ORIGINAL ARTICLE

Does conventional body weight reduction decreasing anaerobic capacity of boxers in the competition period?

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Krzysztof Durkalec-Michalski[1,2ABCDE], Izabela Gościańska[1ABCD], Jan Jeszka[1DE]

[1] Department of Hygiene and Human Nutrition, Dietetic Division, Poznan University of Life Sciences, Poznan, Poland
[2] Polish Wrestling Federation, Warsaw, Poland

Source of support: Grant no. N N312 262340 from the Polish National Science Centre.

Received: 20 January 2015; **Accepted:** 26 June 2015; **Published online:** 12 August 2015

ICID: 1167891

Abstract

Background & Study Aim: Body weight reduction (BWR) is a serious problem in combat sports. Athletes frequently reduce their body weight in an inappropriate manner, which may have a negative effect on their exercise capacity and health. In view of the above and taking into consideration the limited number of studies conducted on trained boxers, the aim of this study was the knowledge about effect of conventional body weight reduction, used in this sports discipline, on body composition and anaerobic adaptation in athletes.

Material & Methods: The study involved 20 trained male boxers. The energy balance was determined based on the 4 day ongoing recording of food and liquids consumption, as well as 24 h energy expenditure estimated using heart rate monitoring. Body composition was measured using bioelectric impedance. The Wingate test was performed in order to determine the effect of BWR on anaerobic capacity.

Results: Boxers reduced their body weight on average by 5.4% within 7.8 ± 3.2 days. The energy value of their diet during BWR was by 51.5% lower (p<0.001) comparing to the training (preparation) period. It was observed that conventional BWR results in the reduction (p<0.05) not only of fat mass (BWR_{PRE}: 11.7 ± 3.6 kg vs. BWR_{POST}: 10.7 ± 3.9 kg), but to a considerable extent (p<0.01) also fat free mass (BWR_{PRE}: 61.1 ± 9.5 kg vs. BWR_{POST}: 59.2 ± 9.3 kg) and body water (BWR_{PRE}: 44.8 ± 6.7 l vs. BWR_{POST}: 43.8 ± 6.4 l). A deterioration was also recorded (p<0.001) in peak power (–9.3%), average power (–4.7%) and time at peak power (+55%), as well as (p<0.001) minimum power (–3.9%).

Conclusion: Conventional BWR adopted by boxers, connected with dietary limitations, is rapid and has an adverse effect on body composition and anaerobic capacity. This is seems necessary to implement an adequate education program in this respect, making it possible for athletes and coaches to plan a rational body weight reduction strategy in the pre-competition period.

Key words: body composition, combat sports, energy balance, Wingate test

Corresponding author: Krzysztof Durkalec-Michalski, Department of Hygiene and Human Nutrition - Dietetic Division, Poznan University of Life Sciences, Wojska Polskiego 31, 60-624 Poznan, Poland; e-mail: durkmich@up.poznan.pl

Bioimpedance analysis – the method for estimating body composition.

Body weight loss – reduction of the total body mass. In combat sports it is used for preparation to start in a lower weight category.

Energy balance – difference between total caloric value and the total daily energy expenditure.

Total caloric value – daily energy intake (24 hour).

Total daily energy expenditure – daily energy expenditure in general physical activities and in sports practice.

Wingate test – the most convenient tests used to evaluate anaerobic capacity (i.e. peak, average and mean power, as well as time to reach peak power).

Introduction

In the case of combat sports pre-competition body weight reduction (BWR) is commonly observed. It gives the athletes the opportunity to compete in a lower weight category, which may potentially provide them with physical advantage over a "lighter" competitor [1-3]. BWR is also an important element in mental preparation of athletes in these disciplines, increasing their self-assurance, a sense of control and commitment [4]. However, studies on boxers using rapid BWR showed a reduction of exercise capacity and vigour, as well as increased fatigue and mental stress [5]. Unfortunately, in this sports discipline there are few studies verifying the effect of rapid body weight reduction on anaerobic capacity of the organism. Such research seems necessary, since recorded results may constitute the basis for essential education of coaches and athletes concerning proper BWR. Probably as a result of this shortage most frequently inappropriate body weight reduction methods are applied in combat sports, e.g. by wrestlers, judoists, karate athletes as well as jujitsu and taekwondo athletes, involving fasting, a lack of fluid replacement, skipping meals, long-term sauna sessions and wearing impermeable clothing [2,3,5,6]. Such a "making weight" regimen leads to actual weight loss, but this effect is obtained mainly by dehydration, muscle glycogen depletion and disturbed levels of tissue components, which eventually may contribute to reduced exercise capacity of athletes [3,7-10]. Inappropriate BWR seems to have a negative effect on mental functions, causing a deteriorated sense of well-being, attention concentration, memory and cognitive functions [3,5,11]. It is particularly significant, since in combat sports not only physical fitness counts, but also technical skills, strategy, fighting spirit and motivation of athletes, thus any disturbance in effectiveness in their action may directly decrease their chance for success. Moreover, fatal cases are even known, resulting from an inappropriate intensive body weight reduction [8,12]. However, it needs to be stressed that in certain cases body weight reduction may have brought desirable results, if it had been performed in a rational manner and not initiated as late as a week before the competition [13,14].

In the case of the effect of body weight reduction in combat sports we need to focus on the fact that in contrast to the so-called grappling disciples, a limited body scientific data did verified the effect of the adoption of conventional BWR on changes in body composition [15] and exercise capacity in boxers. What is more, it needs to be stressed that no studies are available in literature, which would verify the effect of conventional BWR on the level of anaerobic muscle power in trained boxers. It is particularly important, since in a fight the effectiveness of the performed series of attacks of supramaximal intensity may bring victory and this requires high anaerobic potential from the athlete [16-18], which is increasingly difficult to maintain during successive rounds. Thus, in view of the significance of pre-competition BWR, possibly affecting the final success in combat sports and a lack of data concerning its effect on anaerobic exercise capacity of trained boxers, the aim of this study was the knowledge about effect of conventional body weight reduction, used in this sports discipline, on body composition and anaerobic adaptation in athletes.

Material and Methods

Participants

The study involved a group of 20 trained men practicing boxing in sports clubs of the Wielkopolska region (Poland) and aged 20 ± 4 years. Criteria for the participation in the study included, among other things, fulfilling requirements concerning the absence of any health problems at least a 4 year training period and performance of min. 4 boxing training units a week and having a valid currently issued medical certificate confirming their capacity to practice sports. In accordance with the Declaration of Helsinki, all the participants expressed their free and conscious consent to participating in the research procedures [19]. The consent of the Bioethics Committee at Poznan University of Medical Sciences was obtained for this study (decision no. 981/12 of 2012 Nov 8).

Experimental design

The exercise tests were conducted at the Exercise Tests Laboratory at the Department of Human Nutrition and Hygiene, Poznan University of Life Sciences. All the analyses were performed in the morning hours between 8-10 a.m., at a temperature of 20-23°C and relative humidity of approx. 60-70%.

Identical experimental procedures were applied at two stages following each other: in the preparation (training) phase (BWR_{PRE}), which was characterized by a lack of body weight modification (the control period) and following body weight reduction (BWR_{POST}), which was to be executed in the same way as in the conventional manner applied in the pre-competition period (Figure 1). In the course of BWR each athlete regulated their body weight in the conventional manner, using traditional methods and strategies normally applied by them, connected only with dietary limitations, analogously as before important sports competitions. Additionally, after the athletes had been qualified to the study, in the period before BWR a regression dependence was established for $VO_2 \cdot HR^{-1}$. Moreover, the authors of this study did not give their consent to any other actions or methods to reduce body weight, which may be connected with any health hazard or be inconsistent with anti-doping regulations of the Word Anti-Doping Organization (WADA) Code.

Body weight and composition

Body weight and height of the study participants were measured using a WPT 60/150 OW medical anthropometer by RADWAG® (Poland). Body composition was analysed with the use of a BIA 101S analyser by AKERN-RJL (Italy) and Bodygram 1.31 computer software by AKERN-RJL (Italy). Body composition was measured following strictly the recommended measurement conditions – that is, in the morning hours, following overnight fasting, in subjects lying in a supine position, and in the recommended application of measuring electrodes [20]. Athletes were also instructed to abstain from drinking coffee, strong tea, caffeine-containing products, and alcohol for at least 24h before the test, as well as to refrain from physical exercise for a minimum of 18h before measurements.

Anaerobic capacity

Anaerobic capacity was assessed using the classical Wingate test on a cycloergometer (Monark 894E, Sweden) following recommendations for such tests proposed by Bar-Or [21]. The primary test was preceded with a 5 min warm-up period of approx. 50 W power, followed by a 5 min break. The test lasted for 30s. External loading was estimated individually at 7.5% body weight. During the test the athletes were encouraged to maintain maximum effort. Recorded results were analysed using Monark Anaerobic Test Software (ver. 3.0.1, Sweden).

The diet

The diet was assessed based on the ongoing recording of consumed food and beverages [22] using Albums of Photographs of Food and Dishes [23], which made it possible to determine the specific character of conventional limitation of energy value in the diet during the pre-competition body weight reduction by athletes. Athletes were trained to accurately record their diet, which they did for 4 successive days preceding function tests (BWR_{PRE} and BWR), including also possible dietary supplementation.

Based on the recorded data the energy value of daily food rations was determined using a computer data base prepared in the Dietetyk software (ver. 2.0, Poland). The calculations included cooking and technological losses.

Assessment of total daily energy expenditure

Total daily energy expenditure (TDEE) was assessed using heart rate monitoring (POLAR RS400, Finland) following recommendations of validation tests [24]. The athletes' heart rate (HR) was recorded

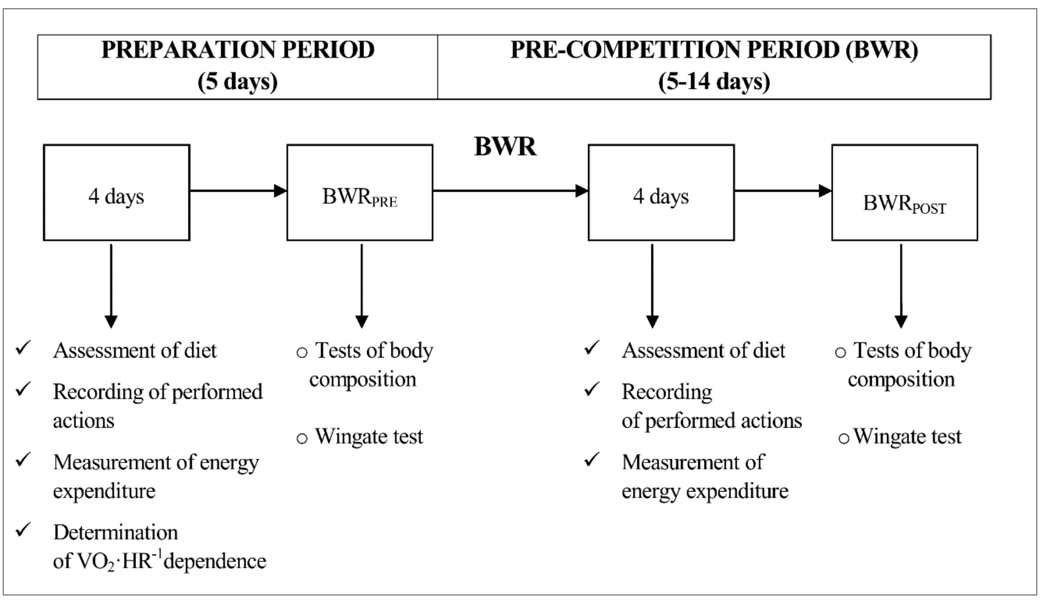

Figure 1. A flow chart of the study.

continuously for a period of 4 successive days. In that time all the performed actions were recorded simultaneously in order to detect possible measurement errors. Upon the completion of recording the data from a wrist-worn monitor were transferred using an interface to a computer equipped with the Polar ProTrainer 5 program (ver. 5.41.002, Finland). To provide appropriate estimation of EE the analysis of regression was performed between oxygen uptake (VO_2) and heart rate (HR) – $VO_2 \cdot HR^{-1}$ – individually for each athlete using an ergospirometer (Cosmed K4b[2], Italy), while the heart rate threshold was determined at HR-FLEX. Recorded HR data, depending on the specific intensity levels of individual activities, were then used to estimate total daily energy expenditure under free living conditions [24].

Statistical analyses

All statistical calculations were performed using the Statistica (ver. 9.0, StatSoft, Poland). Results are presented as arithmetic means ($\overline{x}$) and standard deviations (± SD). In order to verify whether a random sample came from the population with a normal distribution the Shapiro-Wilk test was performed. In order to determine whether the results recorded in the preparation period (before body weight reduction – BWR_{PRE}) and after conventional body weight reduction (BWR_{POST}) performed under identical conditions as in the pre-competition period, differ significantly, basic descriptive statistics were used and arithmetic means were calculated together with their standard deviations applying the t-Student test for dependent samples.

Results

The study participants had practiced boxing for more than 4 years. The specific character of targeted and supplementary training sessions was similar in all study participants. Within a 1 week cycle there were more than 4 boxing training units of a total length 7.2 ± 1.4 hours. An average age, at which the tested group of athletes for the first time reduced their body weight in order to compete with an opponent from a lower weight class was 16.5 ± 3.1 years. In turn, the duration of the BWR period was 7.8 ± 3.2 days (Table 1).

After conventional body weight reduction (BWR_{POST}) simulating conditions of pre-competition BWR the athletes reduced their body weight on average by 5.4% (BWR_{PRE}: 74.1 ± 13.3 kg vs. BWR_{POST}: 70.1 ± 12.5 kg, $p<0.001$) (Table 2, Figure 2a). It was found that in absolute numbers

Table 1. Characteristics of the tested group of athletes

Basic data	± SD	Range
Age of athletes (years)	19.9 ± 4.2	15-27
Training schedule ($h \cdot week^{-1}$)	7.2 ± 1.4	5-10
Age at first BWR (years)	16.5 ± 3.1	12-23
BWR duration in the study (days)	7.8 ± 3.2	4-14

BWR: Body weight reduction

BWR was mainly caused by losses of fat free mass (BWR_{PRE}: 61.1 ± 9.5 kg vs. BWR_{POST}: 59.2 ± 9.3 kg, $p<0.01$) and body water (BWR_{PRE}: 44.8 ± 6.7 l vs. BWR_{POST}: 43.8 ± 6.4 l, $p<0.01$), and to a slightly lesser degree also fat mass (BWR_{PRE}: 11.7 ± 3.6 kg vs. BWR_{POST}: 10.7 ± 3.9 kg, $p<0.05$), which indicated disadvantageous losses of FFM and TBW, at a slightly lesser FM reduction (Table 2, Figure 2a).

Assessment of anaerobic power indexes during the Wingate test after BWR showed significantly reduced values of both peak (BWR_{PRE}: 12.3 ± 1.3 $W \cdot kg^{-1}$ vs. BWR_{POST}: 11.1 ± 1.4 $W \cdot kg^{-1}$, $p<0.001$), mean (BWR_{PRE}: 8.1 ± 0.6 $W \cdot kg^{-1}$ vs. BWR_{POST}: 7.7 ± 0.6 $W \cdot kg^{-1}$, $p<0.001$) and minimum power (BWR_{PRE}: 5.1 ± 0.7 $W \cdot kg^{-1}$ vs. BWR_{POST}: 4.9 ± 0.6 $W \cdot kg^{-1}$, $p<0.05$), amounting to –9.3%, –4.7% and –3.9%, respectively (Table 2, Figure 2b). Moreover, the length of time required to reach peak power was found to extend by as much as 55% (BWR_{PRE}: 2.0 ± 1.0 s vs. BWR_{POST}: 3.1 ± 1.6 s, $p<0.001$) (Table 2, Figure 2b). These results clearly show that anaerobic capacity in boxers was significantly reduced after BWR.

It needs to be stressed that assessment of energy expenditure showed that the total daily energy expenditure (TDEE) in athletes in the preparation period was 3684 ± 954 $kcal \cdot day^{-1}$ and did not differ significantly from TDEE recorded during BWR (3556 ± 440 $kcal \cdot day^{-1}$). However, it was found that during BWR the total caloric value of the diet (TCV) was by 51.5% lower than in the preparation period (BWR_{PRE}: 3204 ± 969 $kcal \cdot day^{-1}$ vs. BWR: 1572 ± 426 $kcal \cdot day^{-1}$, $p<0.001$). For this reason, daily energy deficit calculated during the BWR period was higher ($p<0.001$) than that calculated in the training period (BWR_{PRE}: 482±563 $kcal \cdot day^{-1}$ vs. BWR: 1983±707 $kcal \cdot day^{-1}$) (Table 2, Figures 2c and 3).

Discussion

It needs to be stressed that very few studies concerning boxing verified the effect of body weight

Table 2. Analysis of changes in body weight and composition, indexes of anaerobic capacity and energy balance depending on the preparation phase of athletes before and after conventional pre-competition body weight reduction

Variable	Unit	Period of preparation	
		BWR_{PRE}	BWR_{POST}
BM	(kg)	74.1 ± 13.3*	70.1 ± 12.5*
TBW	(l)	44.8 ± 6.7†	43.8 ± 6.4†
FM	(kg)	11.7 ± 3.6‡	10.7 ± 3.9‡
FFM	(kg)	61.1 ± 9.5†	59.2 ± 9.3†
PP	(W·kg^{-1})	12.3 ± 1.3*	11.1 ± 1.4*
AP	(W·kg^{-1})	8.1 ± 0.6*	7.7 ± 0.6*
MP	(W·kg^{-1})	5.1 ± 0.7‡	4.9 ± 0.6‡
T_{pp}	(s)	2.0 ± 1.0*	3.1 ± 1.6*
TCV	(kcal·day^{-1})	3204 ± 968*	1572 ± 425*
TDEE	(kcal·day^{-1})	3684 ± 953	3555 ± 440
ED	(kcal·day^{-1})	481 ± 562*	1983 ± 707*

, †, ‡ - significant differences (- $p < 0.001$, †- $p < 0.01$, ‡- $p<0.05$)

BWR_{PRE}: "training period" (before body weight reduction); BWR_{POST}: "pre-competition period" (after body weight reduction); BM: body mass; TBW: total body water; FM: fat mass; FFM: fat free mass; PP: peak power; AP: average power; MP: minimal power; T_{pp}: time at PP; TCV: total caloric value; TDEE: total daily energy expenditure; ED: energy deficit.

reduction, connected with conventional dietary limitations, on changes in body composition, particularly anaerobic capacity. The importance of such studies is stressed by the fact that the application of inappropriate methods in order to gain rapid body weight reduction (rapid-BWR) is still very common among athletes practicing combat sports [3,5,15,25]. A disturbing finding was also the young age, at which athletes for the first time start to reduce their body weight before a competition. It was shown in this study that some boxers start to reduce their body weight as early as the age of 12 years (on average starting at 16.5 years). Similar dependencies were shown by Artioli et al. [2] in studies on judoists, among whom some athletes also declared their first BWR already at 12.6 years of age. In turn, Brito et al. [3] in karate and taekwondo fighters and in judoists recorded the first BWR (on average) at 13.6 and 14.2, as well as 17.0 years of age. We need to mention here a striking case in literature on the subject reporting a 5 year old boy practicing wrestling, persuaded by his parent to reduce the amount of consumed food to reduce his body weight [26].

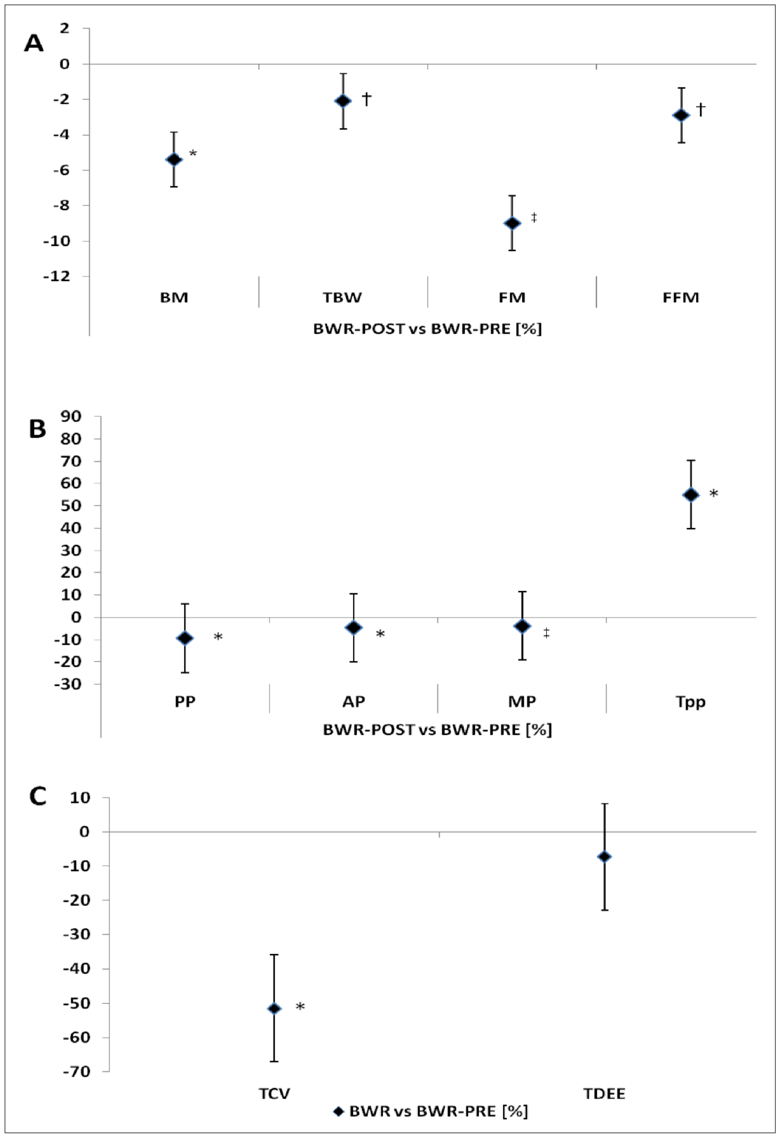

Figure 2. Percentage changes in **(A)** body mass and body composition, **(B)** anaerobic capacity after BWR and **(C)** energy balance during BWR.

* † ‡ - significant differences in comparison to BWR_{PRE} (*- $p < 0.001$, †- $p < 0.01$, ‡ - $p<0.05$)

BWR_{PRE}: "training period" (before body weight reduction); BWR_{POST}: "pre-competition period" (after body weight reduction); BM: body mass; TBW: total body water; FM: fat mass; FFM: fat free mass; PP: peak power; AP: average power; MP: minimal power; T_{pp}: time at PP; TCV: total caloric value; TDEE: total daily energy expenditure; ED: energy deficit.

In relation to the volume of BWR it was shown that a large percentage of athletes reduced their body weight by 5-10%, while some respondents declared as much as a 10% weight reduction [3,5,14-16]. A study by Sterkowicz [27] reported 2 cases of male athletes practicing combat sports, who within 1 week reduced their body weight by as much as 15.3% and 18.1%. In this study boxers reduced their body weight on average by 5.4% initial body weight

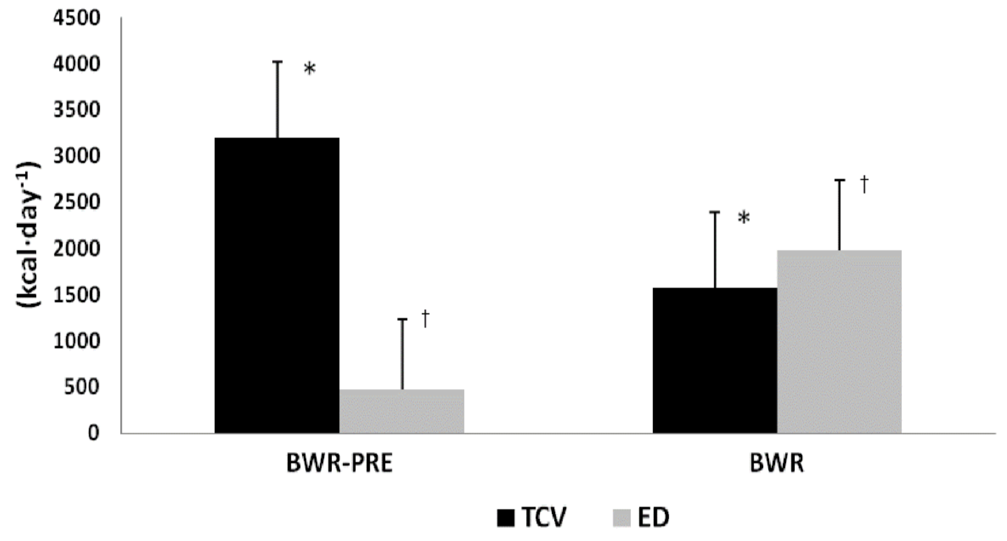

Figure 3. Mean values of energy balance depending on the preparation period of athletes to competitions (before and during BWR).

* † - significant differences ($p < 0.001$)

BWR_{PRE}: "training period" (before body weight reduction); BWR: body weight reduction period; TCV: total caloric value; ED: energy deficit.

(max. 7.7%), within a little less than 8 days before weigh-in (from 4 to 14 days). These results correspond with other studies involving athletes practicing judo, jujitsu, karate, taekwondo, wrestling and boxing, in which rapid-BWR was also executed within as little as several days preceding the competition exercise [3,5,6,25]. We need to stress here that such a recorded body weight reduction, on average 0.5 kg a day, may be definitely considered rapid, irrational and contrary to assumed recommendations [7,13,28].

In order to achieve such a rapid body weight reduction, athletes practice several different methods, e.g. most typically considerably limit amounts of consumed food and fluids [2,3,5,8,14-16,29]. Results of this study confirm habitual use of a low-calorie diet also by boxers in order to attain rapid body weight reduction. TCV in the pre-competition period was by 51.5% lower (Figure 2c) in comparison to the preparation period, which at a lack of significant differences in total daily energy expenditure in the period before and after BWR indicates for the BWR period an energy deficit of as much as 1984 kcal·day^{-1}. Thus it is consistent with literature date, which indicated a 33% [30] reduction of calorie value of the diet in the period before judo tournaments and an energy deficit of 1246 kcal·day^{-1} [29] during BWR in athletes practicing taekwondo. Such a considerable limitation of consumed food and fluids may result in the deficit of effective energy sources such as glycogen, which as a consequence poses a risk of utilization of muscle protein as a source of energy, disturbed regeneration and athletic recovery processes, leading as a consequence to an increased risk of overtraining and an impaired capacity of muscles to perform physical work [3,7-10].

Similarly as in literature sources concerning athletes practicing taekwondo [14] and judo [31], it was found in this study that also in boxers rapid-BWR unfortunately leads to adverse changes in body composition. Rapid-BWR in boxers caused a decrease of body weight by 5.4% mainly at the expense of FFM. These data obviously suggest the potential decrease in exercise capacity of athletes due to the reduced fat free mass and the risk of dehydration.

In combat sports the specific character of muscle work requires from athletes achieving high power, speed and muscle dynamics, which due to the maximal and supramaximal character of exercise requires effective energy supply through anaerobic metabolism [32]. The importance of these aspects in boxers is also confirmed by studies by Siegler [17] and Hübner-Woźniak [18]. Also Smith [16] reported increased anaerobic energy processes based on high post-exercise lactate concentrations (>13.5 $mmol \cdot l^{-1}$) in amateur boxers. In turn, in a study from 1994 Folgelholm [7] observed that certain effects of rapid-BWR, i.e. a limited capacity to buffer disturbed acid-base homeostasis, depletion of muscle glycogen and water-electrolyte imbalance, have a direct effect on the deterioration of anaerobic potential in athletes using non-recommended methods of body weight reduction. Results recorded in this study confirm definitely that conventional BWR methods result in a considerable decrease in anaerobic capacity in boxers, which may probably be also referred to other representatives of combat sports. A significant reduction of anaerobic adaptation (reaching as much as over 9%) was shown for peak and mean power ($p<0.001$), as well as minimum power ($p<0.05$). In a study by McMurray [33] similar conclusions were presented indicating that a rapid body weight reduction, e.g. by consumption of inadequate amounts of carbohydrates, causes a significant decrease in anaerobic capacity in wrestlers. Moreover, boxers participating in this study following body weight reduction reached peak power after a longer time (+55%, $p<0.001$). This indicates a considerable deterioration of their speed, which particularly in boxing may have a negative effect on the capacity to fight effectively.

It needs to be stressed that observations made in this study concerning a reduction of anaerobic muscle power after rapid-BWR were confirmed also by other studies [1,34,35], although they were not conducted using the Wingate test recording muscle work indexes. Additionally, during rapid-BWR total body water was also reduced. Burge et al. [36] and Walsh et al. [37] confirmed a considerable deterioration of systemic tolerance to perform highly intensive exercise already at a dehydration of 1.8-2%. Moreover, it was found that a low carbohydrate consumption, observed during intensive limitation of food consumption when slimming, may cause a 36-54% reduction of muscle glycogen concentration, which – as it was mentioned above – probably results in a reduced anaerobic capacity [36,38]. Thus, although glycogen concentration was not measured in this study, it may be assumed that in trained boxers a deterioration of anaerobic adaptation indexes may also be caused by general weakness, caused by a considerable negative energy balance, which probably led to reduced muscle glycogen storages.

Summing up, it seems that only properly planned and controlled body weight reduction makes it possible to minimize losses of fat free mass, required for the performance of effective muscle work at the simultaneous fat mass reduction, which may in consequence even lead to an increased exercise capacity of athletes [39,40]. Additionally, the related increased ratio of active muscle tissue to adipose tissue seems to have an advantageous effect on exercise capacity connected with a relatively greater power, strength and muscle endurance as well as speed and dynamics, particularly in comparison to athletes competing in their natural weight class or rapidly reducing body weight [39,41].

Conclusions

Results of this study indicate that the conventional body weight reduction in boxers, connected with diet limitations, is rapid and has a negative effect on body composition, causing a reduction e.g. in fat free mass and total body water. What is more, methods to reduce body weight used by these athletes have a negative effect on anaerobic adaptation of athletes, significantly reducing anaerobic power and extending time required to reach peak power. Thus it seems necessary in this sports discipline to implement adequate education, making it easier for athletes and coaches to plan a rational body weight reduction strategy.

Highlights

Conventional body weight reduction, based on a considerably decreased energy value of the diet applied only several days before a competition, is connected mainly with a reduction of fat free mass and has a negative effect on anaerobic capacity. In order to counteract this phenomenon, it is necessary – at an appropriately long time before the competition – to implement a rational dietary strategy, leading particularly to fat mass reduction and minimization of negative effects of rapid-BWR.

Acknowledgements

The authors wish to thank coaches and athletes for their help and participation in the research project.

Competing interest

The authors declare that they have no competing interests.

References

1. Timpmann S, Ööpik V, Pääsuke M et al. Acute effects of self-selected regimen of rapid body mass loss in combat sports athletes. J Sports Scien Med 2008; 7: 210–217
2. Artioli GG, Gualano B, Franchini E et al. Prevalence, magnitude, and methods of rapid weight loss among judo competitors. Med Sci Sports Exerc 2010; 42: 436–442
3. Brito CJ, Roas AF, Brito ISS et al. Methods of body mass reduction by combat sport athletes. Int J Sport Nutr Exerc Metab 2012; 22: 89–97
4. Pettersson S, Ekstrom MP, Ber CM. Practices of Weight Regulation Among Elite Athletes in Combat Sports: A Matter of Mental Advantage? J Athl Train 2013; 48(1): 99–108
5. Hall CJ, Lane AM. Effects of rapid weight loss on mood and performance among amateur boxers. B J Sports Med 2001; 35(6): 390–395
6. Davis SE, Dwyer GB, Reed K et al. Preliminary investigation: the impact of the NCAA Wrestling Weight Certification Program on weight cutting. J Strength Cond Res 2002; 16: 305–307
7. Fogelholm GM: Effects of bodyweight reduction on sports performance. Sports Med 1994; 18: 249–267
8. Oppliger RA, Case HS, Horswill CA et al. ACSM Position Stand: Weight Loss in Wrestlers. Med Sci Sports Exerc 1996; 28: ix–xii
9. Ftaiti F, Grélot L, Coudreuse JM et al. Combined effect of heat stress, dehydration and exercise on neuromuscular function in humans. Europ J Appl Physiol 2001; 84: 87–94
10. Stöhr EJ, Gonzalez-Alonso J, Pearson J et al. Dehydration reduces left ventricular filling at rest and during exercise independent of twist mechanics. J Appl Physiol 2011; 111: 891–897
11. Choma CW, Sforzo GA, Keller BA. Impact of rapid weight loss on cognitive function in collegiate wrestlers. Med. Scien. Sports Exerc 1998; 30: 746–749
12. Centers for Disease Control and Prevention (CDC). Hyperthermia and dehydration-related deaths associated with intentional rapid weight loss in three collegiate wrestlers. North Carolina, Wisconsin, Michigan, November-December 1997. MMWR Morb Mortal Wkly Rep 1998; 47: 105–108
13. Turocy PS, DePalma BF, Horswill CA et al. National Athletic Trainers' Association position statement: safe weight loss and maintenance practices in sport and exercise. J Athl Train 2011; 46(3): 322–336
14. Yang WH, Grau M, Kim P et al. Physiological and psychological performance of taekwondo athletes is more affected by rapid than by gradual weight reduction. Arch Budo 2014; 10: 169–177
15. Perón APON, Garcia LS, Alvarez JFG et al. Nutritional profile of olympic boxers and evaluation of the impact of nutritional intervention in weight adjustment to boxing categories. O Mundo da Saúde, São Paulo: 2009; 33(3): 352–357
16. Smith MS. Physiological profile of senior and junior England international amateur boxers. J Sports Sci Med 2006; 5(CSSI): 74–89
17. Siegler JC, Hirsher K. Sodium bicarbonate ingestion and boxing performance. J Strength Cond Res 2010; 24: 103–108
18. Hübner-Woźniak E, Kosmol A, Błachnio D. Anaerobic capacity of upper and lower limbs muscles in combat sports contestants. JCSMA 2011; 2(2): 91–94
19. Harriss DJ, Atkinson G. Update-ethical standards in sport and exercise science research. Int J Sports Med 2011; 32(11): 819–821
20. Lewitt A, Mądro E, Krupienicz A. Theoretical foundations and practical applications of bioelectrical impedance analysis (BIA). Endokr Otył Zab Przem Mat 2007; 3(4): 79–84 [in Polish]
21. Bar-Or O. The Wingate anaerobic test: An update on methodology, reliability and validity. Sports Med 1987; 4(6): 381–394
22. Thompson FE, Subar AF. Dietary Assessment Methodology. In. Coulston AM, Boushey CJ, Ferruzzi MG (eds.). Nutrition in the prevention and treatment of disease. 3rd ed. London-Waltham-San Diego: Elsevier Acad Press; 2012: 5–7
23. Szponar L, Rychlik E, Wolnicka K. Album of photographs of food products and dishes. Warszawa: IŻŻ; 2008
24. Durkalec-Michalski K, Woźniewicz M, Bajerska J et al. Comparison of various non-calorimetric methods measuring energy expenditure at different intensities. Hum Movement 2013; 14(2): 161–167
25. Coufalová K, Prokešová E, Malý T et al. Body weight reduction in combat sports. Arch Budo 2013; 9(4): 267–272
26. Sansone RA, Sawyer R. Weight loss pressure on a 5 year old wrestler. Br J Sports Med 2005; 39: e2
27. Sterkowicz S. Body weight reduction (BWR) process versus the gender and the sports level of people who practice combat sports. Med Sport Pract 2006; 7(4): 58–61
28. Franchini E, Brito CJ, Artioli GG. Weight loss in combat sports: physiological, psychological and performance effects. J Internat Soc Sports Nutrit 2012; 9: 52
29. Drummond MDM, Couto BP, Eufrásio RJS et al. Energy balance in taekwondo athletes during pre-competition. Arch Budo 2014; 10: 195–199
30. Degoutte F, Jounael P, Begue RJ et al. Food restriction, performance, biochemical, psychological and endocrine changes in judo athletes. Int J Sports Med 2006; 27(1): 9–18
31. Coufalová K, Cochrane DJ, Malý T et al. Changes in body composition, anthropometric indicators and maximal strength due to weight reduction in judo. Arch Budo 2014; 10: 161–168
32. Gacesa PJZ, Barak OF, Grujic NG. Maximal anaerobic power test in athletes of different sport disciplines. J Strength Cond Res 2009; 23(3): 751–755
33. McMurray RG, Proctor CR, Wilson WL. Effect of caloric deficit and dietary manipulation on aerobic and anaerobic exercise. Int J Sports Med 1991; 12: 167–172
34. Webster S, Rutt R, Weltman A. Physiological effects of a weight loss regimen practiced by college wrestlers. Med Sci Sports Exerc 1990; 22: 229–234
35. Kraemer WJ, Fry AC, Rubin MR et al. Physiological and performance responses to tournament wrestling. Med Scien Sports Exerc 2001; 33(8): 1367–1378
36. Burge CM, Carey MF, Payne WR. Rowing performance, fluid balance, and metabolic function following dehydration and rehydration. Med Scien Sports Exerc 1993; 25: 1358–1364
37. Walsh RM, Noakes TD, Hawley JA et al. Impaired high-intensity cycling performance time at low levels of dehydration. Internat. J Sports Med 1994; 15: 392–398
38. Tarnopolsky MA, Cipriano N, Woodcroft C et al. Effects of rapid weight loss and wrestling on muscle glycogen concentration. Clin J Sport Med 1996; 6: 78–84
39. Franchini E, Nunes AV, Moraes M et al. Physical fitness and anthropometrical profile of the Brazilian male judo team. J Physiol Anthropol 2007; 26(2): 59–67
40. Durkalec-Michalski K, Jeszka J. Assessment of body composition and anaerobic strength in a selected group of Polish athletes practicing wrestling and Brazilian jiu-jitsu. In: 7th EFSMA – European Congress of Sports Medicine, 3rd Central European Congress of Physical Medicine and Rehabilitation. 2011 Oct 26-29; Salzburg, Austria. Düsseldorf: German Medical Science GMS Publishing House; 2011
41. Katralli J, Goudar SS. Anthropometric profile and special judo fitness levels of Indian judo players. Asian J Sports Med 2012; 3(2): 113–118

Cite this article as: Durkalec-Michalski K, Gościańska I, Jeszka J. Does conventional body weight reduction decreasing anaerobic capacity of boxers in the competition period? Arch Budo 2015; 11: 251-258