, Australia
Louise.burke@acu.edu.au

Gary J Slater, PhD, BSc, G Dip Nutr Diet MSc
School of Health and Sport Sciences, University of the Sunshine Coast
90 Sippy Downs Dr, Sippy Downs QLD, Australia 4556
gslater@usc.edu.au

Joseph J Matthews, MSc, BSc (Hons)
Research Centre for Life and Sport Sciences (CLaSS), School of Health and Life Sciences, Department of Sport and Exercise, Birmingham City University, United Kingdom.
Sport, Health and Performance Enhancement (SHAPE) Research Centre, Musculoskeletal Physiology Research Group, School of Science and Technology, Nottingham Trent University, United Kingdom.
Mailing address: Birmingham City University, City South Campus, Westbourne Road, Birmingham, B15 3TN.
joseph.matthews@bcu.ac.uk

Carl Langan-Evans, BA (Hons); MRes; PhD; FHEA; IIST; ASCC
Applied Sport Physiology and Nutrition Exercise Metabolism and Adaptation Research Group (EMARG), Research Institute for Sport and Exercise Sciences (RISES)
Room G.06, High Performance Unit, Primrose Hill Sport & Exercise Science Building,
5 Primrose Hill, Liverpool, Merseyside, L3 2AT.
C.LanganEvans@ljmu.ac.uk

Craig A Horswill, PhD
Department of Kinesiology and Nutrition, University of Illinois at Chicago
901 W. Roosevelt Rd, 337 PEB, Chicago, IL 60608
horswill@uic.edu

Abstract

Weight-category sports are defined by the requirement of a weigh-in before competition to provide performance equity and reduced injury risks by eliminating size discrepancies. Athletes in these sports try to gain a theoretical advantage by competing in weight divisions that are lower than their day-to-day body mass (BM), using a combination of chronic strategies (body-fat losses) and acute manipulations over a period of hours to days before weigh-in ("making weight"). Strategies to support safer practices include minimal competition weight classification based on pre-season body composition, reductions in the period between weigh-in and competition, and prohibition of unhealthy weight loss techniques. At an individual level, expert guidance by a sports nutrition professional can help an athlete to establish a pragmatic and long-term approach to BM management, recognizing the nuances of their sport, to achieve favorable outcomes for both health and performance.

Introduction

A number of sports involve competition in weight categories or divisions (hereafter called weight categories), with the main aim of creating an even playing field and safer competition by matching competitors with similar physical characteristics (1). The sports include combat (*e.g.,* boxing, martial and mixed martial arts, wrestling), weightlifting, powerlifting, sprint football, and rowing. An exception is in horse racing, where the weight restriction on the jockey provides a handicap to the performance of the horse. The prevailing culture in such sports is a desire to compete in a category that is lower than their natural or day-to-day training body mass (BM), to gain a real or perceived advantage over lighter opponent(s) (2-4). Concerns over health risks and the fairness of competition underpin the efforts of many weight-category sports to enact rule changes and education programs, in the hope of reducing the prevalence and magnitude of BM manipulation activities (5,6). It may seem convenient to consider weight-category sports as a collective because of their common need to achieve a specified BM prior to competition. However, recent research has highlighted the specificity and nuances of BM manipulation practices within each sport and the need for practitioners to support pragmatic strategies for management of BM around competition to optimize performance while safeguarding health (2-4). This consensus statement provides a summary of factors that should be considered and replaces the 1996 ACSM Position stand on Weight Loss in Wrestlers (7).

Characteristics across different weight-category sports that influence weight-making practices

In weight-category sports, athletes have their BM verified at an official "weigh-in" prior to competition to ensure they meet the specified weight requirements. 'Making' or 'cutting' weight (hereafter called making weight) involves a range of acute and/or chronically applied strategies. The perceived or actual benefits of competing in a lower weight category vary between sports according to the characteristics that determine success (4, 6, 8). Although there are some common weight-making practices across all weight category sports, specific protocols are often determined by the rules, customs and characteristics that influence opportunities to acutely reduce BM prior to the weigh-in, and subsequently recover from this in the period between weigh-in and competition. Table 1 summarizes some of the features of weight-category sports, with brief comments about how these characteristics may influence weight-making practices. Since rule changes can occur in these sports, this information is provided principally to illustrate how various characteristics can influence weight-making per se, or its effect on health and performance.

(Place table 1 here)

Key issues influencing weight-making practices include the number of weight categories available for competition, and the frequency with which the athlete needs to make weight (*e.g.*, frequency of competition and the number of times the athlete must weigh in over the course of an event). While an increased number of weight categories may provide more opportunities for an athlete to find a class that is best suited to their natural physique, the smaller weight increments between divisions may also create greater temptation to 'cut' to a lower division. Sports that provide greater challenges include those with few divisions (*e.g.*, lightweight rowing), and those in which the weight categories vary according to the competition. For example, in many combat sports, there are fewer or different weight categories on the Olympic Games program than on other national or international competitions (see Table 1). Sports involving weekly competition (*e.g.*, horse racing and collegiate wrestling during the competitive season) require frequent perturbations in BM, whereas in others (*e.g.*, professional boxing or lightweight rowing), the athlete may only compete "at weight" a couple of times a year. For further insight into characteristics that shape weight making practices of athletes in weight category sports, the reader is referred to the following references: (2-4, 22).

The timeframe between weigh-in and competition varies between sports, affecting the ability of the athlete to recover from any weight-making strategies. Horse racing represents the greatest challenge since successful jockeys must reweigh after the race, minimizing their opportunities to consume food or fluid before competition (23). At the other end of the spectrum, some sports (*e.g.*, professional boxing and mixed martial arts) offer substantial recovery time (up to 32 hr) between the weigh-in and event, with almost unlimited opportunities for pre-event fluid and food intake. While such sports allow the athlete to be well-fueled and hydrated prior to competition, these conditions support a culture of extreme BM manipulation (24), as evidenced by mean BM gain of up 10% and individual values of 20% BM gain during the recovery period (25-28). Indeed, there may be a link between the amount of post-weigh-in rapid weight gain (RWG) and the duration of the recovery period (4, 29). Some sports (*e.g.*, judo and taekwondo) have tried to circumvent this by introducing a second weigh-in on the morning of the event for randomly selected competitors, with rules prohibiting a BM gain >5% from initial weigh-in. Other sports (*e.g.*, lightweight rowing, Olympic boxing) routinely implement a pre-tournament weigh-in plus repeat weight checks in the hours prior to any subsequent event in which the athlete competes. Unfortunately, there are anecdotal observations that such changes merely encourage the athlete to limit their recovery, rather than curtail the magnitude of the weight-making (30).

Although cultural beliefs and traditions underpin the weight making practices observed in many sports (3, 4, 22, 24, 31), characteristics of performance may also influence the degree to which they persist, due to the advantages of having a greater "true" BM. In sports like rowing, there are significant advantages to having greater muscle mass/power and longer limb "levers" (32). Indeed, despite the considerable physiological stress of a race, often overlaid with thermal stress, and even though the rules of competition try to limit weight-making by implementing serial weigh-ins close to the time of competition, it appears that successful lightweight rowers do not "naturally" fit below their weight targets (31). Furthermore, there is evidence that lightweight rowers can preserve performance via planned nutrition support around some degree of weight making (31, 33, 34). On the other hand, a recent study of jockeys in Great Britain revealed that changes in the historical handicaps for horses have not kept pace with generational increases in BM, meaning that current weight limits are too low for almost all jockeys (35). There may be subtle differences between combat sports regarding the performance advantages of having a larger natural BM, as demonstrated by a correlation between success and the magnitude of RWG (8). It should be noted, however, that although the magnitude of RWG is often used as a surrogate measure of the degree of rapid weight loss (RWL), it may not be an accurate indicator (4). Nevertheless, in grappling sports like wrestling and judo, a larger BM and muscle mass/power may confer performance advantage (36), whereas in striking sports such as taekwondo and boxing, greater stature and limb length provide an advantage that is only partially correlated with BM (37, 38). Meanwhile studies in combat sports involving striking and grappling (*e.g.*, Mixed Martial Arts) have failed to show a correlation between RWG and competition success (39, 40), Aside from any direct competitive advantage, the culture of weight-making is entrenched by perceived psychological benefits around sport identity and the feeling of focus, commitment and self-confidence (41).

Common weight making practices

For the purposes of this position stand, chronic BM management includes strategies implemented over several weeks or months to facilitate a change in fat mass (FM) and fat-free mass (FFM) [sometimes termed interchangeably as lean body mass or LBM]. Here, the athlete aims to reduce FM while maintaining or gaining FFM. Conversely, RWL (sometimes also called acute weight loss or AWL) includes the intentional manipulation of total body water, glycogen stores and gastrointestinal tract contents over a period of hours or days. Typically, RWL has limited impact on FM or FFM, although changes in body water may cause artefacts in assessments of body composition via various modalities and some loss of fat-free dry solid mass can occur in as little as 4 days (42, 43). While specific BM management practices vary according to sport and athlete caliber, the majority of athletes engage in both chronic and acute strategies (3, 22, 24, 25, 29, 31, 44).

The 1996 ACSM Guidelines (7) advocated an emphasis on chronic BM management practices, including gradual dieting and manipulation of training load, while promoting a cautious approach to acute strategies in order to mitigate their potential health and performance implications. Indeed, there is evidence of favorable outcomes when such an approach is implemented (26, 28, 45).

Nevertheless, there is renewed focus on health and performance effects of chronic energy deficits in athletes, due to the recognition of concerns associated with low energy availability and the sequalae described in in the Female and Male Athlete Triad (46) the Relative Energy Deficiency in Sport (RED-S) syndrome (47), including specific issues in weight category sports (48). Since this enhanced interest is beyond the scope of this Statement, the reader is directed to specific resources on strategies and concerns for chronic weight loss in athletes (49-53), allowing the current paper to focus on RWL while acknowledging that it occurs against a larger backdrop of body composition manipulation.

Table 2 provides a summary of commonly utilized RWL strategies, including their associated potential benefits and disadvantages. It is important to understand the degree to which these strategies are utilized when attempting to infer health and/ or performance implications. Acute restriction of fluid intake and/ or promotion of sweat loss through exercise to levels commonly observed in routine training (*e.g.*, 2% to 3% BM reduction) are likely to have few disadvantages, especially if aggressive recovery strategies are implemented subsequent to weigh-in. However, a singular focus on these practices to facilitate larger amounts of weight loss (>3% BM reduction) may have substantial negative implications to health and performance. According to recent surveys of RWL practices among athletes, the concerning strategies of vomiting and use of banned diuretics and diet pills have a low prevalence of use (3, 24, 25). However, the use of thermally stressful environments like saunas to elicit sweat losses remains common (3, 24, 25). There also appears to be an increased interest in the use of other novel strategies such as water loading (3, 24, 25), a practice in which the health and performance implications are only now beginning to emerge (54). The continued reliance on RWL strategies for weight making should not come as a surprise, since athletes identify fellow athletes and coaches as primary influencers on their BM management practices (2, 24, 41). It also should be noted that parents have an important influence on young athletes, but lesser so as athletes age (55, 56). Practitioners who work with weight category athletes should have a clear understanding of their specific weight making practices and timeframes of implementation, not only to assist with better management of weight loss goals, but to consider post-weigh in recovery practices that can mitigate the health and/ or performance consequences.

Opportunities for recovery after weigh-in

The period between weigh-in and the event offers an opportunity for an athlete to consume foods and drinks that address pre-event nutrition goals against a background of the physiological and psychological challenges imposed by their RWL practices (57). What is needed to optimize the athlete's nutritional status for competition will vary according to the type and magnitude of RWL practices undertaken and the competitive event. What is practical to achieve will depend on whether the timeframe will allow consumption, digestion/absorption, and restoration of sub-optimal nutritional status (57). Table 3 summarizes common sports nutrition advice for such processes, emphasizing restoration of body fluids and muscle glycogen stores as common goals (58, 59), and noting specific recommendations should be applied with caution and practical considerations. For example, it may not always be possible to fully recover in the available time period; here the athlete should prioritize recovery of what is most important for their event and ensure that recovery eating does not interfere with event performance, either by creating gut discomfort from the consumption of large volumes of fluid and nutrients or interfering with the requirement to make weight again within day(s).

Several studies have examined how well recovery can be achieved in the typical timeframe between weigh-in and event, investigating the change in physiological parameter (*e.g.*, degree of dehydration) and/or the restoration of performance. The literature is difficult to fully interpret since studies differ in the magnitude of weight loss, whether single or several strategies have been involved in the weight making and/or recovery, and the time course of each process. Most importantly, studies are typically laboratory based, quantifying performance in measures of work, power, or force production. Although these measures are presumed to contribute to success in competition, they may not be a perfect proxy. Furthermore, they may not consider that competitive success is a relative outcome (*e.g.*, comparing athletes to each other) rather than absolute (comparing an athlete to their personal best). The results of studies that have measured the effects of recovery strategies on performance in a meaningful way are discussed in the following section.

Alternative methods of recovery such as intravenous fluid administration might have appeal following the weigh in. Studies demonstrate some efficacy in non-weight-category athletes who partially rehydrate by this means but the effects are no better than those of orally administered fluids (60,61). Use of such methods are strongly discouraged given they are banned by SBGs.

Concerns associated with weight making practices

Weight making strategies may jeopardize the athlete's health and safety and alter attributes or whole elements of performance. Since the issues of health and safety should be of primary concern, these will be addressed first. The most serious consequence of making weight is death; such outcomes have been reported in association with extreme practices in taekwondo (62), college wrestling (63), mixed martial arts (64,65), judo (66), Muay Thai (67), and lightweight rowing (68). Such tragic and avoidable occurrences are typically associated with cardiovascular complications and/or heat stroke secondary to severe fluid restriction, passive heat exposure or strenuous exercise to induce large sweat losses, or combinations of these strategies (62-68). Indeed, substantial reduction in body water, including plasma volume, is associated with cardiovascular strain and impaired thermoregulation in hot environments (69, 70). Depending on the method of water loss, electrolyte imbalances may also occur, and, according to altered EMG activity, increase the risk of muscle heat cramps (71). Acute renal stress or injury has also been associated with extreme fluid loss during RWL in some weight category athletes (72, 73). Although the concept of RWL prior to a competitive event suggests that it is a short-term experience, it should be noted that in sports involving regular competition (*e.g.*, weekly matches during the college wrestling season), this protocol is repeated many times.

Chronic exposure to negative energy balance and low energy availability is associated with effects on many aspects of health and function including impairments to metabolic, endocrine and reproductive systems, as well as protein synthesis and growth in child and adolescent athletes; all contribute to the syndrome known as Relative Energy Deficiency in Sport (RED-S) (47). Reductions in testosterone and IGF-1 concentrations have been observed during the three-to-four-month competitive wrestling season (27, 28, 74, 75, 76), as well as in lightweight rowers (77) and jockeys (78). Acute markers of impairments in protein status in these wrestlers include decreases in rapid-turnover plasma proteins indicative of protein-calorie nutrition status (74, 79), while rates of muscle protein synthesis in response to resistance training are reduced with several days of LEA (80). Meanwhile, its long-term translation into loss of FFM has been reported across a wrestling season (74, 79) and as a significant contribution to the BM losses in a boxing training camp (26). Reduced bone mineral density is often associated with LEA but may be altered by the interaction with bone loading exercise. For example, although some studies of combat athletes have shown evidence of adverse outcomes for acute markers of bone turnover, bone mineral density (BMD) did not appear to be affected by weight reduction (28, 81, 82). However, lightweight rowers report lower BMD than their heavy weight counterparts and a high risk of rib stress fractures (48). Conflicting outcomes exist within the same sport with low BMD reported in jockeys (83) but no differences in BMD observed between novice and veteran jockeys who have many more years of experience and exposure to making weight (84). Other outcomes associated with RED-S observed among weight category athletes include dyslipidemias and reduction in resting metabolic rate (48). The effect of LEA on the immune system is complex (85) and although some markers of diminished immune system function have been reported in weight category athletes (86-91), it is unclear whether these changes put weight-category athletes at greater risk for illness during heavy training or weight loss periods.

The effects of RWL, or its components, on behavioral and psychological issues have been considered from a number of angles. With pressure to either lose weight and/or to maintain meticulous control of body composition (9,19), it is not surprising that athletes may exhibit disordered eating or eating disorders. Studies have reported that some but not all cohorts involved in weight making sports have higher scores on eating disorder survey instruments than age-matched controls or other athletes (23, 93, 94). Other investigations have focused on changes in measures of mood states during RWL activities, with consistent findings of reductions in vigor, and elevations in anxiety, anger, fatigue, depression, and confusion (23,95, 96). Transient and reversible impairment of cognitive functioning, such as memory and ability to complete simple tasks, has been reported in some athletes during active weight making (97, 98), with potential effects on performance outcomes and injury. However, it is important to also consider other, including perceived positive, effects of the psychosocial aspects of RWL. For example, a survey of the attitudes of elite combat athletes reported that their weight regulation practices provided them with a sense of identity as an athlete, contributed to a sense of focus and commitment to pre-competition preparation, and allowed a feeling of advantage over an opponent (99, 100)

Focusing specifically the effects of acute dehydration on cognitive function, magnetic resonance imagining studies have revealed temporary alterations in the brain structure (101-103), which have been associated with transient declines in cognitive test scores (104) and visuomotor performance (105). Interestingly, wrestlers performed worse on concussion screening tests when dehydrated compared to their performance at baseline in an euhydrated state (106). Wide variability in concussion testing responses in non-concussed boxers has also been explained in part by dehydration (107). Implications of structural changes or possibly reduced brain blood flow with dehydration (108) include that the brain might be more physically vulnerable to concussion, or that impaired decision making and motor control during competition may predispose weight-restricted athletes to injuries. However, to date, empirical data are lacking to confirm an increased risk of brain injury with dehydration.

It is important to consider the real and perceived effects of RWL on performance in weight category sports since this is likely to underpin the motives of athletes and coaches around their practices and the capacity for change. A summary of studies of the effect of RWL on sport/exercise performance (Table 4) illustrates the complexity of this issue by demonstrating a range of outcomes (trivial effects, negative effects and positive effects) from a range of study designs. Indeed, no single answer is likely because, as demonstrated in Table 1, chronic weight loss, RWL practices and the characteristics of performance are all variable. Studies of isolated elements, such as the effect of dehydration on an aspect of power or endurance, may be limited by failing to capture some of the characteristics of weight category sports that can either mitigate or accentuate the performance effect. Others that include recovery strategies to overturn some of the negative outcomes of RWL may be more ecologically valid, but still fail to capture elements of performance or characteristics such as repeated performance bouts, the effect of environmental conditions, or the need to weigh-in several times in a multi-day competition. Nevertheless, an overall conclusion from this literature might be that RWL activities cause some direct decrements to elements of sports performance (Table 4), but these can be at least attenuated if there is sufficient time after the weigh-in to allow recovery nutrition strategies.

A major complication of defining the effect of RWL on performance is the concept of relative performance, which notes that competition success is awarded to the athlete who is best within their event pool rather than to the athlete who achieves their best performance level on the day of the event. The culture and experience of many athletes in weight category sports is that although RWL may reduce an athlete's absolute performance, RWL allows them to compete in a lower weight division where they may have a physical or psychological advantage, especially in events where RWL or the chance to recover after the weigh-in have minimal effects on performance. Yet, this is exceedingly challenging to quantify where it is most profound and relevant: in competition. Table 4 also includes studies of real-life attempts to observe correlations between the magnitude of RWL (measured or inferred from the BM increase after the weigh-in) and competition success. Even these studies have shown different outcomes, with findings spread across observations that athletes who appear to compete with the greatest magnitude of weight manipulation can be either less successful (39, 128), equally successful (125, 129, 131) or more successful (36, 132) than their counterparts who practice smaller degrees of apparent BM loss. Although further research is needed to gain better insights, it is recognized that outcomes are affected by methodological issues as well as real differences arising from the requirements of the sport. Regardless, there is evidence that at least some athletes sacrifice performance as well as incur health risks due to their weight making practices.

Programs and rule changes to address unsafe weight making practices

In the 1960s, The National Federation of State High School Athletic Associations (NFHS) instructed US states to introduce weight control plans to limit harmful RWL practices in high school wrestling (134). Initial attempts, focusing largely on athlete and coach education, had limited success (135, 136), necessitating the development of structured programs alongside rule changes to make harmful weight-making impractical (see Table 5).

The first formal intervention was the Wisconsin Wrestling Minimum Weight Program (137), which led to a small, significant reduction in harmful weight-making practices in that state (138). Nevertheless, some wrestlers continued to undergo large RWL (>7 kg) for competition using undesirable methods (*e.g.*, training in heated rooms) and scores on a nutrition knowledge survey were no higher than those recorded before the program began (138). High school wrestlers subject to these rules also continued to engage in aggressive RWL during international-style wrestling tournaments (139), which occurred outside the scholastic season and its weight control regulations.

In 1997, following the tragic deaths of three wrestlers, the National Collegiate Athletic Association (NCAA) introduced a Wrestling Weight Certification Program (140), which expanded on the previous Wisconsin Program. The program: (i) limited weight loss to ≤1.5% BM per week; (ii) determined a minimal competitive weight for each wrestler based on a lower limit of 5% body fat (males); (iii) moved weigh-ins to 1-2 hours pre-competition; (iv) added 7 lbs (3.2 kg) to each weight category limit (*e.g.*, 190 lbs became 197 lbs); (v) prohibited the use of unsafe weight making methods; (vi) randomized the order of weight class competition (instead of heavier athletes competing later); and (vii) required athletes to pass a hydration test (urine specific gravity ≤1.020) at the weigh-in. When compared to practices observed prior to the NCAA Program (135,141,142), studies showed that wrestlers had less seasonal variation in BM (142-146), better retention of FFM (143), and a marked reduction in RWG (reduced to 1.2 ± 0.9 kg) between the weigh-in and competition (146). Taken collectively, the NCAA Program reduced harmful weight-making practices to a greater extent than the Wisconsin Program.

Despite this success, there are some concerns relating to the NCAA methods. The minimal competitive weight rule has been adopted by the US Collegiate Sprint Football League (21), where male athletes must weigh under 178 lbs (81 kg) with no less than 5% body fat; and by the NFHS who set a higher minimum body fat (7% for males, 12% for females) to allow for sex differences and maturation in adolescents (134). However, these standards have not been enforced across the United States and there is no guarantee of healthy weight management in high school or collegiate sports. Another concern is the stark differences in methods and procedures used to determine minimum competitive weight between states (147), which undermines the validity and reliability of the measurements. The use of urine specific gravity to measure hydration status at the official weigh-in also has limitations: current cut-offs can identify euhydrated athletes, but false-positives may be common, leading to athletes being incorrectly classified as dehydrated and excluded from competition (148,149).

Interventions like the Wisconsin and NCAA programs are challenging to implement for sports that lack the organizational structure of the US high-school and collegiate system. However, other combat sports have started to address the issue. Following a death in 2015, ONE Championship—Asia's largest MMA, Muay Thai, and kickboxing promotion—implemented a series of rule changes similar to the NCAA Program (150). More recently, the California State Athletic Commission introduced a 10-point plan in an attempt to reduce RWL to less than 10% (150). While these programs are promising, there are currently no data to show their impact on athlete weight-making behaviors.

A novel approach to eliminate weight-making is the replacement of weight categories with height categories (152,153), which may be a viable approach for striking-based combat sports where limb-length is an important factor for competitive success. Other sport organizations have opted for simple changes to the weigh-in structure. Both World Taekwondo and the International Judo Federation now implement an evening-before competition weigh-in with a re-weigh limit on the morning of competition (12,15). A sample of athletes complete the re-weigh, with those weighing >5% above the upper limit of the weight category excluded from competition. The International Boxing Federation (IBF) apply a similar rule to championship bouts, with a re-weigh limit 10 lbs (4.5 kg) above the upper limit of the weight category (10). A retrospective analysis of 77 IBF bouts showed the average RWG ranged from -0.3 to 6.4 kg (128), but it did not specify how many athletes exceeded the re-weigh limit or if they were excluded from competition. While it is a common rule change, the effect of a morning re-weigh limit on weight making behaviors needs further evaluation. A criticism of the rule is that athletes can easily manipulate their BM to stay within the re-weigh limit, then continue to regain BM between the re-weigh and competition (Table 5).

Despite several decades of work, harmful weight-making still exists in weight-category sports. However, resistance to new ideas should not be a deterrent to change prior to the implementation of the Wisconsin Program, most coaches (>60%) were opposed to it, but four years later nearly all

(>95%) coaches supported it (137). New programs and regulations should involve all key stakeholders, be pilot tested, evaluated and revised, as necessary. These then need to be implemented by the largest sport organizations and adopted downstream by national and regional federations to have the greatest impact.

Summary

A variety of sports involve weight categories with the aim of organizing competition that is safe and equitable between competitors with similar physical characteristics. Athletes in such sports use chronic and acute weight making techniques to compete in a weight category that is lower than their "natural" weight, gaining a theoretical advantage over smaller opponents. Extreme weight making practices, however, often lead to health and performance concerns. The ingrained culture and practices of weight making are difficult to remove and should be recognized as being unique to the specific characteristics of each sport. While no single approach is likely to be successful across all weight category sports, guidelines underpinning programs to address concerns around weight making can be provided in principle (see Table 6). Strategies to support education around safer practices include minimal competition weight classification based on pre-season body composition, reductions in the period between weigh-in and competition, and prohibition of unhealthy weight loss techniques. At an individual level, expert guidance by sports nutrition professionals can help an athlete to establish a pragmatic and long-term approach to BM management, recognizing the nuances of their sport, to achieve favorable outcomes for both health and performance.

References

1. Bešlija T, Čular D, Kezić A, et al. Height-based model for the categorization of athletes in combat sports. *Eur J Sport Sci*. 2020 Apr 7:1-10. doi: 10.1080/17461391.2020.1744735.
2. Pettersson S, Pipping Ekstrom M, Berg CM. The food and weight combat. A problematic fight for the elite combat sports athlete. *Appetite.* 2012; 59(2): 234-42.
3. Reale R, Slater G, Burke LM. Weight management practices of Australian Olympic combat sport athletes. *Int J Sports Physiol Perform*. 2018; 13(4):459-66.
4. Matthews JJ, Stanhope EN, Godwin MS, Holmes MEJ, Artioli GG. The magnitude of rapid weight loss and rapid weight gain in combat sport athletes preparing for competition: a systematic review. *Int J Sport Nutr Exerc Metab*. 2019;29(4):441–52.

5. Artioli GG, Franchini E, Nicastro H, Sterkowicz S, Solis MY, Lancha AH. The need of a weight management control program in judo: a proposal based on the successful case of wrestling. *J Int Soc Sports Nutr.* 2010; 7, 15.
6. Artioli GG, Saunders B, Iglesias RT, Franchini E. It is time to ban rapid weight loss from combat sports. *Sports Med* 2016; 46:1579-84.
7. American College of Sports Medicine. Position statement: weight loss in wrestlers. *Med. Sci. Sports* Exerc. 1996; 28(6):ix-xii.
8. Reale R, Slater G, Burke LM. Acute-weight-loss strategies for combat sports and applications to Olympic success. *Int J Sports Physiol Perform*. 2017; 12(2):142-51.
9. Tokyo Olympic Games. Weight categories: Tokyo Olympic Games Web site [Internet]. [cited 2020 December 17]. Available from: https://tokyo2020.org/en/games/sport/olympic/.
10. International Boxing Association (AIBA) Web site [Internet]. International Boxing Association [cited 2020 December 17]. Available from: https://d21c25674tgiqk.cloudfront.net/2019/03/AIBA-Technical-Competition-Rules-.pdf.
11. World Boxing Association (WBA) Web site [Internet]. World Boxing Association [cited 2020 May 3]. Available from: http://www.wbaboxing.com/wp-content/uploads/2019/04/WBA-Rules-adopted-in-Bulgaria-6-11-15-Updated-2019-1.pdf.
12. International Judo Federation (IJF). Web site [Internet]. International Judo Federation [cited 2020 December 17]. Available from: https://www.ijf.org/.
13. World Karate Federation (WKF): Web site [Internet]. World Karate Federation [cited 2020 December 17]. Available from: https://www.wkf.net/pdf/WKF_Competition%20Rules_2020_EN.pdf.
14. Ultimate Fighting Championship (UFC) Web site [Internet]. Ultimate Fighting Championship [cited 2020 December 17]. Available from: https://www.ufc.com/unified-rules-mixed-martial-arts.
15. World Taekwondo (WT): Web site [Internet]. World Taekwondo [cited 2020 December 17]. Available from: http://www.worldtaekwondo.org/wp-content/uploads/2019/08/WT-Competition-Rules-Interpretation-Manchester-May-15-2019.pdf.
16. United World Wrestling (UWW). Web site [Internet]. United World Wrestling [cited 2020 December 17]. Available from: https://unitedworldwrestling.org/sites/default/files/media/document/wrestling_rules_a.pdf.
17. National Collegiate Athletics Association (NCAA). Web site [Internet]. National Collegiate Athletics Association [cited 2020 December 17]. Available from: http://www.ncaapublications.com/productdownloads/WR20.pdf.
18. International Weightlifting Federation (IWF). Web site [Internet]. International Weightlifting Federation [cited 2020 December 17]. Available from: https://www.iwf.net/doc/Technical&CompRules2009-2012.pdf
19. International Powerlifting Federation (IPF). Web site [Internet]. [cited 2020 December 17]. Available from: https://www.powerlifting.sport/fileadmin/ipf/data/rules/technical-rules/english/IPF_Technical_Rules_Book_2020.pdf.
20. Fédération Internationale des Sociétés d'Aviron (FISA). Fédération Internationale des Sociétés d'Aviron Web site [Internet]. [cited 2020 December 17]. Available from: http://www.worldrowing.com/mm//Document/General/General/13/58/39/FISArulebookEN2019web_Neutral.pdf.
21. College Sprint Football League (CSFL). CSFL Rules for 2019. [cited 2020 December 17]. Available from: https://www.sprintfootball.com/rules.
22. Langan-Evans C, Crighton B, Martin D, Wilson G. Current practices in weight making sport. *Sport Exerc Sci.* 2017; 54:8-9.
23. Wilson G, Drust B, Morton JP, Close GL. Weight-making strategies in professional jockeys: implications for physical and mental health and well-being. *Sports Med*. 2014;44(6):785–96. doi:10.1007/s40279-014-0169-7.

24. Barley OR, Chapman DW, Abbiss CR. Weight loss strategies in combat sports and concerning habits in mixed martial arts. *Int J Sports Physiol Perform*. 2018;13: 933-9.
25. Matthews JJ, Nicholas C. Extreme rapid weight loss and rapid weight gain observed in UK mixed martial arts athletes preparing for competition. *Int J Sport Nutr Exerc Metab.* 2017;27(2):122-9.
26. Morton JP, Robertson C, Sutton L, MacLaren DP. Making the weight: a case study from professional boxing. *Int J Sport Nutr Exerc Metab* 2010; 20(1): 80-5.
27. Kasper AM, Crighton B, Langan-Evans C, et al. 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; 29(3):331-8.
28. Langan-Evans C, Germaine M, Artukovic M, et al. The psychological and physiological consequences of low energy availability in a male combat sport athlete. *Med Sci Sports Exerc.* 2020; Epub ahead of print, PMID: 33105389.
29. Oppliger RA, Steen SN, Scott JR. Weight loss practices of college wrestlers. *Int J Sport Nutr Exerc Metab*. 2003;13(1):29-46.
30. Slater GJ, Rice AJ, Tanner R, Sharpe K, Jenkins D, Hahn AG. Impact of two different body mass management strategies on repeat rowing performance. *Med Sci Sports Exerc.* 2006; 38(1):138-46.
31. Slater GJ, Rice AJ, Sharpe K, Mujika I, Jenkins D, Hahn AG. Body-mass management of Australian lightweight rowers prior to and during competition. *Med Sci Sports Exerc*. 2005; 37(5):860-6.
32. Kerr DA, Ross WD, Norton K, Hume P, Kagawa M, Ackland TR. Olympic lightweight and open-class rowers possess distinctive physical and proportionality characteristics. *J Sports Sci.* 2007;25(1):43-53.
33. Slater G, Rice AJ, Tanner R, et al. Acute weight loss followed by an aggressive nutritional recovery strategy has little impact on on-water rowing performance. *Br J Sports Med.* 2006; 40(1): 55-9.
34. Slater GJ, Rice AJ, Sharpe K, Jenkins D, Hahn AG. Influence of nutrient intake after weigh-in on lightweight rowing performance. *Med Sci Sports Exerc.* 2007; 39(1):184-91.
35. Wilson G, Hill J, Martin D, Morton JP, Close G. GB Apprentice jockeys do not have the body composition to make current minimum race weights: is it time to change the weights or change the jockeys? *Int J Sport Nutr Exerc Metab.* 2020. doi: 10.1123/ijsnem.2019-0288. [Epub ahead of print].
36. Reale R, Cox GR, Slater G, Burke LM. Regain in body mass after weigh-in is linked to success in real life judo competition. *Int J Sport Nutr Exerc Metab.* 2016; 26(6):525-30.
37. Dubnov-Raz G, Mashiach-Arazi Y, Nouriel A, Raz R, Constantini N. Can height categories replace weight categories in striking martial arts competitions?: a pilot study. *J Hum Kinet*. 2015;47:91–8.
38. Reale R, Cox GR, Slater G, Burke LM. Weight regain: no link to success in a real-life multiday boxing tournament. *Int J Sports Physiol Perform*. 2017;12(7):856-63.
39. Brechney GC, Chia E, Moreland AT. Weight-cutting implications for competition outcomes in mixed martial arts cage fighting. *J Strength Cond Res* 2019 Sep 25. doi: 10.1519/JSC.0000000000003368. Online ahead of print.
40. Kirk C, Langan-Evans C, Morton JP. Worth the weight? Post weigh-in rapid weight gain is not related to winning or losing in professional mixed martial arts. *Int J Sport Nutr Exerc Metab.* 2020; 30(5): 357-61.
41. Pettersson S, Ekström MP, Berg CM. Practices of weight regulation among elite athletes in combat sports: a matter of mental advantage? *J Athl Train*. 2013;48(1):99-108
42. Kukidome T, Shirai K, Kubo J, et al. MRI evaluation of body composition changes in wrestlers undergoing rapid weight loss. *Br J Sports Med* 2008; 42(10): 814-8.
43. Kondo E, Sagayama H, Yamada Y, et al. Energy deficit required for rapid weight loss in elite collegiate wrestlers. *Nutrients.* 2018; 10(5): 536.

44. Hillier M, Sutton L, James L, Mojtahedi D, Keay N, Hind K. High prevalence and magnitude of rapid weight loss in mixed martial arts athletes. *Int J Sport Nutr Exerc Metab*. 2019; 29(5): 512–7. doi:10.1123/ijsnem.2018-0393.
45. Wilson G, Chester N, Eubank M, et al. An alternate dietary strategy to make weight improves mood, decreases body fat and removes the necessity for dehydration: A case-study from a professional jockey. *Int J Sport Nutr Exerc Metab*. 2012; 22(3):225-31.
46. De Souza MJ, Koltun KJ, Williams NI. The role of energy availability in reproductive function in the female athlete triad and extension of its effects to men: an initial working model of a similar syndrome in male athletes. Sports Med. 2019; 49(Suppl 2):125-37. doi: 10.1007/s40279-019-01217-3.
47. Mountjoy M, Sundgot-Borgen J, Burke L, et al. International Olympic Committee (IOC) Consensus Statement on relative energy deficiency in sport (RED-S): 2018 update. *Int J Sport Nutr Exerc Metab*. 2018; 28(4):316-31.
48. Burke LM, Close GL, Lundy B, Mooses M, Morton JP, Tenforde AS. Relative energy deficiency in sport in male athletes: a commentary on its presentation among selected groups of male athletes. *Int J Sport Nutr Exerc Metab*. 2018;28(4):364–74.
49. Fogelholm GM, Koskinen R, Laakso J, Rankinen T, Ruokonen I. Gradual and rapid weight loss: effects on nutrition and performance in male athletes. *Med Sci Sports Exerc.* 1993; 25(3):371-7.
50. Manore MM. Weight management for athletes and active individuals: a brief review. *Sports Med*. 2015; 45 Suppl 1(Suppl 1), S83-S92.
51. Langan-Evans C, Close GL, Morton JP. Making weight in combat sports. *Strength Cond J.* 2011; 33(6): 25-39.
52. Garthe I, Raastad T, Refsnes, PE, Koivisto A, Sundgot-Borgen J. Effect of two different weight-loss rates on body composition and strength and power-related performance in elite athletes. *Int J Sport Nutr Exerc Metab*. 2011; 21(2):97-104.
53. Mettler S, Mitchell N, Tipton KD. Increased protein intake reduces lean body mass loss during weight loss in athletes. *Med Sci Sports Exerc*. 2010;42(2):326-37.
54. 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 Sport Nutr Exerc Metab.* 2018; 28(6):565-73.
55. Sansone RA, Sawyer R. Weight loss pressure on a 5 year old wrestler. *Br J Sports Med* 2005; 39(1): e2.
56. Xiong NQ, Xian CY, Karppaya H, Jin CW, Ramadas A. Rapid weight loss practices among elite combat sports athletes in Malaysia. *Malaysian J Nutr.* 2017; 23(2).
57. Reale R, Slater G, Burke LM. Individualised dietary strategies for Olympic combat sports: Acute weight loss, recovery and competition nutrition. *Eur J Sport Sci*. 2017; 17(6):727-40.
58. Evans GH, James LJ, Shirreffs SM, Maughan RJ. Optimizing the restoration and maintenance of fluid balance after exercise-induced dehydration. *J Appl Physiol.* 2017;122(4):945-51.
59. Burke LM, van Loon LJC, Hawley JA. Postexercise muscle glycogen resynthesis in humans. *J Appl Physiol* 2017;122(5):1055-67.
60. Maresh CM, Herrera-Soto JA, Armstrong LE, et al. Perceptual responses in the heat after brief intravenous versus oral rehydration *Med Sci Sports Exerc*. 2001;33(6):1039-45.
61. Casa DJ, Maresh CM, Armstrong LE, et al. Intravenous versus oral rehydration during a brief period: responses to subsequent exercise in the heat. *Med Sci Sports Exerc*. 2000;32(1):124-33.
62. Forsyth L. Schoolboy collapses and dies during taekwondo fight as opponent celebrates 'victory' until he realises what's happened. *Mirror*. August 3, 2018. [cited 2020 December 17.] Available from: https://www.mirror.co.uk/news/world-news/schoolboy-collapses-dies-during-taekwondo-13029078.
63. Centers for Disease Control and Prevention (CDC). Hyperthermia and dehydration-related deaths associated with intentional rapid weight loss in three collegiate wrestlers--North Carolina,

Wisconsin, and Michigan, November-December 1997. *MMWR Morb Mortal Wkly Rep*. 1998;47(6):105-8.
64. Perez AJ. Death of MMA fighter Yang Jian Bing illustrates dangers of weight cutting. USA Today. Dec 11, 2015. [cited 2020 December 17]. Available from: https://www.usatoday.com/story/sports/mma/2015/12/11/death-weight-cutting-yang-jian-bing-mma/77143446/.
65. Bonhan J. Report: MMA fighter Leandro 'Feijao' Souza dies in apparent weight-cutting incident prior to Shooto 43. MMA Mania Sept 27, 2013. [cited 2020 June 1]. Available from: https://www.mmamania.com/2013/9/26/ 4775478/mma-fighter-apparently-dies-in-relation-from-cutting-weight.
66. AP News. Judo Star Dies of Heart Attack; Diet Blamed. AP new. March 20, 1996. [cited 2020 December 17]. Available from: https://apnews.com/951694702afbb76f786b8a4553410496.
67. Menagh J. Jessica Lindsay inquest told teenager died after extreme "weight cutting" for Muay Thai kickboxing fight, ABC News March 10 2020. [cited 2020 December 17]. Available from: https://www.abc.net.au/news/2020-03-10/jessica-lindsay-died-after-extreme-training-for-muay-thai-fight/12042078.
68. Parillo R, Fitzgerald S. Heat stress contributed to rower's death. Philadelphia Inquirer June 25, 2005. [cited 2020 December 17]. Available from: https://poststar.com/sports/college/heat-stress-contributed-to-rowers-death/article_e83ace3b-ac85-5278-92f8-4adf58860aa7.html.
69. McDermott BP, Anderson SA, Armstrong LE, et al. National Athletic Trainers' Association position statement: fluid replacement for the physically active. *J Athl Train.* 2017;52(9):877-95. doi: 10.4085/1062-6050-52.9.02.
70. Sawka MN, Montain SJ, Latzka WA. Hydration effects on thermoregulation and performance in the heat. *Comp Biochem Physiol A Mol Integr Physiol*. 2001; 128(4): 679-90.
71. Caldwell JE, Ahonen E, Nousiainen U. Diuretic therapy, physical performance, and neuromuscular function. *Phys Sports Med.* 1984;12(6): 73-85.
72. Kasper AM, Crighton B, Langan-Evans C, et al. 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*. 2019; 29(3):331-8.
73. Zambraski EJ, Foster, DT, Gross, PM, Tipton, CM. Iowa wrestling study: weight loss and urinary profiles of collegiate wrestlers. *Med Sci Sports*. 1976; 8(2):105-8.
74. Roemmich JN, Sinning WE. Weight loss and wrestling training: effects on growth-related hormones. *J Appl Physiol.* 1997; 82(6):1760-4.
75. Strauss RH, Lanese RR, Malarkey WB. Weight loss in amateur wrestlers and its effect on serum testosterone levels. *JAMA.* 1985; 254(23):3337-8.
76. Karila TA, Sarkkinen P, Marttinen M, Seppala T, Mero A, Tallroth K. Rapid weight loss decreases serum testosterone. *Int J Sports Med.* 2008; 29(11): 872-7.
77. Vinther A, Kanstrup IL, Christiansen E, Ekdahl C, Aagaard P. Testosterone and BMD in elite male lightweight rowers. *Int J Sports Med*. 2008; 29(10): 803-7.
78. Dolan E, Crabtree N, McGoldrick A, Ashley DT, McCaffrey N, Warrington GD. Weight regulation and bone mass: a comparison between professional jockeys, elite amateur boxers, and age, gender and BMI matched controls. *J Bone Min Metab* 2012; 30(2):164-70
79. Horswill CA, Park SH, Roemmich JN. Changes in the protein nutritional status of adolescent wrestlers. *Med Sci Sports Exerc.* 1990; 22(5):599-604.
80. Areta JL, Burke LM, Camera DM, et al. Reduced resting skeletal muscle protein synthesis is rescued by resistance exercise and protein ingestion following short-term energy deficit. *Am J Physiol Endocrinol Metab*. 2014;306(8):E989-E997.
81. Sagayama H, Kondo E, Tanabe Y, Ohnishi T, Yamada Y, Takahashi H. Bone mineral density in male weight-classified athletes is higher than that in male endurance-athletes and non-athletes *Clin Nutr ESPEN.* 2020; 36(4):106-10.

82. Prouteau S, Pelle A, Collomp K, Benhamou L, Courteix D. Bone density in elite judoists and effects of weight cycling on bone metabolic balance. *Med Sci Sports Exerc.* 2006; 38(4): 694-700.
83. Wilson G, Drust B, Morton JP, Close GL. Weight-making strategies in professional jockeys: implications for physical and mental health and well-being. *Sports Med*. 2014; 44(6):785-96.
84. Wilson G, Martin D, Morton JP, Close GL. Male flat jockeys do not display deteriorations in bone density or resting metabolic rate in accordance with race riding experience: implications for RED-S. *Int J Sport Nutr Exerc Metab.* 2018; 28(4):434-9.
85. Walsh NP. Nutrition and athlete immune health: new perspectives on an old paradigm. *Sports Med.* 2019; 49(Suppl 2): 153-68.
86. Imai T, Seki S, Dobashi H, Ohkawa T, Habu Y, Hiraide H. Effect of weight loss on T-cell receptor-mediated T-cell function in elite athletes*. Med Sci Sports Exerc.* 2002; 34(2):245-50.
87. Umeda T, Nakaji S, Shimoyama T, Kojima A, Yamamoto Y, Sugawara K. Adverse effects of energy restriction on changes in immunoglobulins and complements during weight reduction in judoists. *J Sports Med Phys Fitness.* 2004; 44(3):328-34.
88. Kowatari K, Umeda T, Shimoyama T, Nakaji S, Yamamoto Y, Sugawara K. Exercise training and energy restriction decrease neutrophil phagocytic activity in judoists. *Med Sci Sports Exerc*. 2001; 33(4):519-24.
89. Suzuki M, Nakaji S, Umeda T, et al. Effects of weight reduction on neutrophil phagocytic activity and oxidative burst activity in female judoists. *Luminescence*. 2003; 18(4):214-7.
90. Tsai ML, Chou KM, Chang CK, Fang SH. Changes of mucosal immunity and antioxidation activity in elite male Taiwanese taekwondo athletes associated with intensive training and rapid weight loss. *Br J Sports Med.* 2011; 45(9): 729-34.
91. Tsai ML, Ko MH, Chang CK, Chou KM, Fang SH. Impact of intense training and rapid weight changes on salivary parameters in elite female Taekwondo athletes. *Scand J Med Sci Sports.* 2011; 21(6): 758-64.
92. Wells KR, Jeacocke NA, Appaneal R, et al. The Australian Institute of Sport (AIS) and National Eating Disorders Collaboration (NEDC) position statement on disordered eating in high performance sport. *Br J Sports Med*. 2020; 54(21):1247-58.
93. Gorrell S, Nagata JM, Hill KB, et al. Eating behavior and reasons for exercise among competitive collegiate male athletes. *Eating Weight Disorders.* 2019; 10.1007/s40519-019-00819-0. [Epub ahead of print].
94. Chapman J, Woodman T. Disordered eating in male athletes: a meta-analysis. *J Sport Sci.* 2016; 34(2):101–9.
95. Yoshioka Y, Umeda T, Nakaji S, et al. Gender differences in the psychological response to weight reduction in judoists*. Int J Sport Nutr Exerc Metab.* 2006; 16(2):187-98.
96. Horswill CA, Hickner RC, Scott JR, Costill DL, Gould D. Weight loss, dietary carbohydrate modifications, and high intensity, physical performance. *Med Sci Sports Exerc*. 1990; 22(4):470-6.
97. Lakicevic N, Roklicer R, Bianco A, et al. Effects of rapid weight loss on judo athletes: a systematic review. *Nutrients.* 2020; 12(5):1220. https://doi.org/10.3390/nu12051220.
98. Labadarios D, Kotze J, Momberg D, Kotze TJ. Jockeys and their practices in South Africa. *World Rev Nutr Diet*. 1993;71:97–114.
99. Choma CW, Sforzo GA, Keller BA. Impact of rapid weight loss on cognitive function in collegiate wrestlers. *Med Sci Sports Exerc.* 1998; 30(5):746-9.
100. Morgan WP. Psychological effect of weight reduction in the college wrestler. *Med Sci Sports.* 1970; 2(1):24-7.
101. Dickson JM, Weavers HM, Mitchell N, et al. The effects of dehydration on brain volume -- preliminary results. *Int J Sports Med.* 2005;26(6):481-5.
102. Watson P, Head K, Pitiot A, Morris P, Maughan RJ. Effect of exercise and heat-induced hypohydration on brain volume. *Med Sci Sports Exerc*. 2010; 42(12):2197-204.

103. Tan XR, Low ICC, Stephenson MC, et al. Altered brain structure with preserved cortical motor activity after exertional hypohydration: a MRI study. *J Appl Physiol*. 2019;127(1):157-67.
104. Kempton MJ, Ettinger U, Foster R, et al. Dehydration affects brain structure and function in healthy adolescents. *Hum Brain Mapp*. 2011;32(1):71-9.
105. 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(16):e13805.
106. Weber AF, Mihalik JP, Register-Mihalik JK, Mays S, Prentice WE, Guskiewicz KM. Dehydration and performance on clinical concussion measures in collegiate wrestlers *J Athl Train* 2013;48(2):153-60.
107. Ravdin LD, Barr WB, Jordan B, Lathan WE, Relkin NR. Assessment of cognitive recovery following sports related head trauma in boxers. *Clin J Sport Med* 2003;13(1):21-7.
108. Trangmar SJ, Chiesa ST, Llodio I, et al. Dehydration accelerates reductions in cerebral blood flow during prolonged exercise in the heat without compromising brain metabolism. *Am J Physiol Heart Circ Physiol*. 2015; 309(9):H1598-607.
109. Smith MS, Dyson R, Hale T, Hamilton M, Kelly J, Wellington P. The effects of restricted energy and fluid intake on simulated amateur boxing performance. *Int J Sport Nutr Exerc Metab.* 2001;11(2):238-47.
110. Smith MS, Dyson R, Hale T, Harrison JH, McManus P. The effects in humans of rapid loss of body mass on a boxing-related task. *Eur J Appl Physiol.* 2000; 83(1):34-9.
111. Hall CJ, Lane AM. Effects of rapid weight loss on mood and performance among amateur boxers. *Br J Sports Med.* 2001; 35(6):390-5.
112. Filaire E, Maso F, Degoutte F, Jouanel P, Lac G. Food restriction, performance, psychological state and lipid values in judo athletes. *Int J Sports Med*. 2001;22(6):454-9.
113. Koral J, Dosseville F. Combination of gradual and rapid weight loss: effects on physical performance and psychological state of elite judo athletes. *J Sports Sci.* 2009; 27(2):115-20.
114. Silva AM, Fields DA, Heymsfield SB, Sardinha LB. Relationship between changes in total-body water and fluid distribution with maximal forearm strength in elite judo athletes. *J Strength Cond Res.* 2011; 25(9):2488-95.
115. Reljic D, Feist J, Jost J, Kieser M, Friedmann-Bette B. Rapid body mass loss affects erythropoiesis and hemolysis but does not impair aerobic performance in combat athletes. *Scand J Med Sci Sports.* 2016; 26(5), 507-17.
116. Marttinen RH, Judelson DA, Wiersma LD, Coburn JW. Effects of self-selected mass loss on performance and mood in collegiate wrestlers. *J Strength Cond Res.* 2011;25(4):1010-5.
117. Mendes SH, Tritto AC, Guilherme JP, et al. Effect of rapid weight loss on performance in combat sport male athletes: does adaptation to chronic weight cycling play a role? *Br J Sports Med*. 2013;47(18):1155-60.
118. Isacco L, Degoutte F, Ennequin G, Pereira B, Thivel D, Filaire E. Rapid weight loss influences the physical, psychological and biological responses during a simulated competition in national judo athletes. *Eur J Sport Sci.* 2019; 2:1-12.
119. Artiolo GG, Iglesias RT, Franchini E, et al. Rapid weight loss followed by recovery times does not affect judo-related performance. *J Sports Sci*. 2010; 28:21-32.
120. Burge CM, Carey MF, Payne WR. Rowing performance, fluid balance, and metabolic function following dehydration and rehydration. *Med Sci Sports Exerc.* 1993; 25(12):1358-64.
121. Slater GJ, Rice AJ, Sharpe K, et al. Impact of acute weight loss and/or thermal stress on rowing ergometer performance. *Med Sci Sports Exerc*. 2005; 37(8):1387-94.
122. Barley OR, Chapman DW, Blazevich AJ, Abbiss CR. Acute dehydration impairs endurance without modulating neuromuscular function. *Front Physiol.* 2018;9:1562. doi: 10.3389/fphys.2018.01562. eCollection 2018.

123. Yang WH, Heine O, Grau M. Rapid weight reduction does not impair athletic performance of Taekwondo athletes - A pilot study. *PLoS One*. 2018; 26;13(4):e0196568.
124. de Sousa Fortes L, de Vasconcelos GC, de Vasconcelos Costa BD, Paes PP, Franchini E. Effect of 10% weight loss on simulated taekwondo match performance: a randomized trial. *J Exerc Rehabil.* 2017;13(6):659-65.
125. Finn KJ, Dolgener FA, Williams RB. Effects of carbohydrate refeeding on physiological responses and psychological and physical performance following acute weight reduction in collegiate wrestlers. *J Strength Cond Res* 2004; 18 (2):328-33.
126. Rankin JW, Ocel JV, Craft LL. Effect of weight loss and refeeding diet composition on anaerobic performance in wrestlers. *Med Sci Sports Exerc*. 1996;28(10):1292-9.
127. Daniele G, Weinstein RN, Wallace PW, Palmieri V, Bianco M. Rapid weight gain in professional boxing and correlation with fight decisions: analysis from 71 title fights. *Phys Sportsmed.* 2016; 44(4):349-54.
128. Zubac D, Karnincic H, Sekulic D. Rapid weight loss is not associated with competitive success in elite youth Olympic-style boxers in Europe. *Int J Sports Physiol Perform.* 2018; 13(7): 860-6.
129. Coswig VS, Miarka B, Pires DA, da Silva LM, Bartel C, Del Vecchio FB. Weight regain, but not weight loss, is related to competitive success in real-life mixed martial arts competition. *Int J Sport Nutr Exerc Metab*. 2018;29(1): 1-8.
130. Horswill CA, Scott JR, Dick RW, Hayes J. Influence of rapid weight gain after the weigh-in on success in collegiate wrestlers. *Med Sci Sports Exerc*. 1994; 26(10):1290–4.
131. Wroble RR, Moxley DP. Acute weight gain and its relationship to success in high school wrestlers. *Med Sci Sports Exerc.* 1998; 30(6):949-51.
132. Brandt R, Bevilacqua GG, Coimbra DR, Pombo LC, Miarka B, Lane AM. Body weight and mood state modifications in mixed martial arts: an exploratory pilot. *J Strength Cond Res.* 2018; 32:2548-54.
133. Roemmich JN, Sinning WE. Weight loss and wrestling training: effects on nutrition, growth, maturation, body composition, and strength. *J Appl Physiol* (1985). 1997; 82(6):1751-9.
134. National Federation of State High School Athletic Associations (NFHS). *Wrestling Weight Control Standards, in State High School Athletic Associations Handbook 1964-65*. Chicago (IL): National Federation of State High School Athletic Associations. 1964; p 30-1.
135. Steen SN, Brownell KD. Patterns of weight loss and regain in wrestlers: has the tradition changed? *Med Sci Sports Exerc*. 1990; 22(6):762-8.
136. Tipton CM, Tcheng TK. Iowa wrestling study: weight loss in high school students. *JAMA* 1970, 214(7), 1269-74.
137. Oppliger RA, Harms RD, Herrmann DE, Streich CM, Clark RR. The Wisconsin wrestling minimum weight project: a model for weight control among high school wrestlers. *Med Sci Sports Exerc.* 1995; 27(8):1220-4.
138. Oppliger RA, Landry GL, Foster SW, Lambrecht AC. Wisconsin minimum weight program reduces weight-cutting practices of high school wrestlers. *Clin J Sport Med.* 1998; 8(1):26-31.
139. Alderman B, Landers DM, Carlson J, Scott JR. Factors related to rapid weight loss practices among international-style wrestlers. *Med Sci Sports Exerc*. 2004;36(2):249-52.
140. National Collegiate Athletic Association (NCAA). *NCAA Wrestling Weight-Certification Program.* Indianapolis (IN): National Collegiate Athletic Association. 1998; p. 1-32.
141. Scott JR, Horswill CA, Dick RW. Acute weight gain in collegiate wrestlers following a tournament weigh-in. *Med Sci Sports Exerc.* 1994: *26*(9):1181-5.
142. Scott JR, Oppliger RA, Utter AC, Kerr, CG. Body weight changes at the national tournaments—the impact of rules governing wrestling weight management. *Med Sci Sports Exerc.* 2000; 32(5):S131.
143. Utter AC. The new National Collegiate Athletic Association wrestling weight certification program and sport-seasonal changes in body composition of college wrestlers. *J Strength Cond Res.* 2001:15(3): 296-301.

144. Ransone J, Hughes B. Body-weight fluctuation in collegiate wrestlers: Implications of the National Collegiate Athletic Association weight-certification program. *J Athl Train* 2004; 39(2):162.
145. Davis SE, Dwyer GB, Reed K, Bopp C, Stosic J, Shepanski M. Preliminary investigation: the impact of the NCAA Wrestling Weight Certification Program on weight cutting. *J Strength Cond Res*. 2002; 16(2):305-7.
146. Oppliger RA, Utter AC, Scott JR, Dick RW, Klossner D. NCAA rule change improves weight loss among national championship wrestlers. *Med Sci Sports Exerc.* 2006; 38(5):963-70.
147. Curby DG. A Review of the minimum wrestling weight procedures used in American Scholastic Wrestling. *Int J Wrestling Sci*, 2012; 2(1):26-35.
148. Zubac D, Paravlic A, Reale R, Jelaska I, Morrison SA, Ivancev V. Fluid balance and hydration status in combat sport Olympic athletes: a systematic review with meta-analysis of controlled and uncontrolled studies. *Eur J Nutr*. 2019; 58(2):497-514.
149. Zubac D, Reale R, Karnincic H, Sivric A, Jelaska I. Urine specific gravity as an indicator of dehydration in Olympic combat sport athletes; considerations for research and practice. *Eur J Sport Sci.* 2018; 18(7):920-9.
150. ONE Championship. Martial Arts. ONE Championship™: Downtown Core, Singapore, 2020. [cited 2020 December 17]. Available from: https://www.onefc.com/martial-arts/.
151. California State Athletic Commission (CSAC). California State Athletic Commission Meeting Minutes. California State Athletic Commission: California, United States, May 16, 2017. [cited 2020 December 17]. Available from: https://www.dca.ca.gov/csac/meetings/minutes/20170516.pdf.
152. Bešlija T, Čular D, Kezić A, et al. Height-based model for the categorization of athletes in combat sports. *Eur J Sport Sci. 2020* Apr; 8:1-0.
153. Dubnov-Raz G, Mashiach-Arazi Y, Nouriel A, Raz R, Constantini NW. Can height categories replace weight categories in striking martial arts competitions? A pilot study. *J Hum Kinetics.* 2015; 47(1):91-8.

Table 1. Summary of weight-category sports and their respective weigh-in characteristics.

	Weight categories (9)	Weigh-in procedures	Competition characteristics	Comments
Combat Sports				
Boxing (amateur/ "Olympic Style") [10]	AIBA competition: M = 10, F = 10 Olympic Games: M = 8, F = 5	General weigh-in on the first day of tournament, and on the morning of the day in which specific competition is drawn. Weigh in is no less than 3 hr pre- first bout of the day. Official weigh-in can only be attempted once, with athletes allowed to wear a swimming suit or undergarments. When necessary, the weigh in can be conducted naked.	Tournament contested over different days with 4-5 bouts in competition, spread every 2nd day. M: 3 x 3 min rounds F: 3 x 3 min rounds	Different weight categories across competitions (*e.g.*, Olympic Games vs others): some athletes must change to a new weight category.
Boxing (Professional) Note that there are different world bodies governing professional boxing: WBA (11) is provided as an example	Varies by country/ association WBA: M = 17, F = 16	Procedures vary between associations. The official scale is made available to check weigh >2 hr prior to official weigh-in. WBA title fights: official weigh-in = > 16 hr and < 30 hr before start of the first bout on the event card. If either Champion or Challenger fails to make prescribed weight, each will have further 2 hr.	Title fights: 12 rounds Other fights may vary between 4 and 12 rounds. M: 3 min rounds F: 2 min rounds Competitors usually fight 3–4 times per year	Boxers may change weight categories to seek titles. Often lengthy periods between fights, but fighters may not prepare until bout is contracted, thus creating short preparation. Culture often leads to large swings in weight between fights. Failing to make weight can result in imposing a monetary fine, and demotion or suspension.
Judo (12)	All competitions M = 7, F = 7	An alternate scale is made available in the training room for days prior to the	Tournament contested on a single day: 4-8 bouts.	Same weight categories across Olympic Games and all

		official weigh in, which occurs the evening before competition. Random weight checks morning of competition prohibits weight gain of >5% above weight category. Official weigh-in can only be attempted once, with athletes allowed to wear undergarments. When necessary, the weigh-in can be conducted naked. Cadet athletes are given + 0.1 kg allowance for underwear.	M: 1 x 4 min round F: 1 x 4 min round	competition. Random re-weigh on fight day may discourage recovery strategies
Karate (13)	Senior competition: M = 5, F = 5 Olympic Games: M = 3, F = 3	The official scale is made available to check weight >1 hr prior to official weigh-in, which must take place, at the latest, the day before the start of competition, unless specified otherwise. All athletes are given a + 0.2 kg allowance as official weigh-in must be conducted in undergarments (M: underpants F: underpants & bra).	Tournament contested on a single day: 6-8 bouts. M: 1 x 3 min round F: 1 x 3 min round	Different weight categories across competitions (*e.g.*, Olympic Games vs others): some athletes must change to a new weight category
Mixed Martial Arts Note that there are different world bodies governing Mixed Martial Arts: UFC [14] is provided as	Unified Weight Classes - MMA 14 classes UFC Titles M = 8 F = 4	An alternate scale is made available in the training room for days prior to the official weigh-in, which occurs the on morning of day before fight (26-32 hr pre-event). A public 'staged' weigh-in is held on the afternoon of the day before fight. Official weigh in can be attempted	Major "fight nights" each month but fighters normally engage in 2-3 fights per year. Fight duration varies between title and exhibition fights Title or main event: 5 x 5 min	MMA athletes may change weight categories to seek titles. Often lengthy periods between fights, but fighters may not prepare until bout is contracted, thus creating short preparation. Culture often leads to large swings in weight between fights.

example		multiple times, with athletes allowed to wear undergarments. When necessary, the weigh-in can be conducted naked.	rounds Other events: 3 x 5 min rounds	Weigh-ins for title matches televised. Allowances (and penalties of up to 30% of purse) sometimes made for fighters over weight.
Taekwondo (15)	World championships: M = 8; F = 8 Olympic Games: M = 4; F = 4	An alternate scale is made available in the training room for days prior to the official weigh-in, which occurs the on day before competition. Random weight checks morning of competition prohibit weight gain of >5% above weight category. Official weigh-in can only be attempted twice, with athletes allowed to wear undergarments. When necessary, the weigh-in can be conducted naked. Cadet & Junior athletes are given + 0.1 kg allowance for underwear.	Tournament contested on a single day: 4-8 bouts. M: 3 x 2 min rounds F: 3 x 2 min rounds	Different weight categories across competitions (*e.g.*, Olympic Games vs others): some athletes must change to a new weight category Random re-weigh on fight day may discourage recovery strategies
Wrestling (Freestyle) [16]	UWW competition: M = 10; F = 10 Olympic Games: M = 6; F = 6	Weigh-in on morning before competition. There is another weigh-in on the second day of competition with no weight allowance (2 kg is tolerated at world cups and international tournaments). After passing a medical check, athletes must wear a competition singlet during weigh-in.	Tournament contested across two days: 4-8 bouts. M: 2 x 3 min rounds F: 2 x 3 min rounds	Different weight categories across competitions (*e.g.*, Olympic Games vs others): some wrestlers must change to a new weight category
Wrestling	UWW competition:	Weigh-in on morning before	Tournament contested across two	Different weight categories across

(Greco Roman) [16]	M = 10 Olympic Games: M = 6	competition. There is another weigh-in on the second day of competition with no weight allowance (2 kg is tolerated at world cups and international tournaments). After passing a medical check, athletes must wear a competition singlet during weigh-in.	days: 4-8 bouts. M: 2 x 3 min rounds F: 2 x 3 min rounds	competitions (*e.g.*, Olympic Games vs others): some wrestlers must change to a new weight category
Collegiate Wrestling (17)	NCAA and NCWA: M = 10; F = 8	Weigh-in on the day of competition no less than 2 hr pre- first bout. Athletes must wear undergarments at weigh-in and follow a regulated certification program inclusive of <1.5% weekly BM loss, minimum 5% body fat etc. prior to competition.	Dual meets: single day competition between teams from 2 (or more) colleges with single match for each weight category. Tournament: multi-day meet with 2 matches per day. 7 min bouts (3 + 2 + 2 min rounds).	Weekly dual/multiple meets over competition season with tournaments at end of season. Certification program and other protocols attempt to limit unsafe weight loss practices.
Other Sports				
Olympic Weightlifting (18)	IWF: M = 10; F = 10 Olympic Games: M = 7; F = 7	Weigh-in on the day of competition no less than 2 hr pre- first event of the day. Official weigh-in can be attempted multiple times, with athletes allowed to wear undergarments. When necessary, the weigh-in can be conducted naked.	Tournament contested on a single day. 3 lifts in two disciplines (clean-and-jerk and snatch). In case of tie, lightest competitor wins.	Different weight categories across competitions (*e.g.*, Olympic Games vs others): some lifters must change to a new weight category
Powerlifting (19)	IPF: M = 8; F = 8	Weigh-in on the day of competition no less than 2 hr pre- first event of the day. Official weigh-in can only be attempted	Tournament contested on a single day.	

		once (re-weigh in at discretion of referees), with athletes allowed to wear undergarments and socks. When necessary, the weigh in can be conducted naked.	3 lifts in three disciplines (squat, bench press, and deadlift)	
Rowing (20) (lightweight)	M: Average crew weight < 70 kg No individual > 72.5 kg F < 57 kg, 59 kg Coxswain: > 55 kg (M) and > 50 kg (F/mixed)	Weigh-in on day of competition no less than 1 hr and not more than 2 hr before first event. Competitors are expected to weigh in each day wearing their competition uniform and for each event they are competing in.	Regatta over ~ 7 d Most crews race every second day Race = 2000 m course	Many lightweight rowers only race “at weight” a couple of times per year at important races. Many countries provide opportunities in early season races for lightweight rowers to race above weight. Crew boats may require some rowers to be lighter to provide opportunity for heavier rower within boat average
American “Sprint” Football Collegiate League (21)	M: < 170 lb (77 kg) or <183 lb (83 kg) with > 5% BF and USG $\leq$ 1.020	Weight certification for eligibility prior to first practice. Weigh < 178 lb (80.9 kg), 2 and 4 d prior to a game.	Competitive season involves maximum of 7 formal games, and more recently, a play off between top teams of the two divisions.	Complies with American Football rules but promotes speed and agility rather than mass/strength.
Horse racing (jockey)	Different weight handicaps between types of races (*e.g.*, flat vs steeple) and different countries or local race authorities	All jockeys ‘weigh-out’ no later than 45 min before racing for each race. Jockeys on horses that earn prize money (plus all jockeys in certain races which are spot checked) have to ‘weigh-in’ directly *after* the race.	1-2 race meets a week over racing season. Jockeys may have 6–8 rides during one race meet over 5-6 hr. Races are conducted over various distances, usually 1000–2000 m (lasting 1–2 min), but occasionally longer.	Multiple races over a single race meet may require different weight handicaps according to the horse. Need for weigh in after race prevents recovery strategies.

M: male; F: female; AIBA = International Boxing Association; UWW = United World Wrestling; UFC = Ultimate Fighting Championship; NCAA = National Collegiate Athletic Association; NCWA: National College Wrestling Association; IWF = International Weightlifting Federation; IPF = International Powerlifting Federation

Table 2. Benefits and disadvantages of common methods of rapid weight loss (Modified from 56).

Acute weight loss method		Benefits	Disadvantages
Body water manipulation	Passive sweating (thermally stressful conditions *e.g.*, sauna, hot bath, sweat suits etc.)	• Relatively simple method of weight loss • Promotes high sweat rates and thus weight loss	• Preferential loss of plasma volume • Thermally stressful environment exacerbates risk of hyperthermia
	Active sweating (exercise induced)	• Can be easily incorporated into existing training sessions before weigh-in • Better maintains plasma volume (than passive sweating)	• Additional exercise may induce fatigue/ muscle soreness • Additional exercise further reduces muscle glycogen, requiring more aggressive refueling recovery
	Fluid restriction	• May cause less physiological disturbances than other forms of dehydration • Relatively simple to implement and passive	• Increased thirst sensation • Slower rate of loss than promotion of sweat rate
	Water loading (intake of large volumes of fluid for days, followed by sudden fluid restriction on the day before weigh-in)	• May facilitate greater satiety despite low energy intake • Large volume of urine loss with no energy expended	• Still experimental and likely to achieve smaller net fluid (BM) loss than other techniques • Small risk of hyponatremia
	Diuretics	• Moderate volume of fluid removed without need for	• Banned in most sports • Principally reduces plasma volume • Electrolyte imbalance and risk of muscle cramps

	Blood withdrawal pre-weigh-in (for reinfusion post weigh-in)	energy expenditure	• Likely banned in most sports • Requires sterile conditions to mitigate infection risk
Manipulation of body energy stores (principally achieved in the short-term via a reduction in body carbohydrate stores and associated water)	Exercise Restriction of energy intake Specific reduction of dietary carbohydrate intake	• Can be integrated into training program • Can be achieved by change in energy density of food choices • Allows continuation of food intake (i.e. absence of hunger) while still achieving the reduction in muscle glycogen/water content	• Glycogen replacement required for performance needs in many events • If exercise is additional and excessive, can cause fatigue/muscle soreness • Hunger, loss of perceived energy and reduction of muscle glycogen • Restriction of dietary carbohydrate associated with fatigue (especially during exercise)
Manipulation of gastrointestinal tract contents	Food restriction Fiber restriction Laxative/ Bowel preparation use	• Easily implemented • Minimal impact on acute nutritional status or performance • Easily implemented	• Hunger, loss of perceived energy and reduction of muscle glycogen • Only small impact on body mass • Banned in some sports • Body water loss and associated impaired cardiovascular function • Electrolyte imbalances

Table 3. Strategies for recovery of fluid and carbohydrate stores between weigh-in and event

Issues	General recommendations	Practical issues to consider in weight category sports
Rehydration (40)	• Consume a fluid volume equal to ~150% of the fluid deficit to allow for ongoing urine and sweat losses during the recovery period • Replace lost electrolytes, particularly sodium, as part of the fluid plan to promote rapid re-equilibration of fluid compartments and to minimize urine losses. This can be achieved by consuming electrolyte-containing drinks that are specifically developed for rehydration (*e.g.*, oral rehydration solutions or ~50-60 mmol sodium) and/or consuming salt-rich foods with other drink choices • Note that the addition of protein to a drink or in food consumed at the same time can enhance effective rehydration by enhancing fluid retention, and may contribute to other recovery goals • The rate and volume of intake of fluid needs to consider gastric emptying (larger volumes increase rate of emptying) vs fluid retention (a slower more frequent intake of fluid will reduce perturbation in plasma osmolality and reduce urine losses)	• It may not be possible to consume enough fluid in the available timeframe between weigh-in and event to allow for full restoration of fluid losses; a protocol that integrates considerations around gastro-intestinal absorption rates, urinary losses and gut comfort for the event should be developed according to individual experience • Replacement of electrolytes is more important when dehydration has been achieved via sweating (with accompanying loss of electrolytes) than fluid restriction • Consuming a large fluid bolus (*e.g.*, 10 mL/kg) immediately after weigh-in, followed by continued smaller volumes at regular intervals will maintain a high rate of gastric emptying (via high gastric volume). This may also reduce the need to consume fluids just before the event, risking gut discomfort during competition • If further weigh-ins are required (*e.g.*, multiple days of competition), the athlete should rehydrate for the first bout according to the importance of hydration to performance, then repeat the dehydration-rehydration protocol for subsequent days • If further weight limits are imposed (*e.g.*, mat-side weigh-in with limits for regain following official weigh-in), the athlete should be cautious that initial weight making was not so severe that appropriate competition preparation cannot be achieve with the allowable recovery regain
Glycogen	• Take advantage of enhanced rates of glycogen	• Although the athlete may have reduced glycogen stores as

storage/restoration of CHO availability (41)	restoration when muscle stores are most depleted and in the period (up to 4 hr) immediately after an exercise bout. Adequate energy availability is required to optimize glycogen storage from a given amount of CHO. • Enhance early postexercise recovery with a higher rate of CHO intake (~1 g/kg BM/h), especially by consuming in frequent small feedings. • Focus on CHO-rich foods with a moderate–high GI to provide a readily available source of substrate for glycogen synthesis. • Add protein to CHO-rich meals and snacks to promote glycogen storage when CHO intake is suboptimal, especially during the first hours of recovery. An intake of ~20–25 g of high-quality protein appears to optimize this effect while also meeting goals for postexercise muscle protein synthesis. • Target daily CHO intake based on body mass (or proxy for the volume of active muscle) and exercise load. Guidelines can be suggested but need to be fine-tuned according to the athlete's overall dietary goals and feedback from training. o Moderate exercise load: 5–7 g/kg BM/d o Heavy exercise load to glycogen supercompensation: 6–10 g/kg BM/d	a result of weight making strategies, the importance of glycogen to performance will vary according to the type of sport and the number of events/bouts that will be undertaken on a day. The athlete should refuel accordingly • It may not be possible to refuel sufficiently if the post-weigh in period is brief (*e.g.*, 1-2 hr) and weight making practices have involved severe CHO restriction and/or exercise. The athlete should consider this when undertaking weight making practices. • Food choices should consider CHO targets, other nutritional goals (*e.g.*, protein intake) and gut comfort. Compact and fluid-based choices may be most suitable, and intake of fat and fiber should be moderated.

CHO: Carbohydrate, BM: Body mass

Table 4. Effects of Weight Reduction on Performance and Success of Weight-Category Athletes.*

Intervention study: Chronic weight-making without recovery strategy				
Sport	**Strategy of weight making**	**Magnitude of BM loss (%BM mean)**	**Measurement of Performance**	**Outcome with weight making (versus baseline or control group)**
MMA (27)	Case study; M=1: 7-wk energy restriction + 5 d of water loading	18.1%	• VO_2 peak on treadmill	Inability to complete VO_2 peak test (↓11.1% in mL/kg/min).
MMA (28)	Case study; M=1: 8-wk energy restriction (7 wk at RMR and 5 d further reduced)	13.5%	• Upper and lower body maximum dynamic strength (1RM), • Maximum dynamic power (MDP) • VO_2 peak on treadmill	↑strength: 6-9% absolute, 18-19% relative ↑ MDP: absolute upper body, relative lower body ↑13% absolute VO_2 peak ↑19%relative VO_2 peak
			•	
Intervention study: Rapid Weight loss with minimal or no recovery opportunity				
Sport	**Strategy of weight making**	**Magnitude of BM loss (%BM mean)**	**Measurement of Performance**	**Outcome with weight making (versus baseline or control group)**
Boxing (109)	5-d training and energy/fluid restriction; M=8	3.0%	• Punching force during simulated boxing bout (3, 3-min rounds)	↓4.6% (NS) in punching forces ($p>0.05$)
Boxing (110)	~2-h of low-intensity exercise in a sauna and sweat suit; M=7	3.8%	• Punching force during simulated boxing bout (3, 3-min rounds with 108 punches per round)	No change in punching force ($p>0.05$)
Boxing (111)	Athlete-preferred methods using training and energy/fluid restriction, n=16 (sex NA)	5.2%	• Number of repetitions performed during intervals of efforts consistent with boxing training	↓ ~6.7% in repetitions compared to set goals ($p<0.05$)

Judoists (112)	7-d food restriction; M=11	4.9%	• Isometric grip strength • Vertical jump flight time and number in 7 s and 30 s • Single standing jump (SJ) and counter-movement jump (CMJ)	Significant ↓: left grip and jump performance for 30 s ($p<0.05$) NS: right grip, 7 s jump number, SJ, or CMJ ($p>0.05$)
Judoists (113)	Gradual (3 wk) reduction with food/fluid restriction plus rapid reduction w/ exercise in sweat suits(dehydration) vs baseline; M=5, F=5	4.0%	• Judo movements in 5 s or 30 s • Vertical jumps: squat jumps and CMJ	↓ 10% for of judo movement repetitions over 30 s ($p<0.05$) NS for 5 s movements or either vertical jumps ($p>0.05$)
Judoists (114)	~1 month self-prescribed WL vs those who maintained or gained weight, M=27	1.1%	• Forearm maximum isometric contraction (MVC) with visual feedback.	NS: MVC overall Those with > 2%↓ MVC had greater weight reduction ($p<0.05$) Those with ↓TBW had ↓MVC ($p<0.05$)
Combat athletes (115)	RWL over 5-7 days via food/fluid restriction and sweating; and post competition (nondescript recovery) M=14 RWL, M=14 controls	5.5% in RWL group	VO2 peak and peak running velocity • Running speed at which 4 mmol lactate/L (4LT)	No change in VO2 peak or peak velocity with RWL ($p>0.05$) ↑running speed at 4LT
Wrestler – collegiate (96)	4-d energy restriction but iso-protein with high CHO vs low CHO content; M=12	6.2%	• Intermittent high-intensity isokinetic arm ergometry (total work performed)	NS differences in work on high-CHO diet (↓0.8%, p>005); ↓ work on low-CHO diet (↓8.7%, $p<0.05$)
Wrestling – collegiate (116)	10 d self-prescribed weight loss of different magnitude (categorized by authors); M=16	~1%~3%~6%%	• Maximum isometric grip strength • Leg ergometer Wingate test	No change in performances before and after weight reduction regardless of category % weight loss ($p>0.05$)
Intervention study: Rapid weight loss with recovery opportunity				
Sport	**Strategy of weight making and recovery**	**Magnitude of BM loss (%BM mean)**	**Measurement of Performance**	**Outcome**

Combat athletes (judo, jiu-jitsu, MMA and wrestling) (117)	Self-prescribed WM in weight cyclers, M=10, vs non-weight cycler athlete, M=8, with 4-h recovery of approximately 1,600 Cal, 250 g CHO, 50 g pro, 45 g fat, and ad-lib water (volume not specified)	5%	Intermittent high-intensity isotonic arm ergometry work	NS performance difference: weight cyclers vs non-cyclers ($p>0.05$) NS composition of recovery meal: weight cyclers vs non-cyclers ($p>0.05$)
Judoists (118)	Self-prescribed training and food and fluid restriction, M=10, vs non-weight loss control group, M=10	3%	Five judo matches, each followed by • Maximum isometric hand grip strength anaerobic capacity test of upper body (rowing)	↓ in performance with cumulative matches in WM group
Judoists (119)	5-d self-prescribed WM + 4-h ad-lib fluid and food recovery providing 1391 Cal, 201 g, 50 g fat, 34 g protein; M=7 vs control group, M=7	4.8%	• 3- min high-intensity judo drills against an opponent + 5-min rest • 5-min judo combat against comparable opponent (scoring of activity time, number of attacks and attempts) + • 15 min recovery • Three x 30-s Wingate tests with 3-min recovery	NS difference in activity time, number of attacks and Wingate performance ($p>0.05$).
Lightweight rowing (M) (120)	24 hr food + fluid restriction + exercise-induced sweating in sweat suit Recovery post weigh-in (2 hr): 1500 ml water; M=8	5.2% (before recovery)	• Rowing ergometer TT simulating 2000 m	Performance ↓ 22 s ($p<0.05$)
Lightweight rowing (M + F) (121)	24 hr increased exercise and reduced food/fluid intake + 2 hr recovery: 2.3 g/kg CHO, 25 ml/kg fluid + 34 mg/kg Na, and ad lib fluids; M=8, F=9	4% (before recovery)	• 2000 m rowing ergometer TT	Performance ↓2.1 s ($p=0.003$) or 0.7%

Lightweight rowing (M + F) (34)	24 hr increased exercise and reduced food/fluid intake + 2 hr recovery: 2.3 g/kg CHO, 25 ml/kg fluid + 34 mg/kg Na and ad lib fluids; M=8, F=9	4% (before recovery)	• 1800 m on water rowing TT (cool conditions)	Performance ↓1.0 s ($p=0.29$)
Lightweight rowing (M) (33)	24 hr increased exercise and reduced food/fluid intake + 2 hr recovery: 2.3 g/kg CHO, 28 ml/kg fluid + 34 mg/kg Na and ad lib fluids then 2 further trials 48 hr apart • Complete Recovery post-race (regain of 3%) + full WM; M=6 OR • Partial Recovery post-race (regain of 0.3%) + reduced WM; M=6 • No weight loss control; M=4	4% (before recovery)	• 4 x 2000 m rowing ergometer TT, 48 hr apart, (simulates multi-day regatta where weight must be made on any race day)	When outliers removed: Performance ↓3.0 s ($p=0.07$) for first WM race Performance regained in subsequent races, especially with full recovery
Combat athletes (122)	3-h passive dehydration (sauna and sweat suit) + 3-h ad lib fluid and food recovery vs 3-h passive heat exposure with fluid ingestion to stay euhydration. Body weight restored to pre-weight loss weight; M=14	3.2%	• Maximum voluntary isometric knee extension (MVC) • Rate of force production, indices of neural recruitment, • Total number repetitions at 85% MVC	↓26.1%. repeated contractions at 85% MVC ($p<0.05$) Core temp elevated to 39°C with RWL ($p<0.05$) All other outcomes NS ($p>0.05$)
Taekwondo (123)	3.5 d self-prescribed training, passive & active sweating, energy restriction prior to official weigh with performance done after 16 hr recovery using self-prescribed approach of rehydration and carbohydrate intake; M=5	5.0%	Three simulated TKD matches quantifying • kicking frequency • attack time & number • blood lactate • VO_2	↑ kicking frequency, VO_2 (peak and mean), and lactate for those who lost weight ($p<0.05$)

Taekwondo (124)	2-w sport-specific training, passive & active sweating, energy/fluid restriction prior to official weigh and 24-hr period (no details) before performance tests; M=15 vs non-weight loss control group, M=16	10.3%	Three X 2-min bouts of TKD against comparable opponent • matches scored for skill performance including scoring, action and no action.	↑ performance scores in control group vs no change in scores for weight-loss group ($p<0.05$).
Wrestling – collegiate (125)	3-5 d self-prescribed weight loss then 1-2 hr recovery with ~1 L water + 1.5 g kg CHO or ~1 L flavored placebo; M=15	4.6%	• Intermittent high-intensity isotonic arm ergometry	NS change in arm work with weight loss or recovery ($p>0.05$)
Wrestling – collegiate (126)	3-5 d energy-restricted standardized high CHO liquid diet and training, then 5-h recovery with high CHO (75%; 21 kcal/kg) or isocaloric mod-CHO (47%, 21 kcal/kg); M=12	3.3%	• Intermittent high-intensity isotonic arm ergometry	↓ 7.6% arm work after weight loss ($p<0.05$) and trend for no change (↓0.9%) work after recovery on high-CHO treatment vs. ↓8.5% work on mod-CHO treatment ($p=0.10$)
Observational study: Performance outcomes in real-life events using magnitude of RWG as proxy for magnitude of RWL				
Sport	**Reweigh information**	**Magnitude of RWG (%BM mean)**	**Measurement of Performance**	**Outcome**
Boxing - professional boxing (M) (127)	RWG between 24 hr (weigh in) and 12 hr (2nd weigh) pre fight; M=126, F=16	3.8%	• 71 IBF fights	Negligible correlation between fight outcome and RWG ($p>0.05$)
Boxing – Olympic-style elite adolescent (128)	Survey on weight reduction practices in European boxers; M=83	2.8%	• Success in European Championships (medal vs non-medal)	RWG not associated with success (odds ratio; 1.70, ($p>0.05$). Boxing experience linked to success (odds ratio: 1.33, $p<0.05$)
Boxing – Olympic style senior M & F (38)	RWG during 3-12 hr between official weigh in and 1 hr before fight; M=70, F=30	2.1% for M;1.5% for F	• Finalists vs non-finalists and winners vs losers of matches	No difference in RWG between winners vs losers and finalists vs non-finalists ($p>0.05$)

MMA (129)	Typical methods of RWL over 15-30 d and RWG 24h between weigh in and match M=8 bout winners, M=7 bout losers	RWL ~7% RWG: 3% losers 6% winners	Match outcome – win vs. loss • Technical aspects of match	No difference in RWL for winner vs loser ($p>0.05$) RWG greater for winners ($p<0.05$) Technical-tactical and time-motion performance associated with RWG
MMA professionals (40)	24-h recovery between weigh in and bout. 31 winners, 31 losers Sex not stated	RWG: 9.1% losers 10.1% winners	• Match outcome – win vs. loss	No association between RWG ($p>0.05$); both winners and losers regained substantial weight
Wrestling – collegiate (130)	RWG between 17 hr official weigh in and 1 hr before match; M=607	5.%	• Success in 1st round of US collegiate national championships	No relationship between success and RWG or weight discrepancy between 1st round opponents ($p>0.05$). No difference in RWG for place winners (5.2%) vs non-placers (5.3% ($p>0.05$)
Wrestling – adolescent (131)	12 hr between official weigh in and check-in before match; M=260	2.2%	• Victory in the 1st round of day 2 of a tournament	1st round winners regained more weight (2.4%) than 1st round losers (1.9%) ($p<0.05$)
Judoists – senior, M and F (36)	RWG during 15-20 hr between official weigh in and 1 hr before first fight; F=36, M=50	2.3% for M and 3.1 % for F	• Medalists vs non-medalists and winners vs losers of matches	Medalists had greater RWG than non-medalists, especially for males ($p<0.05$); Winners had greater RWG than losers of matches ($p<0.05$)
Observational study: Performance outcomes in real-life events with weight loss reported				
Sport	**Strategy of weight making**	**Magnitude of BM loss (%BM mean)**	**Measurement of Performance**	**Outcome**
MMA (132)	30-d fluid/energy/CHO restriction plus 24-h passive and active sweating; M=12	9.4%	• Victory in fights	No clear relationship between RWL and success
MMA (39)	7-d self-prescribed weight loss before official weigh in. 24-h pre-	8.6% and 10.6%	• Victory in fights	Greater RWL (10.6%) in those who lost fight than those who won

	event recovery not described; M=73, F=2			(8.6%)
Observational study: Effects of a season of weight loss				
Wrestling – adolescent (133)	Typical wrestling training and diet restriction; M=9, vs maturation- and size-matched physical active controls; M=7. Measurements at pre and late competitive season (3.5-4 month span of repeatedly making weight).	3.8%	• Strength assessed using isokinetic peak torque at elbow and knee at 60°/sec and 180°/sec.	↓strength for all assessments in association with ↓FFM (2%) ($p<0.05$). In contrast, for physically active controls, ↔strength ($p>0.05$) and ↑FFM (3.5%) ($p<0.05$).

M = male; F = female, RWL = rapid weight loss; RWG = rapid weight gain; MVC = maximum voluntary contraction; NA: not available; MMA = mixed martial arts, CHO = carbohydrate, TT = time trial.

[*]The literature summarized here was obtained using PubMed searches on the following combination of phrases: boxing, combat sports, judo, mixed martial arts, taekwondo, or wrestling *and* dehydration, making weight, weight loss, or weight reduction, *and* athletic performance, performance, or physical performance. Reporting of change in body mass was a requirement for inclusion in the summary. Acceptable publication dates of the articles started with 1996 (date of ACSM position stand on weight loss in wrestlers) and continued to the present. All published observational studies on weight manipulation and sport-specific success were considered if not included. Intervention studies that were deemed acceptable compared physical performance at baseline vs. post-weigh-in or post-nutrition recovery following weight loss practices typical of the sport-specific combat athletes at the date of publication. Intervention is defined as protocols involving weight manipulation for research purposes, not necessarily for sport competition. Weigh-in protocols change over eras and are sport-specific, but the summary is broad enough to allow a general but valid conclusion regarding advantages and disadvantages of various weight loss scenarios among athletes in weight-category sports.

Table 5. Overview of Strategies and Rule Changes to Minimize Harmful Weight Making Behaviors in Weight-Category Sports

Intervention	Positives	Negatives
Athlete and coach education	• Required to help athletes make better dietary choices and improve awareness of harmful methods	• May be ineffective without concurrent rule changes
Increasing the number of competitive weight categories	• Competitors have more options to choose a weight class that is compatible with their habitual weight	• Creates a problem for sport organizations to ensure adequate number of competitors at each weight • Smaller weight increments between divisions create greater temptation to 'cut' to a lower division
Use of height categories instead of weight categories	• Eliminates the need for RWL and RWG and the health risks associated with making weight • Maintains fairness in striking-based martial arts where limb-length is an important factor for competition success (*e.g.*, karate, taekwondo)	• Potential for large differences in body mass, strength, and power between competitors • Less suited to full-contact martial arts where use of body mass is important (*e.g.*, wrestling or judo) • Measurement error and diurnal variations in height could lead to misclassification
Establishing a minimal competition weight	• Encourages athletes to maintain their BM close to their competitive weight-category • Emphasises chronic BM management through the manipulation of FFM and FM	• Estimation of BF% requires standardized equipment, methods, and trained personnel to ensure reliability • Requires a "season" or a standardized period each year where athletes are measured and certified • Athletes can still undergo large RWL prior to competition if they maintain a higher BF%
Move the weigh-in time closer to the start of competition	• Several sports with a short recovery duration (≤1 hr) do not have issues with large RWL and RWG • Athletes undergo less RWL due to inadequate time to rehydrate/recover and the risk of a negative impact on performance in competition	• A risk that athletes may still undergo RWL and enter competition severely dehydrated due to inadequate recovery time—may increase health risk • Some argue that early weigh-ins are beneficial as it allows for maximum rehydration and mental preparation for competition

Determine the weight classes the day of competition	• Discourages any weight reduction because of unpredictability. • Effective administration at youth wrestling tournaments with abundant participants.	• Some weight discrepancies will exist within a weight class but not one is dehydrated or malnourished. • Difficult to administer for championship tournaments requiring prior qualifying tournaments.
Limit the number of weigh-in attempts during the official weigh-in period	• Athletes who need to re-weigh multiple times will likely use harmful practices (*e.g.*, spitting, vomiting, sauna, or training in rubber suits) in the short timeframe permitted before re-weighing	• To enforce the rule, athletes who miss weight at the first attempt must be excluded from competition
Assess urinary hydration status at the official weigh-in (specific gravity <1.020 indicates adequate hydration)	• Discourages weight-making via dehydration-based methods by ensuring athletes are euhydrated at the time of the weigh-in • Easy to implement for sport organizations/events	• Concerns over the validity and reliability of field-based hydration tests: may lead to a high false-positive rate *i.e.,* hydrated athletes classified as dehydrated and being excluded from competition • Requires a calibrated refractometer at each event • To prevent fraud, each athlete must be closely observed when providing their urine sample (similar to anti-doping) • To enforce the rule, athletes showing dehydration must be excluded from competition

Competitors subject to a re-weigh limit (tolerance) on the morning of competition	• Discourages extreme RWL/RWG due to the need to remain within 5% or 10% of the weight category	• Still able to regain a large amount of body mass within the re-weigh limit (*e.g.*, if 10%) • Competitors can maintain their weight below the limit and continue to rehydrate following the re-weigh (typically 1-2 hr pre-competition, but can be longer) • Athletes may rehydrate, taking them over the re-weight limit, then perform another weight "cut" on the day of competition to be within the limit. • To enforce the rule, athletes who re-weigh above the limit must be excluded from competition
Prohibition of potentially harmful RWL methods (*e.g.,* IV rehydration, training in plastic suits, sauna use, laxatives, emetics, diuretics etc.)	• Encourages athletes to use diet and exercise to slowly reduce their body mass for competition	• Challenging to enforce in the real world (athletes cannot be monitored 24/7) • In specific contexts, some methods deemed potentially harmful can be used in a safe manner

BF% = body fat percentage; IV = intravenous; RWL = Rapid weight loss; RWG = Rapid weight gain.

Table 6. Recommendations for safer weight making practices in weight category sports
• Sporting organizations, practitioners/clinicians, coaches, and athletes involving events with weight categories should recognize the unique characteristics of their sport and support practices that promote safe and equitable competition for all competitors. • Sporting organizations should continually review the weight making practices used within their sport to evolve the specific rules and regulations around weight categories and weigh-ins to deter unsafe practices. • Continued evaluation of formal programs and sharing of best practices between weight-category sports are encouraged to fine-tune protocols based on success and failure to improve rapid weight loss practices, change the culture, and enhance safety and health of the competitors. • Strategies should discourage any weight making among the minors and the youngest of participants and fully inform adult competitors of safety and health risks. • The selection of a suitable weight category for each athlete, and the timely achievement of true alterations in BM towards the event target should underpin all weight making practices. A suitable weight category is one that can be safely achieved by the athlete without undue physical, nutritional or psychological stress. • If formal weight-category selection programs have not been implemented, clinicians are encouraged to evaluate the athlete's body composition, not BM alone, guide weight class selection and provide the caveat that minimal weight may not be the optimal performance weight. • The athlete's natural or day to day BM should be within reach of their specific weight class, allowing them to achieve their usual training goals while maintaining dietary practices that support adequate energy availability, requirements for all nutrients and a healthy relationship with food and its contribution to growth, development, and the quality of life. • Critical planning and education are required to integrate nutrition needs with the training volume to ensure maintaining nutrient status while succeeding with FM reduction, maintaining FFM as much as possible, and improving competition readiness

FM = Fat mass; FFM = Lean body mass