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

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

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## 1 **Abstract**

2 Weight cycling is thought to increase the risk of obesity and cardiometabolic disease in non-  
3 athletic and athletic populations. However, the magnitude and frequency of weight cycling is  
4 not well characterised in elite athletes. To this end, we quantified the weight cycling practices  
5 of a male World Champion professional boxer competing at Super-Middleweight (76.2 kg).  
6 Over a 5-year period comprising 11 contests, we assessed changes in body mass (n=8 contests)  
7 and body composition (n=6 contests) during the training camp preceding each contest. Time  
8 taken to make weight was  $11 \pm 4$  weeks (range: 4 to 16). Absolute and relative weight loss for  
9 each contest was  $12.4 \pm 2.1$  kg (range: 9.8 to 17.0) and  $13.9 \pm 2.0$  % (range: 11.3 to 18.2),  
10 respectively. Notably, the athlete commenced each training camp with progressive increases  
11 in fat mass (i.e., 12.5 and 16.1 kg for contest 1 and 11) and reductions in fat free mass (i.e.,  
12 69.8 and 67.5 kg for contest 1 and 11, respectively). Data suggest that weight cycling may lead  
13 to “fat overshooting” and further weight gain in later life. Larger scale studies are now required  
14 to characterise the weight cycling practices of elite athletes and robustly assess future  
15 cardiometabolic disease risk. From an ethical perspective, practitioners should be aware of the  
16 potential health consequences associated with weight cycling.

17

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

## 19 **Introduction**

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

35

36 In the weeks and months following competition, combat athletes may experience a period of  
37 rebound hyperphagia (Kasper et al. 2019, Langan-Evans et al. 2020) such that a fat mass  
38 “overshoot” occurs, subsequently presenting as increased adiposity and absolute fat mass. This  
39 pattern of “weight-cycling” (i.e., repeated cycles of weight loss and regain within short  
40 timescales) is potentially problematic in terms of increasing the risk of developing obesity and  
41 cardiometabolic disease in later life (Miles-Chan & Isacco, 2020; Montani, Schutz, & Dulloo,  
42 2015). Indeed, it has previously been reported that weight-cycling athletes gain significantly  
43 more weight in the decades after retirement when compared with non-weight cycling athletes

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

49

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

58

### 59 **Presentation of Athlete and Case-Study Design**

60 At the time of final data collection, the athlete was 32 years old competing in the Super  
61 Middleweight category (76.2 kg, 168 lbs) with a record of 29 professional contests, 27 wins  
62 (15 by way of knockout) and 2 losses. The athlete began their professional career in 2010 and  
63 had been consistently engaged in weight making strategies for a period of 9 years. Over the 5-  
64 year data collection period, the athlete participated in eleven contests with contest 1 occurring  
65 in April 2014 and contest 11 occurring in December 2018 (no body composition data were  
66 collected for contest 2-5). As such, body composition data is presented here for contest 1 and  
67 6-11. Throughout the course of the data collection period, the athlete was (at various times) the  
68 British (April 2017), Commonwealth (September 2017) and World Boxing Association

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

77

### 78 **Overview of Athlete Assessments**

79 Measurements of body mass were obtained post void of the bladder/bowels between 07:00-  
80 08:30 hours after a 10 hour fast and determined to the nearest 0.01 kg on a calibrated digital  
81 scale (Seca 702; Hamburg, Germany). Measurements of body composition were obtained  
82 between 9:00-9:30 hours using Dual-energy X-ray Absorptiometry (DXA, QDR Series  
83 Discovery A; Hologic Inc., Bedford, MA, USA – software version 12:4:3) according to the  
84 DXA Best Practice Protocol (Nana et al., 2015; Nana et al., 2016). The frequency of DXA  
85 scans complied with the regulations from the Committee on Medical Aspects of Radiation in  
86 the Environment (COMARE) from the United Kingdom Department of Health. Direct  
87 measurements of resting metabolic rate (RMR) were obtained between 9:30-10:00 hours at the  
88 commencement of camp 6, 7 and 8 via open-circuit indirect calorimetry (GEM Nutriton Ltd,  
89 UK) following the procedures previously outlined in our laboratory (Langan-Evans et al.,  
90 2020). Due to logistical difficulties, RMR was assessed at the beginning of camps 1, 10 and 11  
91 according to the Cunningham equation (1980) where RMR is calculated as  $500 + (\text{Fat free}$   
92  $\text{mass} \times 22)$ .

93

## 94 **Overview of Nutritional Intake and Training Structure**

95 Upon baseline DXA assessments, it was evident that the magnitude of weight loss required to  
96 make the 76.2 kg Super Middleweight category ranged from 9.8 to 17.0 kg (11.3-18.2%) given  
97 that the athlete presented with a baseline body mass at the start of training camp ranging from  
98 86.0 to 93.2 kg (see Table 1). Similar to our previous case-study accounts (Morton et al. 2010;  
99 Kasper et al. 2018; Langan-Evans et al. 2020), evaluation of baseline body composition data  
100 indicated that the target weight class would likely be achieved via a combination of reductions  
101 in fat mass, fat free mass and AWL strategies (Reale, et al., 2017a) undertaken in the final days  
102 before weigh-in.

103

104 With the exception of the final 7 days prior to weigh-in, the athlete reported adhering to a daily  
105 energy intake approximately equivalent to RMR and a macronutrient intake of 3, 2.5 and 1  
106 g.kg<sup>-1</sup> body mass for CHO, protein and fat, respectively. The lunch and evening meal consumed  
107 each day were delivered in pre-prepared food packages with known energy and macronutrient  
108 contents equivalent to 1080 kcal.d<sup>-1</sup> (2 x 540 kcal meals; 50g CHO, 40g protein and 20g Fat).  
109 Breakfast and snacks were self-administered and typically comprised porridge oats, milk, whey  
110 protein supplements (Science in Sport, UK) and Greek yoghurt and berries etc. An example of  
111 total macronutrient intake and distribution during a typical training day is presented in Table  
112 2. The athlete regularly engaged in the remote food photographic method (see Stables et al.,  
113 2021) to report energy and macronutrient intake. In an attempt to maintain immune function  
114 during heavy training periods (Walsh, 2018), the athlete also consumed daily: multivitamin  
115 (Science in Sport, UK), probiotic (Healthspan Elite, UK), calcium (Science in Sport, UK),  
116 electrolytes (Science in Sport, UK), quercetin with green tea (Science in Sport, UK), and 4,000  
117 IU of vitamin D3 supplement (Nutrition-X, UK). Although no detailed assessments of training

118 load were obtained, an overview of the typical training completed during each training camp  
119 is displayed in Table 3.

120

121 At 3-4 days prior to weigh-in, the athlete also engaged in AWL strategies (Reale et al., 2017a)  
122 with the aim of inducing an approximate 5% body mass loss. Such strategies typically  
123 comprised consumption of a low residue diet (e.g., white rice, poultry, fish, dairy, fruit juice)  
124 with reduced energy (approx. 1466 kcal.day<sup>-1</sup>) and CHO intake (1.4g.kg<sup>-1</sup>) when compared  
125 with that consumed prior in the training camp period. At 1-2 days prior to weigh-in, the athlete  
126 often engaged in “glycogen reducing exercise” (low absolute CHO intake, approx. 85g, +  
127 high-intensity exercise i.e., boxing technical work combined with 60-90 min treadmill running  
128 including a combination of repeated sprints and steady state running), reduced sodium intake  
129 (<500 mg per day, all foods cooked without salt, only water consumed) and fluid restriction (2  
130 days prior to weigh in = 2 L of water, 1 day prior to weigh in 1 L of water, morning of weigh  
131 in 200 ml of water) in an attempt to further reduce body mass. In the final hours before weigh-  
132 in, the athlete often engaged in further active sweating techniques (if required) such as light  
133 running or skipping (e.g., 20-30 min treadmill running or 15 min skipping). In the time-period  
134 between weigh-in and competition equating to approximately 19-21 hrs, the athlete reported  
135 consuming 4-6 L of fluid and approximate macronutrient intakes of 9, 2 and 2 g.kg<sup>-1</sup> of CHO,  
136 protein and fat, respectively (thus equating to > 4500 kcal). The athlete reported that this  
137 fuelling and rehydration approach usually increased body mass from 76.2 to 81-82 kg (i.e., 5-  
138 6 kg / 6.5-7.8% increase) in the timescale between weigh-in and competition which is greater  
139 than previous reports (mean 2.5kg) from 142 professional boxers (Daniele et al. 2016).

140

#### 141 **Assessment of Weight Cycling Practices**



142 Twenty-one DXA scans were obtained over a 5-year period (spanning April 2014 to December  
143 2018). A visual representation of changes in body mass, fat free mass, fat mass and percent  
144 body fat are presented in Figure 1 and 2. Additionally, an overview of body composition  
145 changes also presented in Table 1. For contest 11, a more detailed assessment of macronutrient  
146 intake and waking daily body mass is also presented for the final 7 days prior to weigh-in,  
147 weigh-in day and contest day (see Figure 3). In this contest, absolute and relative body mass  
148 loss during the final 24 h prior to weigh-in corresponded to 4.1 kg and 5.3%, respectively.

149

## 150 **Discussion and Critical Reflections**

151 Although we have previously quantified the magnitude of weight loss achieved by combat  
152 athletes over a “single” camp (Morton et al., 2010; Kasper et al., 2018; Langan-Evans et al.,  
153 2020), the present case-study presents a highly novel data set in that we provide the first report  
154 to objectively quantify weight cycling practices in preparation for repetitive contests. In this  
155 regard, the present athlete was required to make weight for 11 contests over a 5-year period.  
156 Whilst practitioners are often focused on the implementation of strategies to “make weight”, it  
157 is hoped that our data may prompt critical reflection of the potential long term health  
158 consequences associated with weight cycling.

159

160 The nature of professional boxing ensures that athletes do not have regular competitive  
161 schedules but rather, are largely dependent on the schedule devised by boxing promoters and  
162 available broadcasting dates from television companies. In this way, boxers are often issued  
163 with contest dates on short notice as opposed to longer term planning of competitive schedules.  
164 For this reason, the duration of training camp completed by the present boxer ranged from 4-  
165 16 weeks and the absolute weight loss required ranged from 9.8 to 17.0 kg (11.3-18.2%). The  
166 athlete studied here reported adhering to a daily energy intake approximately equivalent to

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

174

175 Whilst we did not collect body mass data during the training camp for contest 2-4 the data  
176 obtained throughout the remaining 8 contests provide for an interesting assessment of weight-  
177 cycling practices. Most notably, we observed that the athlete tended to present at the beginning  
178 of his career with lower fat mass and higher fat free mass than that observed towards the end  
179 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  
180 and 11, respectively). Although the athlete's personal lifestyle choices (e.g., abstaining from  
181 formalised training / nutritional strategies between camps) and life events (e.g., parenting  
182 responsibilities following the birth of two children) may have contributed to this pattern of  
183 energy partitioning, such alterations in body composition appear indicative of the rebound  
184 hyperphagia that may occur during the weight regain period (Dulloo et al., 2015; Dulloo et al.,  
185 1997; Fuhrman et al., 1951). In this regard, a central feature of the hypothesis that weight  
186 cycling predisposes obesity is that during each weight cycle, the amount of fat regained is  
187 greater than that previously lost (Miles-Chan and Isacco, 2020). This phenomenon of "fat  
188 overshooting" is thought to be driven by rebound hyperphagia that primarily occurs in an  
189 attempt to restore fat free mass (Dulloo et al., 1997). However, the recovery of fat mass appears  
190 to preferentially occur, and it is thought that hyperphagia may continue until fat free mass  
191 eventually returns to baseline values. In this way, the increased adiposity could be considered

192 a necessary by-product of the requirement to restore fat free mass, thereby presenting as  
193 “collateral fattening” (Dulloo et al., 2018).

194

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

205

206 Despite growing evidence that weight cycling can increase obesity and cardiometabolic disease  
207 risk in the general population (Dulloo et al., 2015), the long-term health consequences  
208 associated with weight-cycling in athletic populations have not yet been definitively  
209 established. Nonetheless, limited reports demonstrate that weight cycling athletes (e.g., boxers,  
210 wrestlers and weightlifters) present with greater weight gain upon retirement when compared  
211 with non-weight cycling athletes (Saarni et al., 2006). Moreover, such athletes are three times  
212 more likely to develop obesity when compared with non-weight cycling athletes (Saarni et al.,  
213 2006). From an ethical perspective, practitioners should therefore be aware of the potential  
214 long-term health consequences associated with the magnitude and prevalence of weight cycling  
215 practices described here. As highlighted by Miles-Chan and Isacco (2020), there is a clear need

216 for well controlled prospective studies to conclusively determine if such causality is present in  
217 elite athletes.

218

219 In summary, we quantify for the first time the weight cycling practices completed by a male  
220 professional boxer. Notwithstanding the limitations associated with case-study observations,  
221 our data suggest that repeated periods of weight cycling may lead to fat overshooting and  
222 hence, may lead to unfavourable body composition changes. Future studies (using large sample  
223 sizes) should further characterise the weight cycling practices of elite athletes whilst also  
224 robustly assessing future cardiometabolic disease risk (i.e. enhanced weight gain,  
225 hyperinsulinemia, insulin resistance, dyslipidaemia, hypertension etc. (Montani et al., 2015).  
226 Where possible, practitioners should encourage combat athletes to maintain a habitual weight  
227 that is closer to their target weight class (whilst also maintaining fat free mass during the weight  
228 loss period) in an attempt to minimise the magnitude of weight cycling that may occur  
229 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 <sup>-1</sup> ) (%)	Acute weight loss achieved in final 7 days (kg) (%)	RMR value (kcal.day <sup>-1</sup> )
1	13	88.6	12.5	69.8	12.4 (13.9%)	1.3 (1.1%)	ND	2035 <sup>#</sup>
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 <sup>#</sup>
11	11	89.6	16.1	67.5	13.4 (14.9%)	1.3 (1.4%)	4.6 (6.0%)	1985 <sup>#</sup>
<b>Mean</b>	<b>11</b>	<b>88.6</b>	<b>15.5</b>	<b>67.8</b>	<b>12.4 (13.9%)</b>	<b>1.4 (1.5%)</b>	<b>3.7 (4.7%)</b>	<b>1972</b>
<b>SD</b>	<b>4</b>	<b>2.1</b>	<b>1.9</b>	<b>1.5</b>	<b>2.1 (2.0%)</b>	<b>2.1 (0.5%)</b>	<b>0.6 (0.8%)</b>	<b>40</b>

Table 2.

MEAL/TIMING	FOOD	QUANTITY (g)	ENERGY (Kcal)	CHO (g) [g.kg <sup>-1</sup> ]	PRO (g) [g.kg <sup>-1</sup> ]	Fat (g) [g.kg <sup>-1</sup> ]
<b>BREAKFAST</b> 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
<b>Meal Totals</b>			<b>478</b>	<b>65</b>	<b>34.7</b>	<b>8.9</b>
<b>LUNCH</b> 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
<b>Meal Totals</b>			<b>732</b>	<b>59</b>	<b>68</b>	<b>24.9</b>
<b>DINNER</b> 18:30	Prepared meal	1 x serving	<b>540</b>	<b>50</b>	<b>40</b>	<b>20</b>
<b>SNACKS</b>	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
<b>Meal Totals</b>			<b>690</b>	<b>59</b>	<b>58</b>	<b>24.8</b>
<b>DAILY TOTALS</b>			<b>2441</b>	<b>232</b>	<b>200</b>	<b>79</b>
				<b>[3.0]</b>	<b>[2.5]</b>	<b>[1.0]</b>

**Table 3.**

<b>TRAINING TIME</b>	<b>MONDAY (mins)</b>	<b>TUESDAY (mins)</b>	<b>WEDNESDAY (mins)</b>	<b>THURSDAY (mins)</b>	<b>FRIDAY (mins)</b>	<b>SATURDAY (mins)</b>	<b>SUNDAY (mins)</b>
<b>MORNING</b> 7:00	Run (45)	Run (45)	Rest	Run (45)	Run (45)	Run (45)	Run (45)
<b>AFTERNOON</b> 13:00	Boxing (90)	Boxing (90)	Boxing (90)	Boxing (90)	Boxing (90)	Rest	Rest
<b>EVENING</b> 18:00	Rest	Strength and Conditioning (60)	Rest	Strength and Conditioning (60)	Rest	Rest	Rest

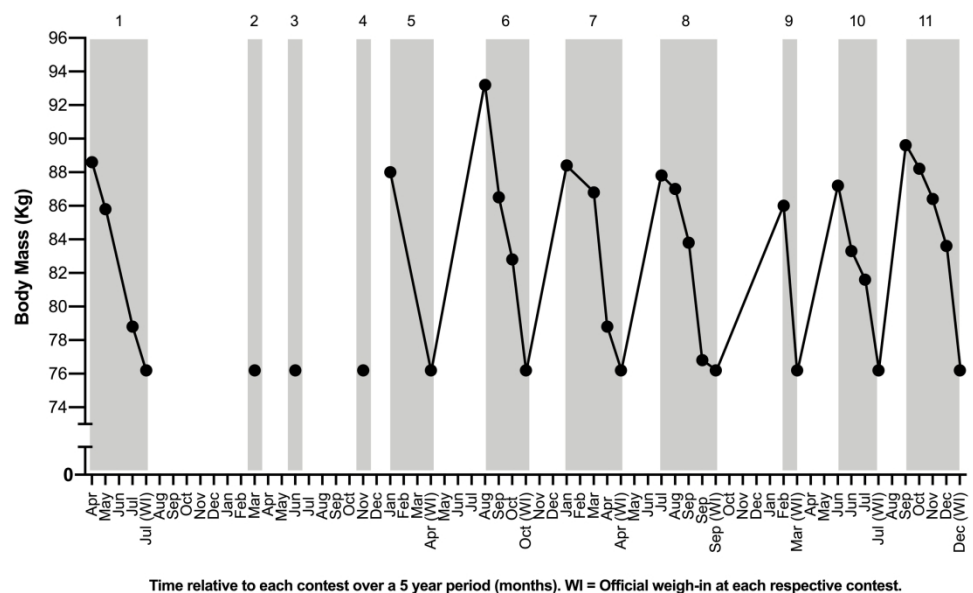


Figure 1. Changes in body mass during the 5-year weight-cycling period. Final DXA scan for contest 1, 6, 7, 8, 10 and 11 was obtained 2, 5, 2, 1, 11 and 15 days before weigh-in respectively.

228x142mm (300 x 300 DPI)

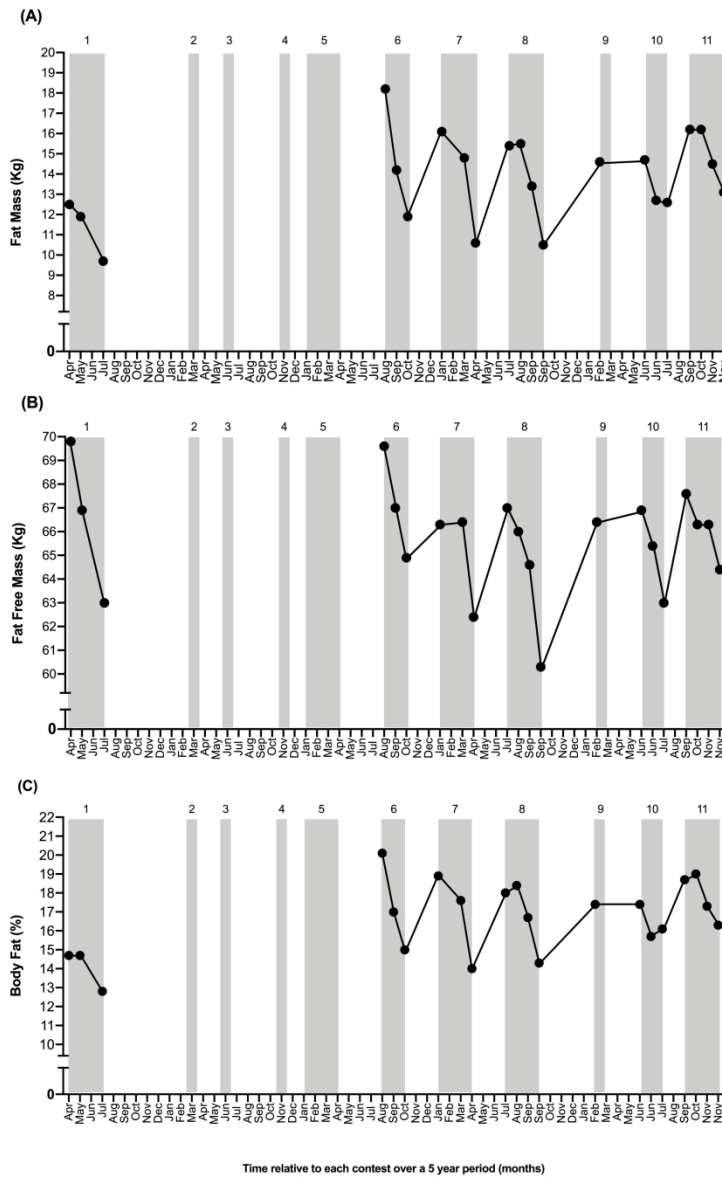


Figure 2. Changes in (A) fat mass, (B) fat free mass and (C) percent body fat during the 5-year weight-cycling period. Final DXA scan for contest 1, 6, 7, 8, 10 and 11 was obtained 2, 5, 2, 1, 11 and 15 days before weigh-in respectively.

179x284mm (300 x 300 DPI)

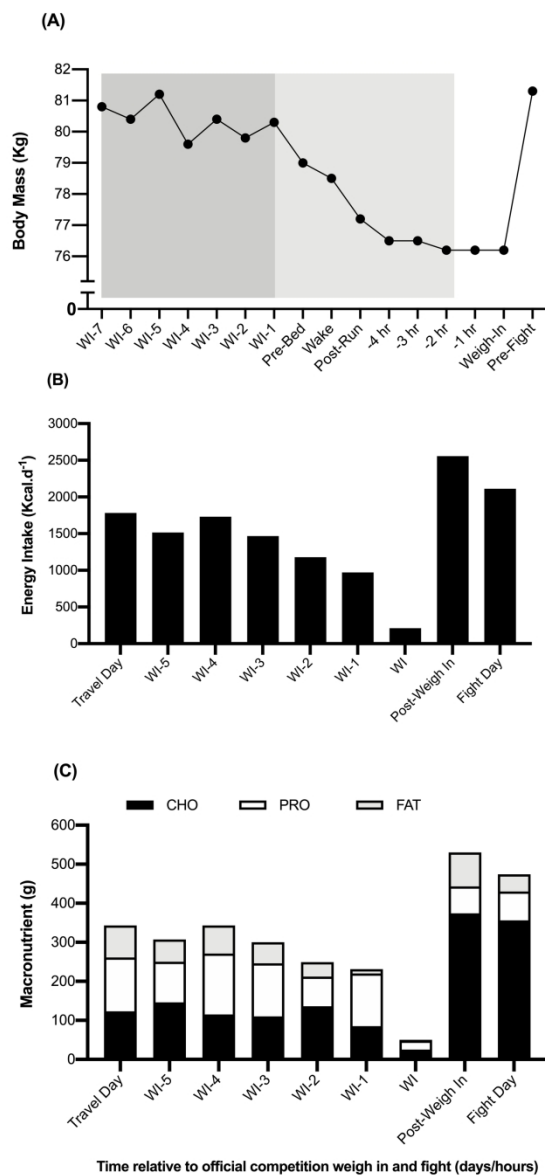


Figure 3. (A) Changes in body mass during the 7 days before the official weigh-in (WI), weigh-in day and contest day (data represent contest 11). (B) Total energy and (C) macronutrient intake consumed during the six-day period before the official weigh-in, weigh-in day and contest day (data represent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

137x286mm (300 x 300 DPI)