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Making Weight in Combat Sports

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SUMMARY

COMBAT SPORTS ARE CATEGORIZED INTO WEIGHT CLASSES INTENDED TO PROMOTE FAIR COMPETITION BY MATCHING OPPONENTS OF EQUAL STATURE AND BODY MASS. MANY ATHLETES AIM TO COMPETE AT THE LIGHTEST WEIGHT POSSIBLE IN THE BELIEF THAT IT WILL OFFER A COMPETITIVE EDGE OVER OPPONENTS. CONSEQUENTLY, COMBAT ATHLETES OFTEN RELY ON ACUTE AND CHRONIC DEHYDRATION AND RESTRICTED ENERGY INTAKE TO *MAKE WEIGHT*. IN CONTRAST, THIS ARTICLE OUTLINES KEY PRINCIPLES FROM EXERCISE METABOLISM AND NUTRITION THAT COMBAT ATHLETES CAN EMPLOY TO MORE GRADUALLY MAKE WEIGHT AND THEREFORE AVOID THE NEGATIVE HEALTH AND PERFORMANCE EFFECTS ASSOCIATED WITH TRADITIONAL WEIGHT-MAKING STRATEGIES.

INTRODUCTION

Combat sports (such as boxing, wrestling, judo, and taekwondo) are categorized into a series of weight classes that are intended to promote fair competition by matching opponents of equal stature and body mass (commonly referred to as "weight" within the sport). Combat sports are usually steeped in their own tradition and culture, particularly in relation to weight-making practices (48). Typically, combat athletes aim to compete at the lightest weight possible in the belief that it will result in a competitive edge over opponents. Consequently, many athletes achieve their target weight via the combination of acute and chronic means that involves severe energy restriction and dehydration (23,24,38,48). The latter weight-making method is common in the days preceding the weigh-in and is known in combat sports as "drying out."

Although data concerning weight-making practices of combat sports are beginning to accumulate, weight making in combat athletes is still a largely underresearched area. The lack of data on this topic may be because of associated difficulties with researching this population, such as lack of consistent weight-making practices, distrust of nonfamiliar researchers by both athletes and coaches, and moreover, athletes not wanting to openly disclose their habitual weight-making routines to public scrutiny.

Not only do exercise scientists require a greater understanding of the habitual practices that combat athletes typically undertake, but we also need to systematically test the efficacy of alternative scientific-based approaches in terms of both making weight and their resulting impact on performance. A much wider research base will surely lead to improved athlete and coach education, which ultimately, can only improve athlete well-being and enhance performance. In those cases where weight-making practices have been documented, weight losses of 3–4 kg are not uncommon in the week preceding competition (1,2,25,32,53). Such levels of acute weight loss can impair components of sport-specific performance, such as reduced punching force (70) and cognitive function (14), whereas the effects of dehydration and energy restriction carry obvious health risks, including hypoglycemia (14). Indeed, the reduction in energy and fluid intake during training and in the days before competition may increase the risk of infection and impair mood (14), whereas the increased cardiovascular and thermoregulatory strain may result in severe injury and in extreme cases cause death (13).

With this in mind, the aim of the present article is to offer some potential strategies to make weight using a more gradual and scientific approach, which is based on key principles of exercise metabolism and nutrition. We begin by presenting an overview of weight classifications of popular combat sports, followed by a summary of those practices that athletes in combat sports commonly adopt to make weight. After providing commentary on guidelines to make weight that are based on an understanding of how timing, composition, and quantity of energy intake affect metabolic regulation, we close by presenting data from a recently published case study (48). Not only do we hope that these guidelines will help improve practice, but we also aim to stimulate interest among readers to conduct further research in the area.

KEY WORDS:
boxing; judo; taekwondo; wrestling; dehydration; energy restriction

OVERVIEW OF WEIGHT CLASSIFICATIONS IN COMBAT SPORTS

The main weight classifications of the common combat sports are shown in Table 1. For the amateur combat sports, data were taken from the International Olympic Committee and relevant world governing bodies. In the case of professional boxing, we have used information from the World Boxing Council, given that it is recognized within the sport as the most prestigious governing body. It is noteworthy that in sports such as taekwondo and wrestling, there can be up to 10-kg differences between weight divisions in contrast to professional/amateur boxing where weight divisions are separated by no more than 3–4 kg. Such large differences between consecutive divisions highlight the potential for the introduction of more closely aligned weight categories so as to improve health and safety standards within the sport.

COMMON ATHLETE APPROACHES TO MAKING WEIGHT

To offer insight in this area, we performed literature searches combining key terms such as "weight loss" and "combat sports" as well as individual sport names using relevant databases (e.g., PubMed, MedLine, Web of Science). Because of space constraints, it is not possible to review all the relevant literature in this area. However, contemporary articles that we considered the most informative are summarized in Table 2. The consistency of approach used to summarize the findings differs between articles because of methodological differences between studies. Nevertheless, as expected from the culture of weight-making sports, common approaches to making weight included skipping meals, fasting, saunas, sweat suits, laxatives, diuretics, diet pills, and vomiting. These weight loss strategies are prevalent across all the combat sports examined and are not just specific to certain sports.

GUIDELINES TO MAKING WEIGHT

ASSESSMENT OF BODY COMPOSITION, RESTING METABOLIC RATE, AND DAILY TRAINING ENERGY EXPENDITURE

As with any intervention, the first stage should always be to conduct a sound athlete assessment that is based on reliable and valid assessment tools. Although dual-energy x-ray absorptiometry is now beginning to replace hydrodensitometry as the reference method for studies of body composition in athletic populations (59), a limitation of this technique is its expense and exposure to low-dose ionizing radiation. In a sporting context, therefore, more practical methods, such as skinfold assessments and subsequent use of prediction equations to estimate percent body fat and lean body mass, are more commonly employed (21,22,59,60).

Practitioners should be aware of the limitations of these equations (59), however. In fact, a potential avenue for future research is to develop reliable and valid prediction equations specifically for combat athletes similar to those developed for other sports, such as soccer (59). Given that direct measurement of resting metabolic rate (RMR) is not always practical, it is a common practice to estimate RMR on the basis of prediction equations. The equation of Cunningham (17) has been validated for athletic populations, where RMR = (lean body mass in kg × 22) + 500.

It is also important to estimate the typical daily training expenditure, and in this instance, measurements of heart rate provide the most user-friendly method (27). Having obtained relevant baseline physiological data, dietary analysis should then be conducted by a suitably qualified individual so as to identify nutritional habits that can be improved. Only then can a sound nutritional and conditioning program be developed to attempt to attain the target weight loss in the relevant period. It is difficult to provide precise recommendations in the present article because every athlete will present a different scenario. Nevertheless, we advise a daily energy intake that is *at least* equivalent to RMR (and as discussed in later sections, an increased protein intake) and a target weight loss of 1–1.5 kg/wk so as to avoid any loss of lean mass and decline in RMR (9,71).

OVERVIEW OF METABOLIC REGULATION IN EXERCISE AND FEEDING

The regulation of substrate utilization during exercise and feeding is a longstanding research area among biochemists. In contrast to the traditional glucose-fatty acid cycle (58), it is now generally accepted that fat oxidation during exercise is largely controlled by carbohydrate (CHO) availability given that insulin attenuates lipolysis so much so that it appears to limit fat oxidation (34). Furthermore, the suppressive effect of pre-exercise CHO ingestion on rates of lipolysis and lipid oxidation can persist for up to 4 hours after a meal (46). In this regard, ingestion of CHO, which ranks low to moderate on the glycemic index (and thus induces a low insulin response), does not attenuate lipolysis and lipid oxidation as much as those CHOs that are high glycemic (83).

In addition to pre-exercise feeding, it is also important to appreciate basic substrate utilization during exercise of varying intensities and duration. Early studies using stable isotope methodology demonstrated that lipid oxidation is reduced, whereas CHO utilization predominates at intensities above 65% $\dot{V}O_2max$ (62,77). Moreover, as exercise of moderate intensity becomes more prolonged, there is an increased reliance on plasma free fatty acids derived from adipose tissue lipolysis and reduced reliance on CHO sources (62). The precise cellular mechanisms regulating this shift in substrate utilization are beyond the scope of this review. In brief, evidence suggests that the increased glycolytic flux associated with high-intensity exercise limits the availability of free carnitine, which in turn reduces the activity of carnitine palmitoyl

Table 1
Overview of the weight categories in common combat sports

Sport	Weight categories					Weigh-in protocol	Competition format
Amateur boxing	Ten categories for men and 3 categories for women at the Olympic Games. Ten categories for men and women at the World Championship Events						
	Division	Olympic/ World men (kg)	World/ women (kg)	Olympic/ women (kg)			
	Light fly	46–49	45–48	—		All boxers must pass a medical examination before weigh-in	The official draw for all events is held 1 d before the competition
	Fly	−52	−51	48–51		All boxers who pass the medical examination must attend a general weigh-in, which is organized no more than 24 h before the medical check of the first competition day	Bouts for men are 3 × 3–min rounds and bouts for women are 4 × 2–min rounds
	Bantam	−56	−54	—		All boxers must also attend a daily weigh-in on the day they have been drawn to fight. The time from the end of the general weigh-in to the start of the first bout is less than 6 h	
	Feather	—	−57	—		The time from the end of the daily weigh-in to the start of the first bout of the remaining days of competition is less than 3 h	
	Light	−60	−60	—			
	Light-welter	−64	−64	57–60			
	Welter	−69	−69	—			
	Middle	−75	−75	—			
	Light heavy	−81	−81	69–75			
	Heavy	−91	+81	—			
	Super heavy	+91	—	—			
Professional boxing (WBC)	Eighteen categories for men and thirteen for women						
	Division	Men (lb)	Women (lb)				
	Pin	—	−101			All boxers must submit themselves for an annual medical examination and before weigh-in to keep WBC licensing	Title fights consist of 12 rounds of 3-min duration
	Straw	−105	—			The official weigh-in is held no less than 24 h but not more than 30 h before the bout. Extra official weigh-ins are held 30 and 7 d before the official 24–30 h weigh-in	Round number for other bouts can vary according to the nature of the fight
	Light fly	−108	−106				

(continued)

Table 1 (continued)

	Flyweight	−112	−110			A 30-d weigh-in is held 4 wk before the bout, and the boxer's weight must not exceed 10% of the weight limit for the bout	
	Super fly	−115	—			A 7-d weigh-in is held before the bout, and the boxer's weight must not exceed 5% of the weight limit for the bout	
	Light bantam	—	−114			In the event that the boxer exceeds the weight qualifications stated, the WBC may refuse to sanction the bout	
	Bantam	−118	−119				
	Super bantam	−122	—				
	Feather	−126	−125				
	Super feather	−130	—				
	Lightweight	−135	−132				
	Super light	−140	—				
	Light welter	—	−138				
	Welter	−147	−145				
	Super welter	−154	—				
	Light middle	—	−154				
	Middle	−160	−165				
	Super middle	−168	—				
	Light heavy	−175	−176				
	Cruiser	−200	—				
	Heavy	+200	+189				
Taekwondo (WTF)	Four categories for men and women at the Olympic Games. Eight categories for men and women at the World Championship Events						
	Division	World/ men (kg)	World/ women (kg)	Olympic/ men (kg)	Olympic/ women (kg)		
	Fin	−54	−46	—	—	There is no medical examination before weigh-in, which is held the day before the competition (time decided by the organizing committee)	The official draw is held the day before the start of the competition and at majors is seeded on the world ranking system
	Fly	−58	−49	−58	−49		Bouts for men and women are 3 × 2–min rounds
	Bantam	−63	−53	—	—		
	Feather	−68	−57	−68	−57		
	Light	−74	−62	—	—		

Table 1
(continued)

	Welter	−80	−67	−80	−67		
	Middle	−87	−73	—	—		
	Heavy	+87	+73	+80	+67		
Wrestling (Greco-Roman and freestyle) (FILA)	Seven categories (Greco-Roman and freestyle) for men at the Olympic and the World Championship Events. Four categories (freestyle only) for women at the Olympic Games and 7 (freestyle only) at the World Championship Events						
	Olympic/ world men (kg)	World/ women (kg)	Olympic/ women (kg)				
	50–55	44–48	−48			All wrestlers must pass a medical examination before weigh-in	The official draw is conducted during the weigh-in. As a wrestler passes the weigh-in and leaves the scales, he or she is paired with another competitor in that division
	−60	−51	—			The weigh-in for each category takes place on the same day as the competition	Bouts for men and women are 3 × 2–min rounds
	−66	−55	−55				
	−74	−59	—				
	−84	−63	−63				
	−96	−67	—				
	−120	−72	−72				
Judo (IJF)	Seven categories for men and women at all major events						
	Division	Men (kg)	Women (kg)				
	Extra light	−60	−48			There is no medical examination before weigh-in	The official draw is held the day before the start of the competition and at majors is seeded on the world ranking system
	Half light	−66	−52			The weigh-in for each category takes place on the same day as the competition	Bouts for men and women are a 1 × 5–min round
	Light	−73	−57				
	Half middle	−81	−63				

(continued)

Table 1
(continued)

	Middle	−90	−70				
	Half heavy	−100	−78				
	Heavy	+100	+78				

Units of measurement are given in the units employed by the governing body.

FILA = Fédération Internationale des Luttes Associées/ International Federation of Associated Wrestling Styles; WBC = World Boxing Council; WTF = World Taekwondo Federation.

transferase (CPT1), the rate-limiting enzyme for transport of long-chain fatty acids (LCFAs) across the mitochondrial membrane (77).

Similarly, when rates of glycolytic flux are reduced, such as when muscle glycogen availability is progressively reduced during prolonged exercise, free carnitine availability is not as drastically compromised, and consequently, LCFAs are more readily transported into the mitochondria for oxidation (61). Although lipid oxidation appears to be increased in conditions of reduced CHO availability, it is important to note that amino acid oxidation also increased (43). Over time, this may lead to a loss of lean mass (35,45), which would likely be disadvantageous for the combat athlete (given the role of lean body mass in generating force), unless of course (and although not advised) the athlete is required to lose muscle mass to make the target weight class (48).

Finally, it is also important to note that fat storage in the postprandial period is increased with successive meals throughout the day (63). Such findings are likely because of the accumulation of successive insulin increases, increased esterification, and increased lipoprotein lipase activity such that adipose tissue becomes *primed* for storage (as opposed to hydrolysis) of fat as the day progresses. As a result, fat storage after a meal is greatest in the hours after the evening dinner meal when compared with breakfast and lunch (63). To compensate for this effect, it is advised that the training load is spread out over 2–3 sessions per day, as opposed to a single session of longer duration, so that there is continual interplay between substrate utilization and storage. In practice, this is often structured as an early morning run designated for fat burning, a late morning/early afternoon sport-specific technique/fitness session, and an early evening strength and conditioning session (48).

BASIC NUTRITION AND HYDRATION PRINCIPLES IN MAKING WEIGHT

In considering the information presented above, it appears that timing, quantity, and composition of the macronutrient intake are all critical factors to consider when devising weight-making strategies. Nutritional practices should therefore be devised according to the *structure* of the daily training sessions so as to maximize the capacity for lipid oxidation during both exercise and recovery while also minimizing fat storage throughout the day.

Logical strategies to implement therefore initially center on a diet that is based around reduced (but we stress not zero) carbohydrate intake (given the role of CHO in regulating lipid metabolism), especially as the day progresses and also reduced saturated fat intake. In fact, there is now a growing body of literature from our laboratory and others demonstrating that training in conditions of reduced CHO availability actually enhances the oxidative capacity of skeletal muscle (47,85), as opposed to traditional guidelines surmising that daily training should be supported with high CHO intake. When CHO is consumed, it is recommended that it is low glycemic, and in the case of pre-exercise, CHO ingestion, approximately 3 hours before exercise, is advised so as to minimize the suppressive effect of insulin on lipolysis. With the combination of intense training and reduced CHO intake, it is likely that many training sessions will be commenced with muscle glycogen stores that are not considered full or optimal for the energy requirements of the particular session. Given the capacity for such conditions to increase amino acid oxidation, it follows that the daily diet should increase protein intake so as to maintain (or at least minimize) any associated lean mass loss by maintaining the amino acid pool. In fact, we (48) and others (45) have shown that elevated daily protein intake can maintain lean mass even in the face of high daily training energy expenditure and when total daily CHO intake is reduced.

Where protein supplements are being used to support daily protein intake, it is also worth using a supplement that is both casein and whey based so as to minimize the suppressive effects of insulin on lipolysis (given that casein exerts a less pronounced insulin response than whey) (76) as well as increase feelings of satiety by inducing a prolonged feeding effect (33).

When considering the timing of training sessions, performing sessions solely dedicated to the purpose of fat burning are best performed in the early morning after an overnight fast and at moderate intensity and duration (34). In this way, the negative

Table 2
Summary of research findings outlining common strategies employed by combat athletes to make weight

Sport (reference)	Subjects	Summary of findings
Judo (2)	822 (607 men and 215 women) subjects (age: 19.3 ± 5.3 y; height: 170.6 ± 9.8 cm; weight: 70 ± 7.5 kg)	Subjects were sampled by a validated questionnaire at a number of competitions between 2006 and 2008. After analysis, data showed that average magnitude of weight loss was 5% of body mass usually achieved within 7 d of competition. Methods to lose weight included gradual dieting (18.4%), skipping meals (19.3%), fasting (12.2%), restricting fluids (20.5%), increased exercise (61.7%), heated training rooms (25.5%), saunas (3.9%), training and using sweat suits (30.2%), spitting (18.9%), laxatives (3.0%), diuretics (2.0%), diet pills (0.9%), and vomiting (0.2%).
Amateur boxing (32)	16 male subjects (age: 23.5 ± 4.8 y; weight: 74.47 ± 12.25 kg; no height data provided)	Subjects were interviewed to see how much weight they would often lose and what methods they would use to make weight. Interview results reported that there are 4 phases in the weight control program: natural weight, training weight, interclub competition weight, and championship weight. All participants reported using dieting as a method of weight loss (including eating less and fluid restriction). Seventy-three percent of subjects reported losing weight through increased exercise (including long runs and skipping) as well as dehydrative methods, such as sweat suits and saunas.
Professional boxing (48)	Case study—1 professional male boxer (age: 27 y; height: 170 cm; weight: 68.3 kg)	Habitual approach to making weight relied on 1 meal per day for 6 wk before fight and on dehydration in days preceding weigh-in achieved via sweat suits, no fluid intake, and light exercise. Refueling after weigh-in was achieved by high intakes of saturated fat.
Taekwondo (25)	30 male subjects (age: 23.4 ± 4.6 y; height: 174 ± 7.6 cm; weight: 68.8 ± 11.4 kg)	Subjects were sampled by a validated questionnaire. After analysis, 100% of the subjects had lost more than 1 kg of body mass to make weight, with 3 kg being the most frequent weight loss target (33%) within 2–4 wk before competition. A number of methods were reported to lose weight, including restricted food intake (10%), restricted fluid intake (3%), increased training (7%), restricted food intake and increased training (36%), restricted food and fluid intake (7%), restricted food and fluid intake and increased training (37%), saunas (20%), and training in sweat suits (13%).
Taekwondo (24)	7 male subjects (age: 20.4 ± 4.6 y; height: 172 ± 7.7 cm; weight: 65.2 ± 11.5 kg)	Dietary intake of the subjects was assessed via food diary assessments during a 2-wk weight loss period before competition. The athlete's habitual dietary intake of 2,257 ± 854 kcal/d was dramatically reduced during the weight loss period to 1,464 ± 481 kcal (a 35% reduction), incurring an energy deficit of 793 kcal.
Wrestling (53)	741 male subjects (age: 20.0 ± 1.6 y; height: 174.1 ± 6.9 cm; weight: 73.2 ± 10.2 kg)	Subjects were sampled by a validated survey that assessed weight loss practices during the course of a collegiate wrestling season. Most common ways to lose weight for competition were gradual dieting (79.5%) and increased exercise (75.2%). However, subjects also reported fasting (54.8%) as well as the use of saunas (27.6%) and sweat suits (26.7%). Five of the subjects within the study met 3 of the criteria for bulimia nervosa.
Wrestling (38)	2,532 male subjects (no anthropometric data provided)	Subjects were sampled by a validated survey and reported using weight loss practices across a period of 2–3 mo, although the most weight lost was reported 5 d before weigh-in. Subjects reported losing weight via gradual dieting (61%), restricting food (58%), fasting (37%), restricting fluids (42%), increasing exercise (77%), heated wrestling room (39%), saunas (14%), sweat suits (16%), spitting (42%), laxatives (3.9%), diet pills (3.1%), diuretics (4.1%), enemas (1.2%), and vomiting (3.1%) on a daily, weekly, and monthly basis.
Wrestling (1)	45 men (no anthropometric data provided)	Subjects were selected at random and interviewed at a cadet/junior championship. Subjects reported losing weight via a variety of methods, including running (91.1%), cycling (33.3%), swimming (24.4%), sauna (55.6%), sweat suits (48.9%), and diuretics (11.1%).

Table 3
Common supplements often cited to aid weight loss and boost immune function during weight loss

Supplements claimed to increase weight loss	Claim/active ingredients	Key references	Summary of research findings	Star rating
Caffeine and/ or green tea	Caffeine is reported to have thermogenic effects and increase lipolysis during exercise. Green tea contains catechins, which are polyphenolic compounds reported to increase energy expenditure as well as increasing fat oxidation. Green tea is also high in caffeine.	(29,30,36,37, 44,56,80,84)	Growing evidence that green tea can increase fat oxidation during moderate-intensity exercise. Benefits appear particularly effective in overweight individuals.	***
Conjugated linoleic acid (CLA)	CLA is a naturally occurring fatty acid claimed to increase insulin sensitivity, decrease plasma glucose, and decrease fat mass.	(7,40,65,69)	Most of the strong evidence has come from animal studies, which should be treated with caution. However, there is some evidence that prolonged use of ~3.5 g/d can reduce body fat and importantly abdominal body fat in moderately overweight people.	***
Carnitine	Carnitine is obtained through the diet and through endogenous synthesis; it is stored in muscle and plays an important role in the transport of fatty acids into the mitochondria for oxidation.	(4,72–74,81)	The major problem is that oral supplementation of carnitine alone does not increase muscle carnitine content. Studies have shown that combining carnitine with an insulin infusion or with 188 g of high GI carbohydrates does increase muscle carnosine content. However, if this additional high GI carbohydrate negates the effects of the supplement on total fat oxidation remains unanswered.	**
Alpha-lipoic acid (ALA)	ALA is a potent antioxidant that has also been claimed to reduce fat mass. There have been many proposed mechanisms of action for ALA reducing fat mass, including the activation of PPAR-gamma, which regulates fatty acid storage and glucose metabolism. It is also a cofactor of many mitochondrial enzymes and has been reported to reduce voluntary food intake as well as increasing energy expenditure.	(39,55)	Most of this research has been performed using rodents. Some studies have shown modest weight loss in obese humans given 1,800 mg/d of ALA, although the evidence for it working in athletic humans is lacking.	*
Supplements claimed to boost immune function during weight loss	Claim/active ingredients	Key references	Summary of research findings	Star rating

Table 3 (continued)				
Multivitamin	Most athletes will obtain sufficient vitamins and minerals from their diet; however, there is a significant risk of deficiencies during dietary restriction when making weight, and this can have several health consequences. B vitamins, vitamin C, vitamin D, iron, calcium, magnesium, and zinc are the most likely to be low on a calorie-restricted diet.	(6,26)	A daily intake of low-dose multivitamin and mineral supplement (containing no more than the RDA) may prove useful when making weight. However, it should also be noted that more is not always best, and in high doses, many vitamins and minerals can become toxic.	***
Fish oils	Fish oils contain the long-chain omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), both of which are claimed to have a variety of health benefits, including the reduction of inflammation.	(8,11,51,57,68)	Research suggests that many athletes consuming a Western diet have an imbalance in their omega-3 to omega-6 ratio. There is some evidence that increasing EPA/DHA intake by ~1–2 g/d can boost immune function, although not all authors agree with this. Calorie-restricted diets are also more likely to lack DHA/EPA, and increasing fish oil consumption can improve markers of health during weight loss.	***
Quercetin	Quercetin is a dietary flavonoid present in a variety of fruits and vegetables, including apples and onion skin. Claimed to have antiviral activity and reduce the risk of upper respiratory tract infections (URTIs)	(19,50)	Growing evidence that daily 1,000 mg supplementation may reduce URTI. More studies are required, although on elite athletes.	***
Manuka honey	Honey has antibacterial qualities, and it has been claimed that manuka honey from the Manuka bush (Leptospermum scoparium) native to Australia and New Zealand is particularly potent.	(3,42,82)	Lots of evidence suggesting it may be effective in wound healing; however, limited data available on its role in URTI commonly seen with athletes.	*
Bovine colostrum (BC)	BC is the first milk produced from cows and is claimed to be rich in immune, growth, and antimicrobial factors. Many athletes take BC in the belief that these properties found in BC will improve their health and performance.	(10,15,16,20,67)	Growing evidence that 10–25 g/d of BC given for 4–5 wk may have positive effects on the immune system and reduce the risk of URTI, although many of these studies require further large-scale clinical trials.	***
Echinacea	Echinacea is an herbal supplement derived from the plant family Asteraceae (Compositae) and endemic to North America. It contains several bioactive compounds, including alkamides that are claimed to have immunomodulatory effects. Echinacea is commonly taken by athletes in the belief that this will prevent URTIs.	(31,66,75)	Evidence regarding echinacea and immune function is largely equivocal. Anecdotally, many athletes report reduced incidence of URTIs when using it, and there is some scientific support for these claims on athletic populations. However, more recent studies have reported no benefits on infection or URTI symptoms. Athletes need to be especially careful using herbal supplements to ensure none of the ingredients are banned by the WADA.	**

(continued)

Table 3
(continued)

Beta-glucan	Pleuran (β-glucan from *Pleurotus ostreatus*) is a polysaccharide derived from the cell wall of yeast, fungi, algae, and oats, which is claimed to reduce the incidence of URTIs in athletes.	(5,18,49,52)	Recent studies have shown considerable promise regarding β-glucan supplementation demonstrating increased natural killer cell activity, maintenance of phagocytosis during exercise, and reduction in the number or URTIs reported. This may be particularly useful during intense training and weight loss to boost immune function, although there are some studies suggesting no major effects of β-glucan on immune function.	***
Glutamine	Glutamine is a conditionally essential amino acid and is the most abundant amino acid in human muscle and plasma. It is used by leukocytes, although they cannot synthesize it, so must get their supply from muscle. Because (prolonged intense) exercise can reduce muscle glutamine concentration, it has been suggested that athletes need more glutamine for optimal immune cell function.	(12,28,41,54)	Some evidence in rats that glutamine may help, but feeding studies in humans have generally failed to show any effects on exercise-induced changes in immune cell function. No reported adverse effects, although of modest supplementation (<30 g/d).	**

The star rating is the authors' own opinion (based on the available scientific literature) on a 1–5 scale, with 1 indicating little evidence and 5 indicating valid scientific evidence to justify their use. Note the list is not exhaustive as a detailed critique of each supplement is beyond the scope of the present article. Star rating system: *Scientific rationale, however, no supported evidence using human subjects in peer-reviewed journals but some anecdotal reports. ***Scientific rationale and equivocal published evidence in peer-reviewed journals using human subjects. *****Scientific rationale and unequivocal evidence in peer-reviewed journals using human subjects.

PPAR = Peroxisome Proliferator-Activated Receptors; RDA = Recommended Daily Allowance; WADA = World Anti Doping Agency.

effects of pre-exercise meal ingestion (i.e., high plasma insulin concentrations) and high exercise intensities (i.e., high glycolytic flux limiting LCFA transport) are negated and the exercise stimulus is more closely aligned to maximizing lipid oxidation. In fact, recent data have suggested that fasted training (i.e., training before breakfast), as opposed to training after breakfast, enhances training-induced adaptations of skeletal muscle and may improve insulin sensitivity (78,79). Furthermore, data also demonstrate that fat oxidation was reduced by 30% during an 8-hour recovery period when CHO was ingested before exercise, as opposed to that ingested after exercise (64). For those sessions that are more dedicated to developing technique and sport-specific fitness (and hence are usually of much greater intensity), it is best to undertake them at least in the early morning, late afternoon, or evening time so that some liver and muscle glycogen is available (albeit not considered full) as a result of breakfast, lunch, and dinner ingestion, respectively. In such situations, it is again important to maximize potential lipid oxidation (despite the high exercise intensity) by attempting, if possible, to ensure that the last meal ingested before exercise is done several hours before and is always low glycemic.

It is difficult to provide exact recommendations in terms of the amount and percentage contribution of each macronutrient toward total energy intake that should be consumed. This is especially true considering the importance of individualized recommendations given that every athlete presents a different scenario in terms of RMR, target weight loss, daily training energy expenditure, time to achieve target weight, and so on. As documented earlier, a sound athlete assessment is the first stage that should be undertaken before devising and implementing any intervention. Indeed, in our experience, we have achieved success with daily CHO and fat intake varying from 2 to 5 and 0.5–1 g/kg body mass, respectively. Although current guidelines for daily protein intake are often controversial, in the case of making weight, we usually advise 2–2.5 g/kg body mass owing to the requirement to maintain lean mass in the face of daily energy deficits.

In considering the culture of combat sports where athletes tend to use weight-making methods relying on acute and chronic dehydration, emphasis needs to be placed on coach and athlete education so as to develop a training culture that promotes hydration before, during, and after training. In this regard, performing regular but simple measures of hydration status (such as monitoring training-induced acute weight loss, urine color and osmolality, and hemoglobin and hematocrit status) as well as monitoring habitual drinking patterns are useful educational tools to change athlete and coach perceptions. In instances such as professional boxing where there is typically >24 hours between the weigh-in and competition, an intentional dehydration-induced weight loss in the hours preceding the weigh-in may not be that problematic in terms of health or performance decrements. However, such instances should be carefully supervised by suitably qualified personnel so as to ensure that athlete safety and appropriate refueling and hydration strategies are administered. In combat sports where competition proceeds weigh-in by several hours, acute dehydration may not be appropriate as the short timescale may not allow for optimal refueling and hydration, which could therefore result in impaired performance (14,70). Further research to establish safe levels of acute dehydration in terms of athlete safety and impacting performance is required before definitive guidelines can be provided.

Finally, when devising nutritional and training interventions for combat athletes that *simultaneously* make weight, improve fitness and develop technique, limiting factors are often the structure of the athlete's day in terms of when coaches schedule training sessions and also whether the athlete is full-time or alternatively, have other daily commitments related to employment and family responsibilities, etc. Considering such limitations, effective communication and a multidisciplinary approach among support staff (e.g., the technical coach, strength and conditioning coach, sports nutritionist) are required so as to develop the best-case scenario in relation to the particular athlete.

POTENTIAL DIETARY SUPPLEMENTS DURING WEIGHT LOSS

In addition to the nutritional strategies described above, there are also a number of supplemental strategies that may help to aid weight loss and perhaps

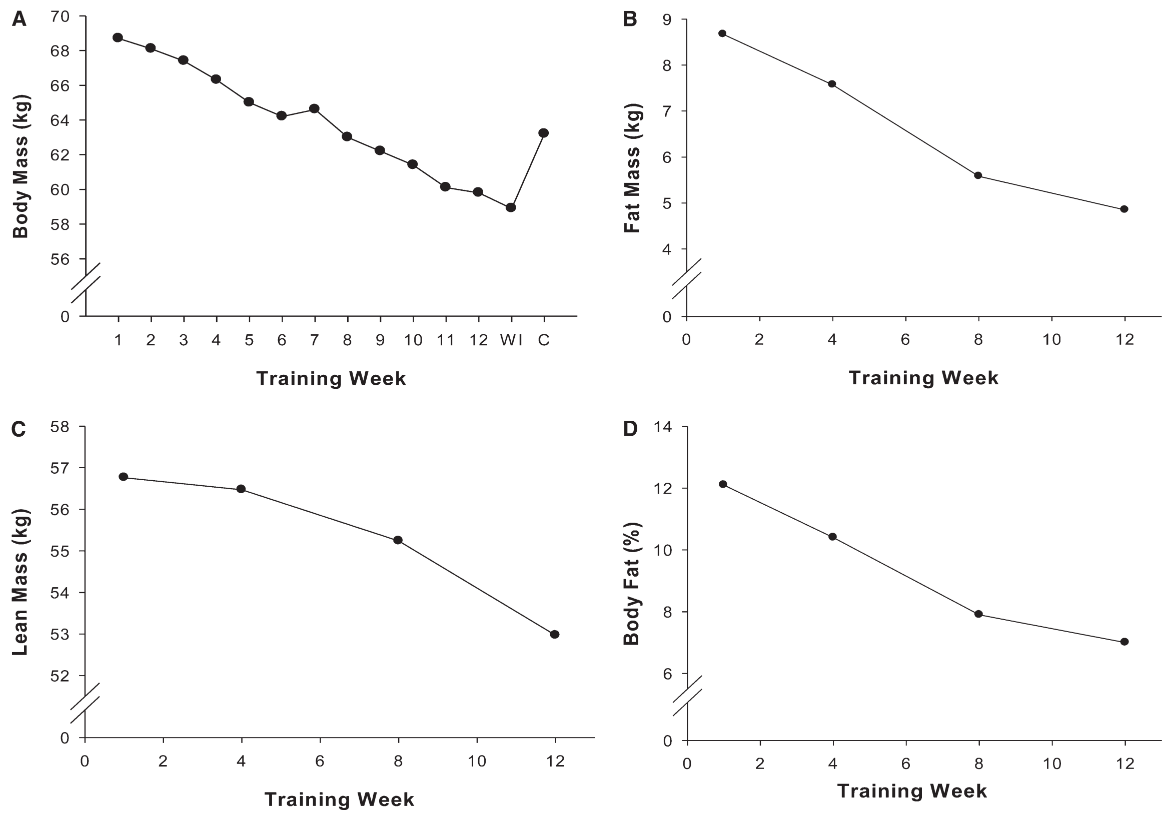


Figure. Changes in (a) body mass, (b) fat mass, (c) lean mass, and (d) percent body fat of a professional male boxer making weight for the 59-kg super featherweight division throughout a 12-week intervention period. Data are taken from Morton et al. (48). C, competition; WI, weigh-in.

more importantly maintain immune function during times of intense training when energy availability is reduced. The latter is particularly important for those athletes whose dietary preferences may prevent them from obtaining key macro- and micronutrients from food choices per se. Unfortunately, empirical evidence supporting these supplements, especially in athletic populations, is limited, and practitioners are often left to base their decisions on anecdotal reports. A review of potential supplements is shown in Table 3.

CASE STUDY FROM PRACTICE

On the basis of the principles described herein, we have recently published a case study account (48) outlining a nutritional and conditional strategy designed to help a male professional featherweight boxer (57 kg) make weight for a new weight division of super featherweight (59 kg). Over a 12-week period, the client athlete adhered to a daily diet approximately equivalent to his RMR (6–7 MJ; 40% CHO, 38% protein, and 22% fat). Average body mass loss was 0.9 ± 0.4 kg/wk, equating to a total loss of 9.4 kg. This weight loss resulted in a decrease in percent body fat from 12.1 to 7.0% (Figure). In the 30 hours between weigh-in and competition, the client consumed a high-CHO diet (12 g/kg body mass) supported by appropriate hydration strategies and subsequently entered the ring at a fighting weight of 63.2 kg.

This nutritional strategy represented a major change to the athlete's habitual weight-making practices and did not rely on any form of intended dehydration during the training period or preceding weighing-in. However, in this instance, it was evident after baseline assessment that the athlete would have to lose muscle mass to make the target weight. Nevertheless, we suspect that this is commonplace for many combat athletes (who do not have scientific input from support staff), but they have never had the knowledge that lean mass will be compromised.

In fact, following continual coach and athlete education, this athlete has now moved up another weight division to lightweight (61.3 kg), 9 lb heavier than

Table 4
Overview of guidelines for timing and composition of nutritional and fluid intake in relation to the structure of the daily training schedule

Time	Training session and/or nutritional and fluid intake	Training and/or nutritional aims
6:30 to 7:15 AM	Moderate-intensity steady-state run undertaken in fasted state accompanied with appropriate fluid intake	Maximize lipid oxidation and promote hydration
7:30 AM	Moderate-CHO/moderate-protein/low-fat breakfast with appropriate fluid intake	Promote *some* restoration of liver and muscle glycogen and protein synthesis as well as rehydration
10 AM	Low-CHO/moderate-protein and low-fat snack	Promote glycogen and protein synthesis
11 AM to 12:30 PM	Sport-specific training session accompanied with appropriate fluid intake	Development of sport-specific fitness/technique and promote hydration
1 PM	Moderate-CHO/moderate-protein and low-fat lunch accompanied with appropriate fluid intake	Promote *some* restoration of liver and muscle glycogen and protein synthesis as well as rehydration
4 PM	Moderate protein intake	Stimulate protein synthesis before strength and conditioning session
4:30 to 5:30 PM	Strength and conditioning training session accompanied with appropriate fluid intake	Development of sport-specific aspects of strength and conditioning and promote hydration
5:30 PM	Moderate-CHO/moderate-protein and low-fat snack accompanied with appropriate fluid intake	Promote *some* restoration of liver and muscle glycogen and protein synthesis as well as rehydration
7 PM	Low-CHO/moderate-protein and low-fat dinner	Promote protein synthesis and hydration as well as minimizing evening fat storage
10 PM	Moderate protein intake	Promote protein synthesis before sleeping

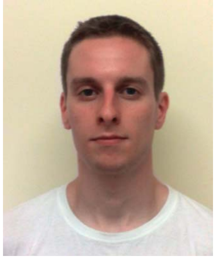
Note that quantities of foods are not disclosed owing to the need for formulating individualized interventions.

when he won his first domestic national title and also held a version of the world featherweight title. With improved food choices when out of training, this particular athlete now reports to the beginning of training camps no more than 5–6 kg over his competitive weight. As such, the target weight is now achieved with greater ease and in a shorter duration. In some instances, we have also used acute intentional dehydration of 1–1.5 kg in the hours preceding weigh-in with no performance decrements or symptoms of ill health.

CONCLUSIONS

The present article has attempted to outline how adhering to basic principles of metabolic regulation that emphasize *timing*, *composition*, and *quantity* of energy intake can help inform nutritional and conditioning programs to strategically make weight. Based on these principles, we provide an overview of guidelines in Table 4 where we pay particular attention to timing and composition of meals in relation to the structure of a combat athlete's training day. For illustrative purposes, we base our plan on a professional boxer who may train 3 times per day thought it is important to note that every athlete presents an individual scenario.

In addition to the published case study outlined in the previous section, we have used similar approaches with professional boxers ranging in weight division from flyweight to heavyweight (in the latter case, to change body composition and not necessarily mass) and observed positive results. Essentially, it is through continual education of both coach and athlete and also the willingness of both parties to adopt novel practices, which is crucial to the success of these interventions. Given the lack of research in this area, we consider it vital that similar case study–type accounts from other combat sports are published in the scientific literature. It is only through sharing such information that the safety and performance of combat sport athletes can be enhanced.



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