Effect of rapid weight loss on performance in combat sport male athletes: does adaptation to chronic weight cycling play a role?

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ABSTRACT

Background Studies failing to show a negative effect of rapid weight loss (RWL) on performance have been conducted in athletes who have been cycling weight for years. It has been suggested that chronic weight cycling could lead combat athletes to become resistant to the stresses associated with weight loss. To investigate the effects of RWL up to 5% of body mass on high-intensity intermittent performance in weight cyclers (WC) and non-weight cyclers (non-WC).

Methods Eighteen male combat athletes (WC: n=10; non-WC: n=8) reduced up to 5% of their body mass in 5 days. Body composition, high-intensity performance and plasma lactate were assessed preweight loss and postweight loss. Athletes had 4 h to re-feed and rehydrate following the weigh-in. Food intake was recorded during the weight loss and the recovery periods.

Results Athletes significantly decreased body mass, lean body mass (most likely due to fluid loss) and fat mass following weight loss. No significant changes in performance were found from preweight loss to postweight loss in both groups. Plasma lactate was significantly elevated after exercise in both groups, but no differences were found between groups and in response to RWL. For all these variables no differences were observed between groups. Athletes from both groups ingested high amounts of energy and carbohydrates during the recovery period after the weigh-in.

Conclusions Chronic weight cycling does not protect athletes from the negative impact of RWL on performance. The time to recover after weigh-in and the patterns of food and fluid ingestion during this period is likely to play the major role in restoring performance to baseline levels.

INTRODUCTION

Combat sports are becoming increasingly relevant to the world's sports scenario. Today, they comprise approximately 25% of the total medals in the Olympic Games and professional combat events, such as Mixed Martial Arts and Boxing, are very popular, gathering millions of spectators from all over the world.[1] In most combat sports, competitions are organised into weight classes, which aim to promote fairer and more equitable matches. However, the vast majority of combat athletes, regardless of the specific combat discipline, reduce their body mass significantly in a short period of time in order to compete in a lighter weight division.[2–5] It has been argued that athletes perceive rapid weight loss (RWL) to confer competitive advantage by competing against smaller and weaker opponents in lighter weight classes.[3] The widespread use of RWL methods in combat sports has long been a matter of concern[6] and may even be employed by young children and adolescents.[3 7]

The acute negative effects of RWL on health-related parameters have been extensively demonstrated and include hormonal imbalance,[8] hydroelectrolytic imbalance,[9] hyperthermia,[10] cardiovascular distress,[11] increased bone resorption,[12] reduced immune function,[13] impaired mood profile,[14] and may even lead to death.[15] Athletes' 'normal' body mass is normally heavier than their competition body mass, meaning they are not able to maintain competition weight throughout the entire season.[16] As a consequence, they tend to reduce weight before every competition during the season and subsequently regain it in the days following.[16] Chronically, this repeated weight loss-and-regain cycle (ie, WC) is also associated with health problems, such as obesity[17] and, in adolescents, temporary growth impairment.[17 18]

Although the impact of RWL on health is undisputed, its effects on exercise capacity and competitive performance remain largely controversial.[19] Most studies examining the effects of RWL on performance have found significantly impaired anaerobic and aerobic capacities when athletes have no time to refeed and rehydrate following weigh-in.[20–23] Conversely, most studies simulating the 'loading period' that exists between the weigh-in and the beginning of the combats in actual competitions[16 24] have shown no negative effects owing to RWL followed by re-feeding and rehydration on performance in a variety of exercise models,[25–29] even when the 'loading period' is as short as 2 h.[30] Carbohydrate ingestion during the 'reloading' period appears to maximise performance recovery after RWL.[31] Notably, all of the studies failing to show a negative effect of RWL on performance were conducted in experienced athletes, who have been cycling weight for a long period of time.[25–29] Several authors have suggested that chronic weight cycling may lead to adaptations to the stresses associated with RWL and, therefore, athletes would become more resistant to its negative effects on performance.[25 29 30 32–34] It is also believed that non-experienced athletes would likely experience performance decrements following RWL. However, evidence to support this assumption is still absent and no study until has directly compared the responses of experienced (WC) and non-WC to RWL.

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This study aimed to investigate the effects of RWL up to 5% of body mass on high-intensity intermittent performance in two distinct groups of combat athletes: experienced WC and non-WC. The hypothesis of the present investigation was that performance in experienced WC would be less affected by RWL than in non-WC.

METHODS

Participants

Twenty-one male combat athletes with a major grappling background (judo: n=12, Brazilian jiu-jitsu: n=2, wrestling: n=2; mixed martial arts: n=5) took part in the study. According to their previous experience on weight cycling, the athletes were allocated into two groups: (WC, n=10 and non-WC, n=11). Three athletes from the non-WC group dropped out of the study (one due to an injury unrelated to study participation and the other two athletes due to personal reasons). Therefore, the total number of participants was n=18 (WC group: n=10; non-WC group: n=8) (table 1). To be eligible for the WC group, athletes must have reduced their weight by more than 4% before competitions at least six times per season for the last two seasons. To be eligible for the non-WC group, athletes must not have reduced more than 2% of their body mass before competitions on more than two occasions per season. Any athlete who could not be clearly defined as an experienced WC or as a non-WC was not eligible. At the time of data collection, athletes from the WC group were 5.9±1.9% above their weight class upper limit, whereas athletes from the non-WC group were 1.1 ±2.6% below the limit. Further exclusion criteria were: regular use of tobacco, use of steroids or any other illegal performance enhancer and the presence of any medical condition that would preclude participation in maximal exercise tests. All athletes were actively trained, as they were in the competitive season during data collection. However, all experimental sessions were scheduled for a period with no official competitions, so that athletes did not lose weight to compete at least 2 weeks prior to the study. All participants were informed about the procedures and risks before signing the informed consent.

Study design

Athletes attended the laboratory on three different occasions: one familiarisation session, one preweight loss session (baseline) and one postweight loss session. Athletes were informed to arrive in a well-fed and well-hydrated state without having consumed caffeine or performed intense exercise in the last 24 h.

Two to 7 days following the familiarisation trial, athletes were required to be present at the laboratory in the morning (10:00–12:00) for the baseline session, when body composition, exercise performance and blood lactate at rest and 5 min postexercise were determined. Following the baseline trial, athletes were required to reduce their body mass by 5% in not more than 5 days, using the same methods they would use if they were making weight for a competition. No competition was scheduled during the experimental period. During the final 3 days of the weight-reduction period, athletes recorded all food ingested using a 3-day food diary, since there is substantial evidence to show that most of the weight is lost in the 72 h prior to the weigh-in.[3 34] Fluid ingestion was not recorded during the weight-loss period. Athletes received instructions from a dietician on how to properly complete a food diary. Energy and macronutrient intake was examined using software based on a national table of food composition (Diet Pro). Extreme methods such as the use of diuretics, laxatives, diet pills and forced-vomiting were not permitted in the study.

Table 1 Participants' characteristics

	WC group (n=10)	non-WC group (n=8)	p Value
Age (years)	28±7	21±3	0.019
Body mass (kg)	77.7±12.3	73.8±9.5	0.426
Height (m)	1.75±0.06	1.77±0.06	0.633
Training experience (years)	12±3	9±3	0.135
Training volume (h/week)	17±4	15±5	0.470

WC, weight cyclers.

Following the baseline trial, athletes reduced their body weight over a 5-day period and returned to the laboratory in the morning (7:00–8:00) for the postweight loss trial. During the simulated weigh-in, athletes were evaluated to determine whether their goal to reduce 5% of baseline body mass was achieved. Athletes were allowed to weigh-in only once. After the simulated weigh-in, athletes were assessed for body composition and reported the methods used to reduce weight. Following this, they were given 4 h to recover from weight loss, during which they were requested to eat and drink ad libitum in order to mimic the patterns of food and beverage intake they would perform in a real competition. All food and beverages ingested during this period were recorded. Afterwards, athletes were required to perform the exercise test and blood samples were collected for lactate determination at rest and 5 min postexercise. The experimental design is illustrated in figure 1.

High-intensity intermittent exercise capacity assessment

High-intensity intermittent exercise capacity was assessed on a mechanically braked arm-ergometer (EB4100, Cefise, Nova Odessa, Brazil) with 8×15 s all-out arm–crank exercise bouts separated by 20 s passive recovery periods. The load was set at 4% of baseline body mass and absolute load was identical for all experimental sessions. The protocol is identical to that used by Rankin *et al*,[31] adapted from Hickner *et al*.[23] It has been shown to be highly reproducible (ICC>0.92) and sensitive to detect a 8.5% decrease in performance after ~3.5% weight loss.[31] A test–retest analysis (n=13) performed in our laboratory has shown it is free from systematic error and highly reproducible (total work carried out: test=27.8±3.5 kJ; retest=27.1±3.8 kJ; t=0.001, p=0.99; ICC=0.967; per cent variation= −0.05 ±4.75%).

Blood sampling and lactate analysis

Capillary blood samples (30 μL) were collected at rest and 5 min postexercise, and centrifuged for plasma lactate determination using the enzymatic–colorimetric method as provided by a commercially available kit (Biotecnica, Brazil). Standards with known concentrations of lactate were used to generate an equation from which unknown values were calculated by interpolation.

Underwater weighing

Each athlete was weighed underwater after maximum expiration at least 8 times. The mean of the three highest values was considered as the underwater weight. Residual volume was estimated according to Goldman and Becklake[35] and body fat was calculated using the Siri formula.[36] In a two-compartment model, body fat percentage was used to calculate absolute body fat and lean body mass (LBM).

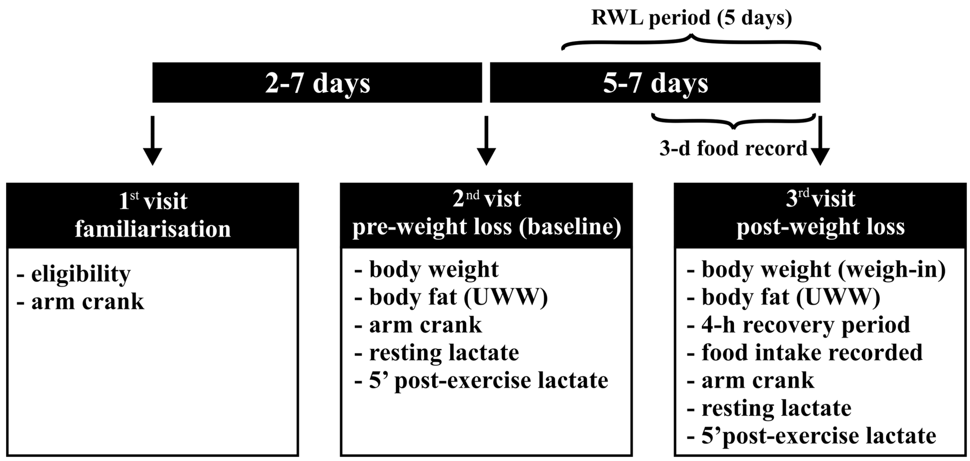

Figure 1 Illustrative representation of the experimental design. RWL, rapid weight loss; UWW, underwater weighing.

Statistical analysis

Body composition, performance and plasma lactate data were analysed using mixed-models for repeated measures (SAS software V.9.3). Food intake data obtained from 3-day food records were also analysed using mixed-models; the dietary data obtained during the recovery period was compared between groups using non-paired t test. The sample size was estimated a priori based on the F test for repeated measures with within–between interaction using the G*Power software V.3.1.6. Assuming a 8.5% reduction in total well-being diet after weight loss with an effect size of 0.70, as reported by Rankin *et al*,[31] sample size necessary to reach a power of 0.80 with α-level being 5% was calculated as n=8 in each group. Data is presented as mean±SD and the significance level was previously set as $p<0.05$.

RESULTS

Both groups reduced body mass from preweight loss to postweight loss (WC group: pre=77.8±12.3 kg, post=73.8 ±11.4 kg, pre vs post: $p<0.001$; non-WC group: pre=73.5 ±9.5 kg, post=69.5±9 kg, pre vs post: $p<0.001$; figure 2). No differences in body mass were found between groups at both preweight loss and postweight loss periods (p=0.35 and p=0.32, respectively). Body mass reduction was achieved by decreased body fat and LBM (figure 2).

Despite the significant reduction in body mass, no effects of RWL were shown on mean power, peak power or total work carried out in both groups (figure 3). Figure 4 depicts the second-by-second power output curve obtained in each of the eight bouts.

Plasma lactate was significantly elevated after exercise in both groups before and after RWL ($p<0.001$). However, no significant differences were found between groups. Similarly, no effects of RWL were observed on plasma lactate in response to exercise in any of the groups (figure 5).

Both groups dramatically reduced their daily food intake during the weight loss period, which resulted in decreased energy, carbohydrate, protein and lipid intake ($p<0.001$ for all variables; figure 6). However, no differences were found between WC and non-WC groups for any of the variables, indicating that weight loss strategies were similar between groups (figure 6). In contrast to the very low energy intake during the weight loss, all athletes ingested a considerably large amount of food during the 4 h recovery period, allowing for the consumption of large quantities of energy and macronutrients. No differences were found between groups for all variables analysed during recovery (figure 6). Total energy intake and carbohydrate intake over the 4 h recovery were higher than daily intake over the weight loss period, with no significant differences being found between groups (main effect of time: p=0.007 and 0.002 for energy and carbohydrates, respectively). For protein and fat intake, no significant differences were found for any of the comparisons.

DISCUSSION

The present study aimed to investigate whether combat sport male athletes who constantly cycle their body mass can become adapted and, therefore, are resistant to the negative effects of RWL on exercise capacity and performance. To our knowledge, this is the first study to provide experimental evidence refuting the theory that chronic weight cycling confers protection against the impact of RWL on performance,[25 29 30 32–34] since the performance responses were quite comparable between non-WC and WC. Our data are in agreement with several previous investigations[25–30 34] and provides further evidence that RWL does not affect high-intensity performance, at least in male athletes, when weight reduction is of ~5% of initial body mass and they have a few hours to re-feed and rehydrate after the weigh-in.

Studies addressing the effects of RWL on exercise performance and capacity have produced conflicting data, with negative[20–23 31] and negligible.[25–28 30] effects being demonstrated. Multiple reasons may explain such discrepancy, but perhaps the most important is the difference in the time to recover after the simulated weigh-in. Despite the conflicting data, the majority of the studies using no recovery periods after weigh-in or periods shorter in duration than 1 h have shown a significant reduction in performance.[20–23] On the other hand, most studies allowing athletes to 'reload' for 2 h or more have demonstrated no performance impairment following RWL.[25–30] As an explanation for the lack of effect of RWL on performance, several authors have suggested that repeated weight cycling could result in physiological adaptations leading athletes to become resistant to the negative effects of RWL.[25 29 30 32–34] This theory was strengthened by the fact that all data in literature came from athletes well-familiarised with competing after reducing weight rapidly. Although compelling evidence for adaptation has never been demonstrated, it has been speculated that it could be related to the increased ability to perform in hypohydrated and food-deprived states.[30 32] Others have suggested that this

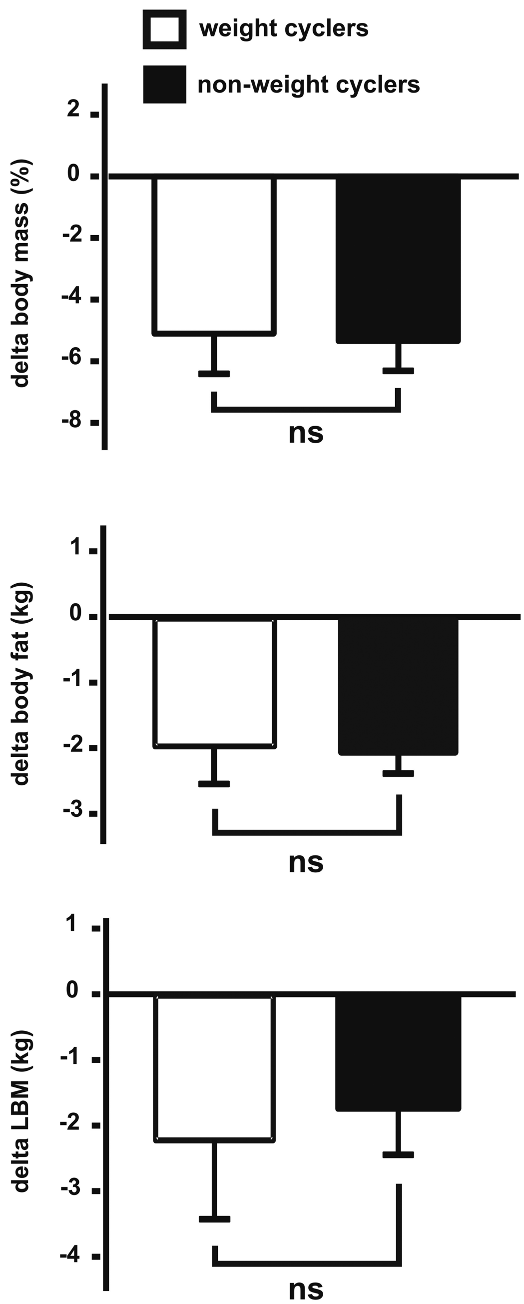

Figure 2 △ Values obtained for body mass (relative changes), body fat (absolute changes) and lean body mass (LBM) (absolute changes). No significant differences (ns) were found between groups for any of the variables.

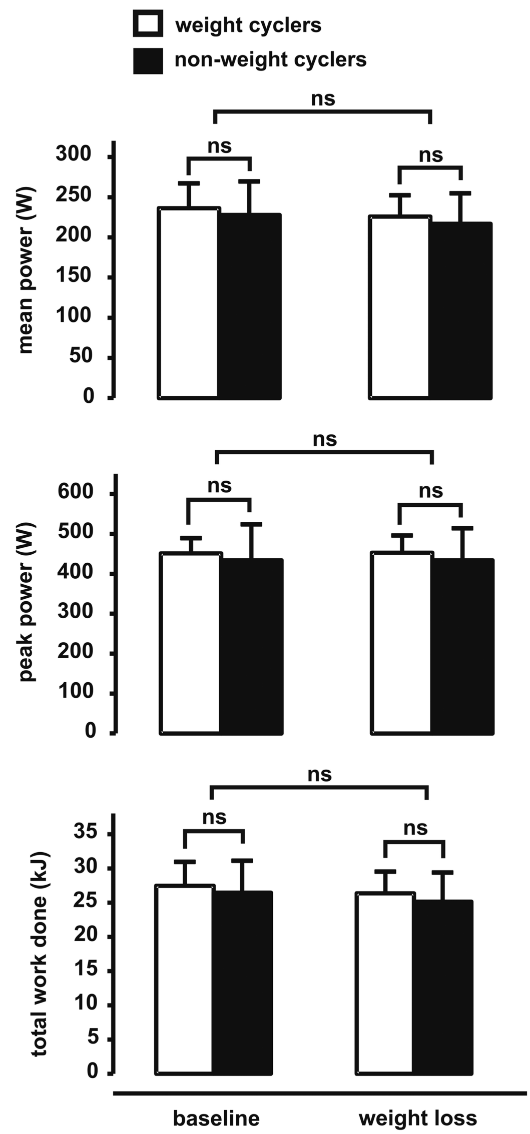

Figure 3 Mean power output, peak power output and total work performed by weight cyclers and non-weight cyclers before (baseline) and after rapid weight loss. No significant differences (ns) were found between groups for any of the variables.

adaptation could be related to an attenuation in glycogen depletion accompanying food deprivation during weight loss, to an increased rate of glycogen resynthesis accompanying re-feeding during the recovery period or to differences in the rate of glycogen usage during exercise after weight loss.[25] Although these hypotheses were not directly addressed in the present study, our data do not support the concept that chronic weight cycling is protective to performance. Moreover, plasma lactate responses to exercise after weight loss were similar between WC and non-WC groups, suggesting no differences in glycogen usage rate between groups. Similarly, the changes in body composition in response to weight loss of up to 5% of body mass were almost identical between groups, which indicate that any putative adaptation could not rely on increased preservation of LBM.

Importantly, a study by Hickner *et al*[23] demonstrated that an arm crank performance test similar to that used in our study was sensitive enough to detect a 3.5% performance reduction in five trained athletes following a 4.5% weight loss (no recovery time was given after simulated weigh-in). Accordingly, Rankin *et al*[31] observed a 8.5% decrease in upper body performance using a testing protocol identical to that used in our study after a ~3.5% weight reduction. This suggests that the lack of a negative effect in our study cannot be explained by low-sensitivity of the testing protocol. In order to be able to detect the small differences in performance, we chose to employ a laboratory-based test, which is not as specific as field-based tests, yet more accurate and sensitive.

Our data suggests that, rather than physiological adaptations brought about by weight cycling, a better explanation for the lack of effects of RWL is that ~5% or less of weight reduction can be adequately compensated during the few hours after

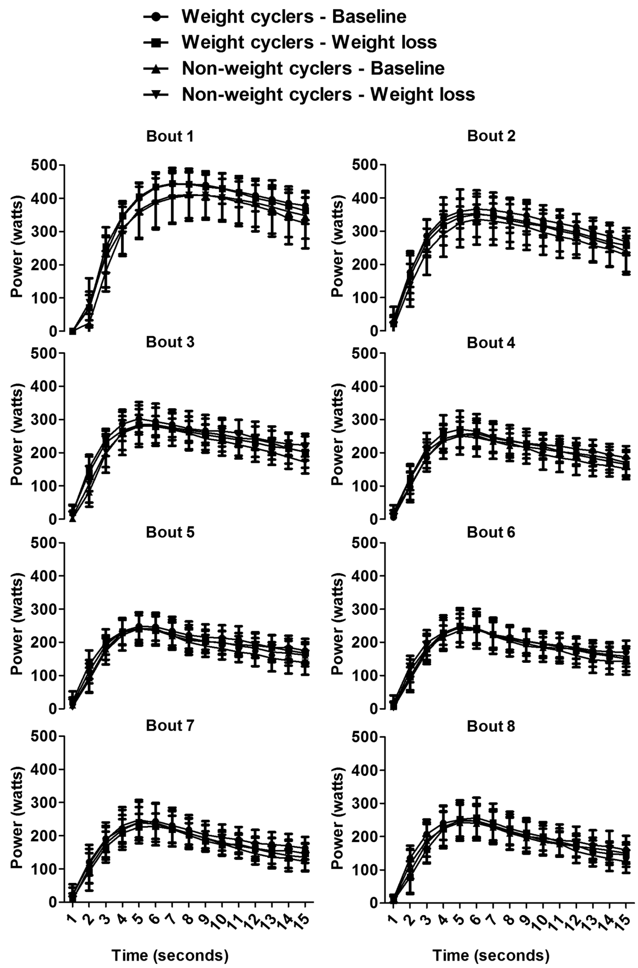

Figure 4 Second-by-second power output performance in each of the eight 15 s arm crank bouts by both weight cyclers and non-weight cyclers.

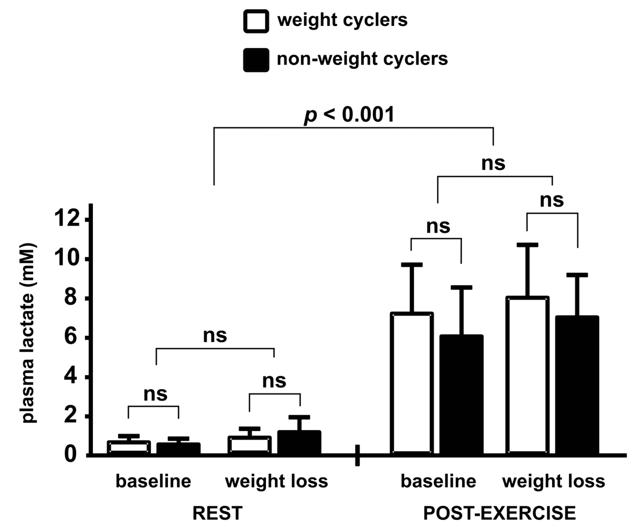

Figure 5 Plasma lactate at rest and in response to arm–crank exercise before and after rapid weight loss (RWL). A significant main effect of time was found with lactate being higher after exercise as compared to rest. No differences (ns) were found between groups or in response to RWL.

weigh-in, regardless of the previous experience in weight regulation practices. It is important to highlight that during the recovery period, athletes were able to ingest enormous amounts of food and fluid. This includes elevated amounts of carbohydrates, which has been shown to be important to return performance to preweight loss levels.[31] In fact, the energy and carbohydrate intake during the 4 h recovery period was significantly higher than the average daily intake during the weight loss period. In the case of judo, recent temporary changes in the official rules establish that weigh-in takes place in the evening prior to the competition day, allowing athletes to experience a longer and more complete recovery. In the case of other combat sports, such as jiu-jitsu and wrestling, competitions occur a few hours after the weigh-in and, if the recovery period is shorter than 4 h, a different outcome might be expected.

It would be plausible to assume that, instead of becoming physiologically adapted, experienced WC would learn from experience how to make better choices in terms of food selection during weight loss and recovery periods as well as in terms of method selection for RWL. Our data do not support this hypothesis because, despite the fact that athletes were free to select their own weight loss methods and recovery diet, all athletes from both groups presented similar patterns of weight loss and recovery, with no difference between groups. Based on our data, it is possible to conclude that combat sport male athletes, regardless of having previous experience in weight cycling, are not susceptible to the negative effects of RWL up to 5% of body mass on performance. This is probably not explained by physiological adaptations caused by weight cycling, but is most likely explained by their ability to re-feed and rehydrate in the short recovery period that takes place after the weigh-in. Food selection (ie, high amounts of food and carbohydrate-rich sources) also seems to play a determinant role on the lack of negative effects. However, this, was not related to experience in chronic weight cycling.

The present study may not have fully addressed the question as to whether chronic weight cycling plays a role in preventing performance decrements following acute weight loss. More stressful weight loss challenges, such as a large weight reductions (≥10% of body mass), could have resulted in measurable performance impairments, even after a recovery period, possibly resulting in differences between WC from non-WC. Therefore, the hypothesis of adaptation from chronic weight cycling cannot be entirely ruled out. However, requesting athletes to reduce more than 5% of body mass would considerably affect participants' compliance with the intervention and raise ethical concerns, thus compromising the feasibility of the study. Furthermore, the investigations that led to the hypothesis of adaptation have employed ∼5% of body mass loss, and we sought to test the hypothesis under similar conditions. Finally, most athletes normally reduce <5% of body mass to compete[3 6] and, hence, our results apply to the majority of cases in real settings. Therefore, the lack of negative effects observed in this study is a strong indicator that RWL has no impact on performance in most of the 'real-life' cases (≤5% of body mass loss with ∼4 h or more for recover after weigh-in). Similarly, the lack of differences between groups indicates that, in most of 'real-life' cases, adaptation from weight cycling plays no role in the lack of effect of RWL on performance. However, it must be highlighted, that our study has tested only male combat sport athletes and the effects of RWL on women are yet to be investigated. Another limitation of our study is the lack of measurement of fluid intake during the 5-day weight loss period. Despite this, athletes from both groups reduced similar amounts

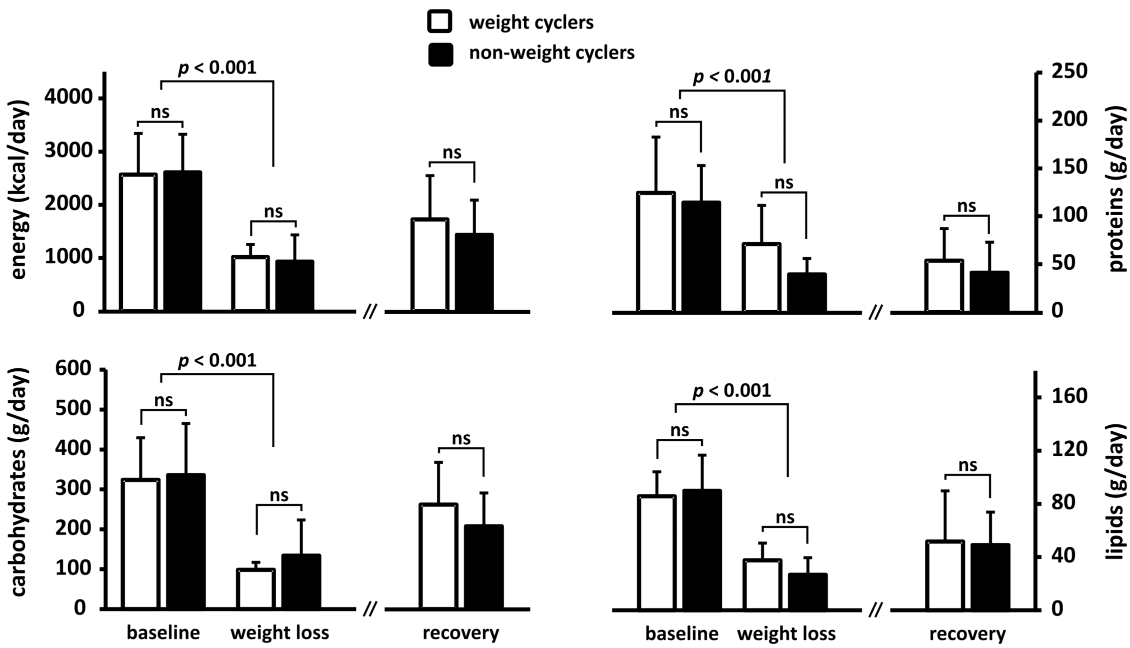

Figure 6 Daily energy and macronutrient intake by both weight cyclers and non-weight cyclers during baseline, weight loss and recovery periods. Values presented for baseline and weight loss periods represent the daily average of the 3-day food record. Values presented for the recovery period was calculated from the total food ingested during this period.

of body mass and the patterns of energy and nutrient restriction were quite comparable between groups, suggesting that the relative levels of dehydration were also similar between groups.

In conclusion, there were no differences in performance responses to RWL up to 5% of body mass between experienced male WC and non-WC, suggesting that chronic weight cycling does not lead male athletes to become resistant to its negative effects on performance. The present data corroborates the evidence that RWL does not affect performance, expanding this concept to athletes without familiarisation to RWL procedures. This holds true when weight loss is of ∼5% or less, and the recovery period after weigh-in is of ∼4 h or more. Future studies should confirm whether WC and non-WC respond to larger weight reductions in a similar manner and how female athletes respond to RWL.

What are the new findings

- Weight cyclers and non-weight cyclers respond to a rapid weight loss (RWL) regimen in a very similar manner.
- Five per cent of body mass reduction followed by a 4 h recovery period does not elicit measurable impairments in high-intensity upper-body intermittent performance, regardless of previous experience in rapid weight loss procedures.
- Chronic weight cycling does not lead athletes to become resistant to the negative effects of RWL on performance.

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Contributors EF, AHL and GGA participated in research design. SHM, ACT, MYS and DEV conducted experiments. SHM, ACT, JPLFG, MYS and DEV performed the data analysis. JPLFG, EF, AHL Jr and GGA contributed to the writing of the manuscript.

Competing interests None.

Ethics approval The study was approved by the Institutional Ethics Committee (School of Physical Education and Sport, University of São Paulo).

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