INTERNATIONAL JOURNAL OF
SPORT NUTRITION AND
EXERCISE METABOLISM

A 5-year analysis of weight cycling practices in a male World Champion professional boxer: potential implications for obesity and cardiometabolic disease

Journal:	*International Journal of Sport Nutrition & Exercise Metabolism*
Manuscript ID	IJSNEM.2021-0085.R1
Manuscript Type:	Case Study
Keywords:	combat sports, rebound hyperphagia, DXA, fat mass

Abstract

Weight cycling is thought to increase the risk of obesity and cardiometabolic disease in non-athletic and athletic populations. However, the magnitude and frequency of weight cycling is not well characterised in elite athletes. To this end, we quantified the weight cycling practices of a male World Champion professional boxer competing at Super-Middleweight (76.2 kg). Over a 5-year period comprising 11 contests, we assessed changes in body mass (n=8 contests) and body composition (n=6 contests) during the training camp preceding each contest. Time taken to make weight was 11 ± 4 weeks (range: 4 to 16). Absolute and relative weight loss for each contest was 12.4 ± 2.1 kg (range: 9.8 to 17.0) and 13.9 ± 2.0 % (range: 11.3 to 18.2), respectively. Notably, the athlete commenced each training camp with progressive increases in fat mass (i.e., 12.5 and 16.1 kg for contest 1 and 11) and reductions in fat free mass (i.e., 69.8 and 67.5 kg for contest 1 and 11, respectively). Data suggest that weight cycling may lead to "fat overshooting" and further weight gain in later life. Larger scale studies are now required to characterise the weight cycling practices of elite athletes and robustly assess future cardiometabolic disease risk. From an ethical perspective, practitioners should be aware of the potential health consequences associated with weight cycling.

Keywords: combat sports, rebound hyperphagia, DXA, fat mass

Introduction

Combat athletes compete in designated weight classes that are intended to promote fair competition by matching opponents of similar stature and body mass. As such, these athletes typically engage in chronic (CWL) and acute weight loss (AWL) strategies (referred to as "making weight") that largely comprise prolonged periods of energy restriction and acute episodes of dehydration (Burke et al., 2021). When making weight, combat athletes often partake in training camps that typically range in duration from 4-12 weeks where a large part of the training period is completed in conditions indicative of sub-optimal energy availability (Kasper et al., 2019; Langan-Evans et al., 2020; Morton et al., 2010). Following weeks of CWL, combat athletes may subsequently resort to AWL methods (i.e. dehydration, glycogen and gut content manipulation) (Reale et al., 2017a & 2017b) in the final hours and day(s) before weighing-in, the result of which can lead to impaired health (Kasper et al., 2019; Langan-Evans et al., 2020) and performance outcomes when sufficient post weigh-in recovery nutrition strategies are not implemented (Reljic et al., 2013; Smith et al., 2001). However, in professional boxing promotions, athletes typically weigh-in the day before the contest and subsequently have between 16-22 hours to prepare for a bout the following day.

In the weeks and months following competition, combat athletes may experience a period of rebound hyperphagia (Kasper et al. 2019, Langan-Evans et al. 2020) such that a fat mass "overshoot" occurs, subsequently presenting as increased adiposity and absolute fat mass. This pattern of "weight-cycling" (i.e., repeated cycles of weight loss and regain within short timescales) is potentially problematic in terms of increasing the risk of developing obesity and cardiometabolic disease in later life (Miles-Chan & Isacco, 2020; Montani, Schutz, & Dulloo, 2015). Indeed, it has previously been reported that weight-cycling athletes gain significantly more weight in the decades after retirement when compared with non-weight cycling athletes

(Saarni et al., 2006) and there is also evidence to suggest these patterns of weight-cycling aren't attributed to genetic factors (Pietiläinen et al., 2012). Nonetheless, the magnitude and prevalence of the repetitive weight cycling practices typically adopted by athletic populations is often documented using retrospective questionnaire-based methods as opposed to objective data that is collected "real-time" during the athlete's career.

With this in mind, the primary aim of the present case report was to quantify the weight cycling practices (i.e., weight loss and weight regain) and associated changes in body composition of a male professional boxer. To this end, we monitored a British, Commonwealth and World Champion boxer over a 5-year period comprising 11 professional contests. This athlete competed at the highest level of the sport where the data collection period culminated in a World Title (World Boxing Association, WBA) defence at Madison Square Garden, New York. In relation to the latter contest, we also quantified energy intake and the associated changes in body mass during the final 7 days prior to weigh-in.

Presentation of Athlete and Case-Study Design

At the time of final data collection, the athlete was 32 years old competing in the Super Middleweight category (76.2 kg, 168 lbs) with a record of 29 professional contests, 27 wins (15 by way of knockout) and 2 losses. The athlete began their professional career in 2010 and had been consistently engaged in weight making strategies for a period of 9 years. Over the 5-year data collection period, the athlete participated in eleven contests with contest 1 occurring in April 2014 and contest 11 occurring in December 2018 (no body composition data were collected for contest 2-5). As such, body composition data is presented here for contest 1 and 6-11. Throughout the course of the data collection period, the athlete was (at various times) the British (April 2017), Commonwealth (September 2017) and World Boxing Association

(WBA) Super Middleweight champion (July 2018). The final contest of data collection was the WBA title defence at Madison Square Garden, New York (December 2018). Measurements of body mass and composition were obtained at regular intervals (depending on the duration of the camp) throughout the training camp period for each contest. For contest 11, the athlete also reported weighed food intake and provided body mass measurements during the final 7-days prior to weigh-in and the 24 h prior to competition. The athlete gave written informed consent for publication of the case-report and the study was approved by ethical committee of Liverpool John Moores University.

Overview of Athlete Assessments

Measurements of body mass were obtained post void of the bladder/bowels between 07:00-08:30 hours after a 10 hour fast and determined to the nearest 0.01 kg on a calibrated digital scale (Seca 702; Hamburg, Germany). Measurements of body composition were obtained between 9:00-9:30 hours using Dual-energy X-ray Absorptiometry (DXA, QDR Series Discovery A; Hologic Inc., Bedford, MA, USA – software version 12:4:3) according to the DXA Best Practice Protocol (Nana et al., 2015; Nana et al., 2016). The frequency of DXA scans complied with the regulations from the Committee on Medical Aspects of Radiation in the Environment (COMARE) from the United Kingdom Department of Health. Direct measurements of resting metabolic rate (RMR) were obtained between 9:30-10:00 hours at the commencement of camp 6, 7 and 8 via open-circuit indirect calorimetry (GEM Nutriton Ltd, UK) following the procedures previously outlined in our laboratory (Langan-Evans et al., 2020). Due to logistical difficulties, RMR was assessed at the beginning of camps 1, 10 and 11 according to the Cunningham equation (1980) where RMR is calculated as 500 + (Fat free mass x 22).

Overview of Nutritional Intake and Training Structure

Upon baseline DXA assessments, it was evident that the magnitude of weight loss required to make the 76.2 kg Super Middleweight category ranged from 9.8 to 17.0 kg (11.3-18.2%) given that the athlete presented with a baseline body mass at the start of training camp ranging from 86.0 to 93.2 kg (see Table 1). Similar to our previous case-study accounts (Morton et al. 2010; Kasper et al. 2018; Langan-Evans et al. 2020), evaluation of baseline body composition data indicated that the target weight class would likely be achieved via a combination of reductions in fat mass, fat free mass and AWL strategies (Reale, et al., 2017a) undertaken in the final days before weigh-in.

With the exception of the final 7 days prior to weigh-in, the athlete reported adhering to a daily energy intake approximately equivalent to RMR and a macronutrient intake of 3, 2.5 and 1 $g.kg^{-1}$ body mass for CHO, protein and fat, respectively. The lunch and evening meal consumed each day were delivered in pre-prepared food packages with known energy and macronutrient contents equivalent to 1080 $kcal.d^{-1}$ (2 x 540 kcal meals; 50g CHO, 40g protein and 20g Fat). Breakfast and snacks were self-administered and typically comprised porridge oats, milk, whey protein supplements (Science in Sport, UK) and Greek yoghurt and berries etc. An example of total macronutrient intake and distribution during a typical training day is presented in Table 2. The athlete regularly engaged in the remote food photographic method (see Stables et al., 2021) to report energy and macronutrient intake. In an attempt to maintain immune function during heavy training periods (Walsh, 2018), the athlete also consumed daily: multivitamin (Science in Sport, UK), probiotic (Healthspan Elite, UK), calcium (Science in Sport, UK), electrolytes (Science in Sport, UK), quercetin with green tea (Science in Sport, UK), and 4,000 IU of vitamin D3 supplement (Nutrition-X, UK). Although no detailed assessments of training load were obtained, an overview of the typical training completed during each training camp is displayed in Table 3.

At 3-4 days prior to weigh-in, the athlete also engaged in AWL strategies (Reale et al., 2017a) with the aim of inducing an approximate 5% body mass loss. Such strategies typically comprised consumption of a low residue diet (e.g., white rice, poultry, fish, dairy, fruit juice) with reduced energy (approx. 1466 $kcal.day^{-1}$) and CHO intake ($1.4g.kg^{-1}$) when compared with that consumed prior in the training camp period. At 1-2 days prior to weigh-in, the athlete often engaged in "glycogen reducing exercise" (low absolute CHO intake, approx. 85g, + high-intensity exercise i.e., boxing technical work combined with 60-90 min treadmill running including a combination of repeated sprints and steady state running), reduced sodium intake (<500 mg per day, all foods cooked without salt, only water consumed) and fluid restriction (2 days prior to weigh in = 2 L of water, 1 day prior to weigh in 1 L of water, morning of weigh in 200 ml of water) in an attempt to further reduce body mass. In the final hours before weigh-in, the athlete often engaged in further active sweating techniques (if required) such as light running or skipping (e.g., 20-30 min treadmill running or 15 min skipping). In the time-period between weigh-in and competition equating to approximately 19-21 hrs, the athlete reported consuming 4-6 L of fluid and approximate macronutrient intakes of 9, 2 and 2 $g.kg^{-1}$ of CHO, protein and fat, respectively (thus equating to > 4500 kcal). The athlete reported that this fuelling and rehydration approach usually increased body mass from 76.2 to 81-82 kg (i.e., 5-6 kg / 6.5-7.8% increase) in the timescale between weigh-in and competition which is greater than previous reports (mean 2.5kg) from 142 professional boxers (Daniele et al. 2016).

Assessment of Weight Cycling Practices

Twenty-one DXA scans were obtained over a 5-year period (spanning April 2014 to December 2018). A visual representation of changes in body mass, fat free mass, fat mass and percent body fat are presented in Figure 1 and 2. Additionally, an overview of body composition changes also presented in Table 1. For contest 11, a more detailed assessment of macronutrient intake and waking daily body mass is also presented for the final 7 days prior to weigh-in, weigh-in day and contest day (see Figure 3). In this contest, absolute and relative body mass loss during the final 24 h prior to weigh-in corresponded to 4.1 kg and 5.3%, respectively.

Discussion and Critical Reflections

Although we have previously quantified the magnitude of weight loss achieved by combat athletes over a "single" camp (Morton et al., 2010; Kasper et al., 2018; Langan-Evans et al., 2020), the present case-study presents a highly novel data set in that we provide the first report to objectively quantify weight cycling practices in preparation for repetitive contests. In this regard, the present athlete was required to make weight for 11 contests over a 5-year period. Whilst practitioners are often focused on the implementation of strategies to "make weight", it is hoped that our data may prompt critical reflection of the potential long term health consequences associated with weight cycling.

The nature of professional boxing ensures that athletes do not have regular competitive schedules but rather, are largely dependent on the schedule devised by boxing promoters and available broadcasting dates from television companies. In this way, boxers are often issued with contest dates on short notice as opposed to longer term planning of competitive schedules. For this reason, the duration of training camp completed by the present boxer ranged from 4-16 weeks and the absolute weight loss required ranged from 9.8 to 17.0 kg (11.3-18.2%). The athlete studied here reported adhering to a daily energy intake approximately equivalent to

RMR (with a macronutrient composition reflective of low CHO and high protein). Although we are limited in that we did not assess exercise energy expenditure and/or health and performance consequences associated with relative energy deficiency in sport syndrome (i.e., RED-S; Mountjoy et al., 2014), it is highly likely that the athlete presented with low daily energy availability (i.e., <20 $kcal.kg^{-1}$ FFM) throughout the majority of each training camp. Moreover, the athlete was actively making weight (and likely in a state of daily energy deficit) for 112 out of 228 weeks (i.e., 49% of the 4-year period).

Whilst we did not collect body mass data during the training camp for contest 2-4 the data obtained throughout the remaining 8 contests provide for an interesting assessment of weight-cycling practices. Most notably, we observed that the athlete tended to present at the beginning of his career with lower fat mass and higher fat free mass than that observed towards the end of his career (i.e., 12.5 and 16.1 kg fat mass and 69.8 and 67.5 kg fat free mass for contest 1 and 11, respectively). Although the athlete's personal lifestyle choices (e.g., abstaining from formalised training / nutritional strategies between camps) and life events (e.g., parenting responsibilities following the birth of two children) may have contributed to this pattern of energy partitioning, such alterations in body composition appear indicative of the rebound hyperphagia that may occur during the weight regain period (Dulloo et al., 2015; Dulloo et al., 1997; Fuhrman et al., 1951). In this regard, a central feature of the hypothesis that weight cycling predisposes obesity is that during each weight cycle, the amount of fat regained is greater than that previously lost (Miles-Chan and Isacco, 2020). This phenomenon of "fat overshooting" is thought to be driven by rebound hyperphagia that primarily occurs in an attempt to restore fat free mass (Dulloo et al., 1997). However, the recovery of fat mass appears to preferentially occur, and it is thought that hyperphagia may continue until fat free mass eventually returns to baseline values. In this way, the increased adiposity could be considered a necessary by-product of the requirement to restore fat free mass, thereby presenting as "collateral fattening" (Dulloo et al., 2018).

A limitation of our data collection is that we did not objectively assess energy intake in the days and weeks following each contest. Nonetheless, the athlete anecdotally commented on his "desire to keep eating and lack of motivation for training" in the time period between formalised training camps. Moreover, our body composition data appear to support the fat overshoot theory described above and the apparent rebound hyperphagia agrees with our previous case-study accounts on a male mixed martial artist (Kasper et al., 2018) and taekwondo athlete (Langan-Evans et al., 2020). Importantly, our data also refute the hypothesis that the high levels of physical activity and the potential conscious control of energy intake (associated with being an elite athlete) can protect against the increased adiposity that may occur with weight cycling (Miles-Chan and Isacco, 2020).

Despite growing evidence that weight cycling can increase obesity and cardiometabolic disease risk in the general population (Dulloo et al., 2015), the long-term health consequences associated with weight-cycling in athletic populations have not yet been definitively established. Nonetheless, limited reports demonstrate that weight cycling athletes (e.g., boxers, wrestlers and weightlifters) present with greater weight gain upon retirement when compared with non-weight cycling athletes (Saarni et al., 2006). Moreover, such athletes are three times more likely to develop obesity when compared with non-weight cycling athletes (Saarni et al., 2006). From an ethical perspective, practitioners should therefore be aware of the potential long-term health consequences associated with the magnitude and prevalence of weight cycling practices described here. As highlighted by Miles-Chan and Isacco (2020), there is a clear need for well controlled prospective studies to conclusively determine if such causality is present in elite athletes.

In summary, we quantify for the first time the weight cycling practices completed by a male professional boxer. Notwithstanding the limitations associated with case-study observations, our data suggest that repeated periods of weight cycling may lead to fat overshooting and hence, may lead to unfavourable body composition changes. Future studies (using large sample sizes) should further characterise the weight cycling practices of elite athletes whilst also robustly assessing future cardiometabolic disease risk (i.e. enhanced weight gain, hyperinsulinemia, insulin resistance, dyslipidaemia, hypertension etc. (Montani et al., 2015). Where possible, practitioners should encourage combat athletes to maintain a habitual weight that is closer to their target weight class (whilst also maintaining fat free mass during the weight loss period) in an attempt to minimise the magnitude of weight cycling that may occur throughout an athlete's career.

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Table 1. Overview of training camp duration and associated changes in body mass during the 5-year weight-cycling period. * denotes measured RMR; #denotes predicted RMR; ND, denotes no data.

Table 2. Reported macronutrient intake and distribution during a typical training day.

Table 3. Overview of weekly training structure during a typical training camp.

Figure 1. Changes in body mass during the 5-year weight-cycling period. Final DXA scan for contest 1, 6, 7, 8, 10 and 11 was obtained 2, 5, 2, 1, 11 and 15 days before weigh-in respectively.

Figure 2. Changes in (A) fat mass, (B) fat free mass and (C) percent body fat during the 5-year weight-cycling period. Final DXA scan for contest 1, 6, 7, 8, 10 and 11 was obtained 2, 5, 2, 1, 11 and 15 days before weigh-in respectively.

Figure 3. (A) Changes in body mass during the 7 days before the official weigh-in (WI), weigh-in day and contest day (data represent contest 11). (B) Total energy and (C) macronutrient intake consumed during the six-day period before the official weigh-in, weigh-in day and contest day (data represent contest 11). WI = weigh in. Black bars = CHO, white bars = protein content, grey bars = fat content.

Table 1.

Contest	Training camp duration (weeks)	Starting weight (kg)	Starting fat mass (kg)	Starting fat free mass (kg)	Total weight lost (kg) (%)	Weight loss per week associated with training camp (i.e., not inclusive of final 7 days) ($kg.week^{-1}$) (%)	Acute weight loss achieved in final 7 days (kg) (%)	RMR value ($kcal.day^{-1}$)
1	13	88.6	12.5	69.8	12.4 (13.9%)	1.3 (1.1%)	ND	2035#
2	ND	ND	ND	ND	ND	ND	ND	ND
3	ND	ND	ND	ND	ND	ND	ND	ND
4	ND	ND	ND	ND	ND	ND	ND	ND
5	16	88.0	ND	ND	11.8 (13.4%)	ND	ND	ND
6	11	93.2	18.3	69.5	17 (18.2%)	1.7 (1.8%)	4.0 (5.2%)	1983*
7	15	88.4	16.0	66.3	12.2 (13.8%)	0.8 (0.9%)	3.0 (3.9%)	1939*
8	10	87.8	15.3	67.0	11.6 (13.2%)	1.2 (1.4%)	3.2 (4.1%)	1920*
9	4	86.0	ND	ND	9.8 (11.3%)	ND	ND	ND
10	6	87.4	14.6	66.9	11.2 (12.8%)	2.2 (2.5%)	3.6 (4.7%)	1971#
11	11	89.6	16.1	67.5	13.4 (14.9%)	1.3 (1.4%)	4.6 (6.0%)	1985#
Mean	**11**	**88.6**	**15.5**	**67.8**	**12.4 (13.9%)**	**1.4 (1.5%)**	**3.7 (4.7%)**	**1972**
SD	**4**	**2.1**	**1.9**	**1.5**	**2.1 (2.0%)**	**2.1 (0.5%)**	**0.6 (0.8%)**	**40**

Table 2.

MEAL/TIMING	FOOD	QUANTITY (g)	ENERGY (Kcal)	CHO (g) [g.kg^{-1}]	PRO (g) [g.kg^{-1}]	Fat (g) [g.kg^{-1}]
BREAKFAST 07:00	Whey Protein	30	116	1.5	22.5	2.2
	Americano	260 (ml)	5	1	0.1	0.1
	Oats	54	190	32.2	5.9	4.2
	Semi-skimmed milk	135 (ml)	64	6.1	4.7	2.3
	Banana	120	103	24	1.4	0.1
Meal Totals			**478**	**65**	**34.7**	**8.9**
LUNCH 11:45	Prepared meal	1 x serving	540	50	40	20
	Semi-skimmed milk	135 (ml)	64	6.1	4.7	2.3
	Whey Protein	30	116	1.5	22.5	2.2
Meal Totals			**732**	**59**	**68**	**24.9**
DINNER 18:30	Prepared meal	1 x serving	**540**	**50**	**40**	**20**
SNACKS	Smoked salmon slice	56	103	0.2	12.8	5.7
	Ryvita cracker	20	72	14.1	2.3	0.7
	Cottage cheese	20	20	0.5	2.6	0.7
	Casein Protein	35	119	1.9	23.3	2
	Semi-skimmed milk	135 (ml)	64	6.1	4.7	2.3
	Organic Flavoured Milk	330 (ml)	300	34.7	11.2	12.9
Meal Totals			**690**	**59**	**58**	**24.8**
DAILY TOTALS			**2441**	**232 [3.0]**	**200 [2.5]**	**79 [1.0]**

Table 3.

TRAINING TIME	**MONDAY (mins)**	**TUESDAY (mins)**	**WEDNESDAY (mins)**	**THURSDAY (mins)**	**FRIDAY (mins)**	**SATURDAY (mins)**	**SUNDAY (mins)**
MORNING 7.00	Run (45)	Run (45)	Rest	Run (45)	Run (45)	Run (45)	Run (45)
AFTERNOON 13:00	Boxing (90)	Boxing (90)	Boxing (90)	Boxing (90)	Boxing (90)	Rest	Rest
EVENING 18:00	Rest	Strength and Conditioning (60)	Rest	Strength and Conditioning (60)	Rest	Rest	Rest

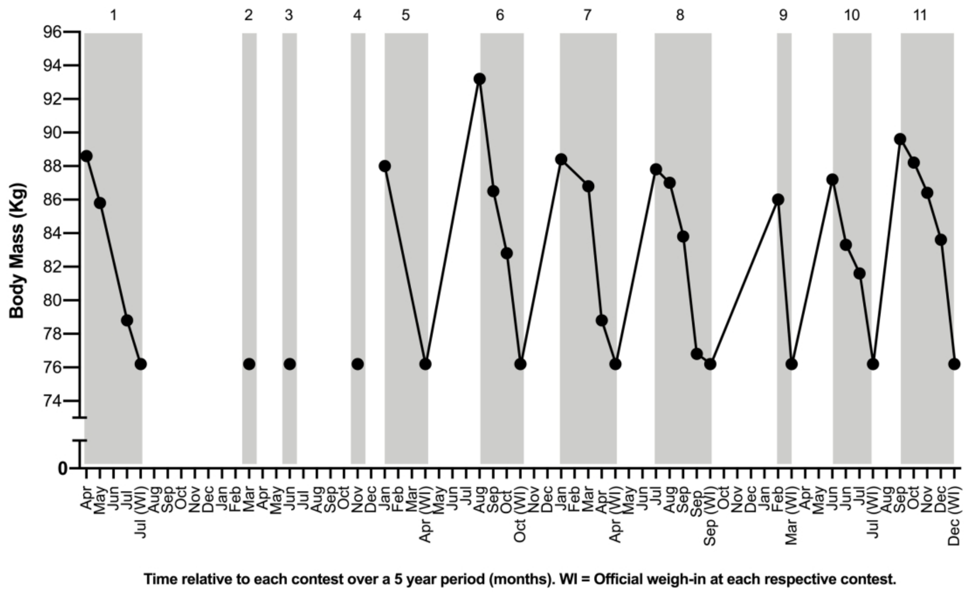

Figure 1. Changes in body mass during the 5-year weight-cycling period. Final DXA scan for contest 1, 6, 7, 8, 10 and 11 was obtained 2, 5, 2, 1, 11 and 15 days before weigh-in respectively.

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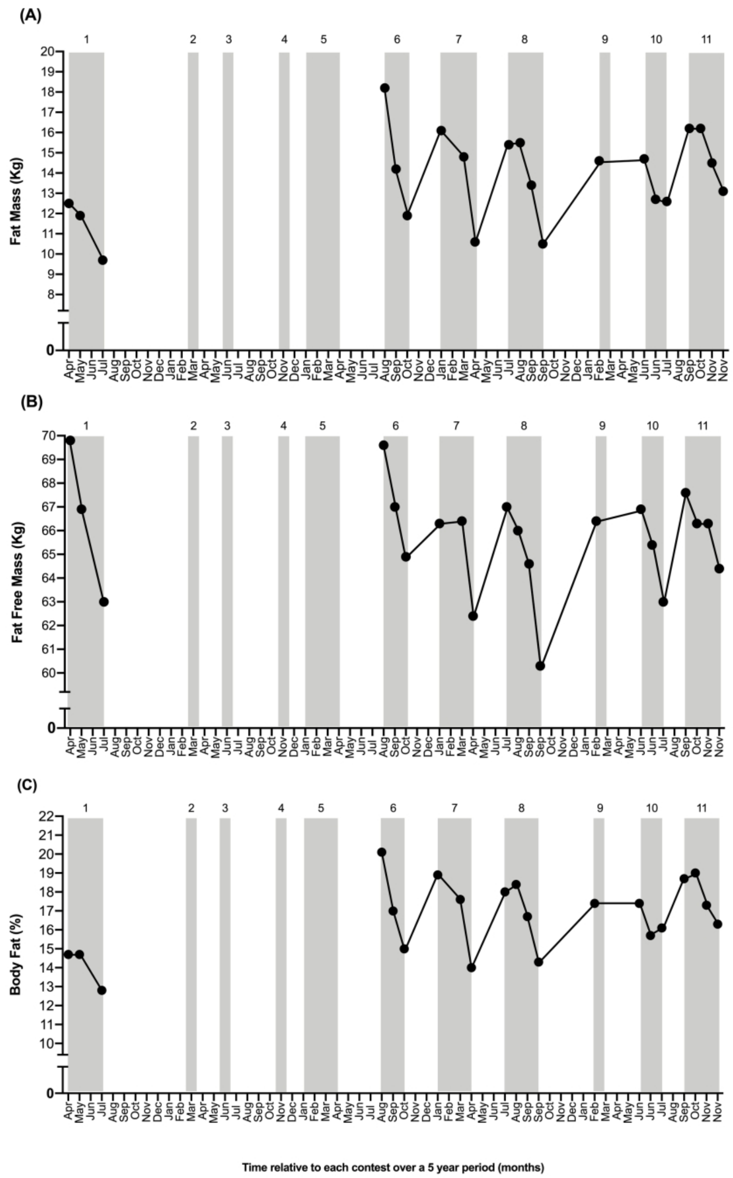

Figure 2. Changes in (A) fat mass, (B) fat free mass and (C) percent body fat during the 5-year weight-cycling period. Final DXA scan for contest 1, 6, 7, 8, 10 and 11 was obtained 2, 5, 2, 1, 11 and 15 days before weigh-in respectively.

179x284mm (300 x 300 DPI)

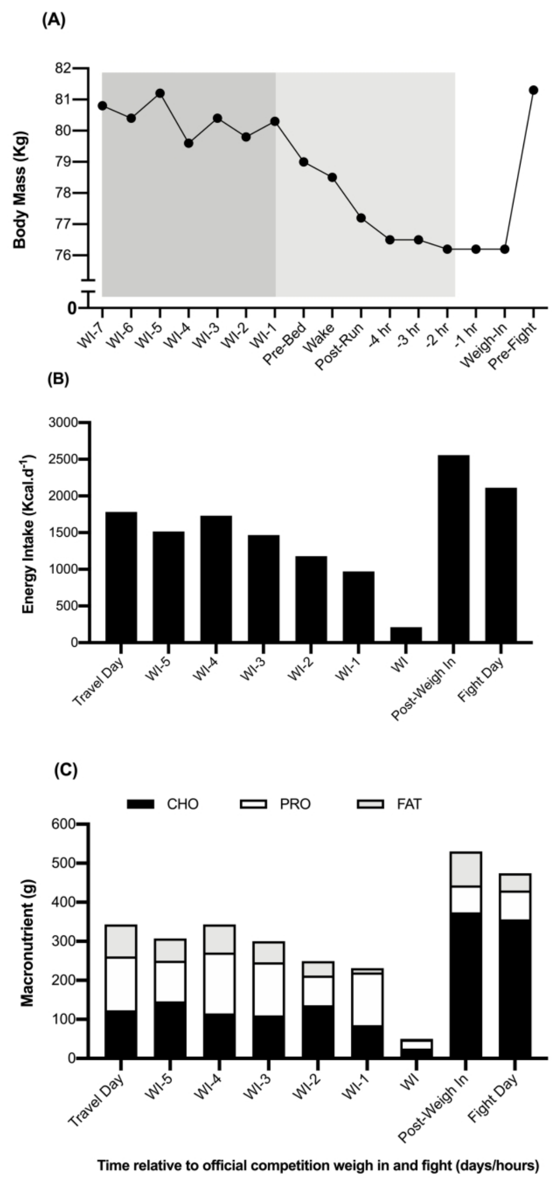

Figure 3. (A) Changes in body mass during the 7 days before the official weigh-in (WI), weigh-in day and contest day (data represent contest 11). (B) Total energy and (C) macronutrient intake consumed during the six-day period before the official weigh-in, weigh-in day and contest day (data represent contest 11). WI = weigh in. Black bars = CHO, white bars = protein content, grey bars = fat content.

137x286mm (300 x 300 DPI)