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Rapid Weight Loss in Congolese Judo: Energy Profile, Performance and Haematological Effects

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Abstract

While the deleterious effects of rapid weight loss (RWL) on the health in combat sports athletes are well known, the issue of exertion energy expenditure and motor performance remains controversial. The aim of this study was to investigate the impact of RWL on energy cost and judo performance, and associated haematological characteristics. Among 21 top Congolese judoists who took part in an intensive judo program lasting 5 1/2 days (or 11 sessions), 16 of them rapidly lost 4% to 5.5% of body mass; corollarly with a reclassification in one of the 3 weight categories: −60 kg (n = 7), −80 kg (n = 5) and −100 kg (n = 4). During sessions 1 and 11, the energy cost during the different training sequences was evaluated from the heart rate (HR). During the program, a judo performance test evaluated 2 performance indicators: the number of uchi-komi achieved and the height of uke's center of gravity during a throw. Basal blood parameters were determined before RWL and at S_1, S_{11} (after the judo combat series). The results show a significant increase in heart rate from session S_1 to session S_{11}, in the different training sequences. HR after fights was around 98% of HR_{max}. In addition, a significant decrease in number of uchi-komi was observed on each of the bearings 4 to 6 and throughout the performance test, and in height of uke's center of gravity during fall movements. While most of the basal blood parameters remained unaltered during the program, red blood cell was reduced significantly and a significant plasma volume changes increase was found. The modification of each of the variables measured thus reflects the negative effect of the rapid weight loss associated to the increase in energy cost in judo.

Keywords

Rapid Weight Loss, Judo, Heart Rate, Performance, Basal Blood Parameters

1. Introduction

The Olympic disciplines of combat sports (i.e., judo, wrestling, taekwondo and boxing) account for almost 25% of the total medals disputed in the Olympic Games (Gutierrez-Garcia et al., 2010). Judo is a martial art and Olympic sport comprising standing and ground fighting. It interred the Olympic program in 1964 as a demonstrative sport in Tokyo, Japan and officially in 1972 for men during Olympic Games in Munich, Germany, and 1992 for women. During competitions, judo athletes (or judoists) are divided by sex, sometimes by grade or judo experience, and organized in age class and weight divisions (categories) (Pococco & Burtscher, 2013). Nowadays, judo ranks among the most popular Asian martial arts in the world (Gutierrez-Garcia et al., 2010). The judo can be characterized as high-intensity, intermittent activity (Franchini et al., 2011a) and consequential adaptations are consistently found in judoists (Franchini et al., 2011b). In competition, judo is characterized by fights between two athletes of the same weight category. A judo fight lasts in actual time, from the junior categories, 5 minutes for men and 4 for women. This total time is made up of several combat sequences, with an average duration of 22 ± 10 s for juniors and 33 ± 30 s for seniors (Miarka et al., 2012). These assault sequences are interspersed with recovery sequences of 7 to 15 seconds because we are witnessing a succession of effort times of 20 - 40 s interspersed with pauses of 10 - 15 s (Favre-Juvin et al., 1989; Paillard, 2010). This type of profile strongly solicits anaerobic processes during intense and maximum efforts, verified by high blood lactate concentrations (Maillat & Gaillat, 1987); but also, aerobic processes to last the duration of the fight and to recover efforts during periods of recovery or lower intensity (Paillard, 2010). This author emphasizes that aerobic metabolism, including maximum oxygen uptake (VO_{2max}), maximum strength, and especially anaerobic power (explosiveness) are major factors of performance in judo. In addition, the work of Muller Deck (1987) and some studies on the energy profile by spectroscopy (Gariod et al., 1995) show two profiles of judo fighters: an explosive profile (judoist winner of a fight at the start of the assaults) and an enduring profile (judoist winning the fights rather at the end). The physiological requirements of judo vary according to these profiles and weight categories, which follow in the men: −60 kg, −66 kg, −73 kg, −81 kg, −90 kg, −100 kg, +100 kg (IJF, 2020). This is why the term of weight category is attached to weight loss. Indeed, the majority of athletes reduce their body mass in order to fight in a lower weight category, this being perceived as "an advantage in competition against an opponent of a lighter weight category" (Artioli et al., 2010). It would seem necessary for athletes to maintain their weight sustainably throughout the sporting season, but this is scarcely the case. Thus, weight loss is an entire part of judo as a competitive weight class sport, like all combat sports.

In the judo world, "weight loss often resonates with increased performance" (Schaffter, 2004): fighters practice it in order to be opposed to "smaller and weaker opponents" (Brito et al., 2012). For this, they often practice it unreasonably, without the help of qualified coaches. For example, Artioli et al. (2010) report that the most influential people in relation to the weight loss management behaviors of a judoist are his trainer (23.7%) and another judoist (20.6%); the dietitian nutritionist is cited only in sixth place (7.3%). However, it can be safely assumed that the majority of coaches and judoists are not qualified to supervise these practices. Moreover, Franchini et al. (2012), in a large review of the Medline, Lilacs, PubMed and SciElo databases, note that 60% to 90% of fighters, and 90% of judoists have already practiced rapid weight loss, that is to say spread over 10 days maximum. They also note that 40% of judoists had already lost more than 5% of body mass at least once, with, in most cases, rapid weight loss (RWL). One of the techniques associated to judo RWL is increased physical activity, with a frequency of 90% according to Brito et al. (2012).

Franchini et al. (2012) find different effects of RWL on performance in judo. The effects are primarily psychological: decrease in self-esteem and increase in confusion, nervousness and depression, due to fatigue attributed to the restriction of energy intake mainly (Degoutte et al., 2006). Brito et al. (2012) report similar effects in their review of the literature, also based on studies specific to combat sports: decreased concentration, short-term memory, and the speed of cognitive processing. Cognitive functions are altered with the decrease in blood glucose caused by the restriction of energy intake (Choma, 1998). The effects of RWL on performance and health are also well known, particularly: decrease in aerobic and anaerobic performance (Fogelholm, 1994), attributed to decreased plasma volume; increased risk of injury (Green, 2007); alteration of thermoregulatory processes (Yang et al., 2017; Koral & Dosseville, 2009), consequence of dehydration (linked to restriction of fluid intake and the search for weight loss through sweating, when this is the case); decreased anaerobic performance: reduced anaerobic power, anaerobic capacity and maximal strength (except maximal lower limb strength which does not appear to be anaerobic) (Webster et al., 1990). The reduction in aerobic and anaerobic performance can be attributed to the decrease in plasma volume and glycogenic depletion linked respectively to the restriction of water and energy intake (Fogelholm, 1994). In addition, previous studies indicated that RWL increases oxidative stress, leads to an imbalance of electrolytes and hormones, changes in blood flow, and decreases plasma volume (Costill et al, 1976; Oppliger et al, 1996; Sawka & Pandolf, 1990). The literature review also reports that dehydration following rapid weight loss is characterized by hyperosmolarity which increases blood viscosity, which can alter the ventilation/pulmonary perfusion ratio and therefore the oxygen transport capacity at the cellular level (Caldwell et al., 1984). The RWL technique therefore requires the judoist to drink a lot after the competition to restore his water balance and eliminate his overproduction of uric acid. However, this compensatory phase is never complete in the short term (Shephard & Shek, 1995). In fact, several days after the competition, the athlete still presents physiological sequelae inherent in this transient water manipulation. This manifests itself in a mineral loss which impairs his physical capacities and his faculties of recovery. In addition, analyzing some studies implies a difference between physical performance in laboratory tests and athletic performance in real competition after RWL. Strength, power, VO_{2max}, and anaerobic performance measured on the one hand in a vertical jump test (Viitasalo et al., 1987), and on the other hand in a Wingate test (Serfass et al., 1984; Reljic et al., 2016; Fogelholm et al., 1993), were not affected by WRL. These appear to be controversially discussed because of percentages of RWL and various measurements of athletic performance (Serfass et al., 1984). All of these factors mentioned above represent limits to athletic performance. Moreover, from aforementioned it is not clear if and how RWL affects judo-specific performance but also blood basal parameters and lactatemia during and after consecutive judo fights. However, Paillard (2010) suggests that these limits would appear for rapid weight loss from 4% to 6% of body mass. In addition, the increase in energy cost is contradictory with sharpening, a period consisting in a reduction in the volume of training before a competition whose aim is to optimize performance on the D-day. Indeed, this period of sharpening causes different adaptations: increase in strength and power, possibly due to changes in contractile properties in muscle fibers; repair of tissue damage; recharging of energy stores of glycogen (Klissouras, 2017).

In view of the scarcity of studies which have objective this hypothesis among judoists, we considered it important and necessary to undertake this work in Congo-Brazzaville to test this hypothesis. Indeed, in Congo where judo is now the fifth most practiced sport with 6 participations in the Olympic Games (FECOJU, 2018), RWL by increasing judo activity is the most common technique. In view of the constant deterioration of living conditions and the ever-increasing poverty of the social strata from which the majority of judoists come (PNUD, 2018; WHO, 2018), this practice can only accentuate this negative impact. In addition, to our knowledge, no study has shown the effects of RWL on judo performance assessed by a field test. To this end, the purpose of the present investigation was to test the hypothesis of Paillard (2010), with the following objectives: identify weight loss practices beyond the increased energy expenditure associated with the intensive practice of judo; estimate and analyze the energy expenditure of Congolese judoists during a judo session during a period of 5 1/2 days of intensive judo training for a weight loss of about 5%; determine and examine the associated physiological and haematological responses, depending on the weight category.

2. Materials and Methods

2.1. Participants

A total of 21 male judoists (black belt, degree: 1^{st} dan to 3^{rd} dan) volunteered to take part in this observational and experimental study. Aged 19 to 26 years (mean age: 22.3 ± 1.5 years), they belonged to the −66 kg (n = 10), −90 kg (n = 7) and +100 kg (n = 4) weight categories; they wanted to move to the next lower weight category: −60 kg, −81 kg and −100 kg. These judoists were competitors accustomed to performing rapid weight losses such as the one used in this study. Only any judoist was included in this work: no smoker; no having consumed alcohol in the last 24 hours before the experiment; without cardiorespiratory and haematological pathology; familiar with the practice of rapid weight loss; no having a competitive deadline close to the protocol followed for the study so as not to interfere with his athletic performance. The anthropometric characteristics of the subjects before the implementation of the program are shown in **Table 1**.

The study was approved by the National Commission of Ethics for Research in Health Sciences (CNERSSA) of the General Delegation of Scientific and Technological Research, Ministry of Scientific Research and Technological Innovation of Congo Brazzaville. The protocols applied during this experiment complied with the Declaration of Helsinki II. All participants signed a written consent form.

2.2. Study Design

The study took place in February 2020 in a modern gymnasium including a dojo (judo room). The body mass loss objective set at 4% - 5.5% in these 5 1/2 day works, corresponded to the average objective set by judoists practicing a state of dehydration in the studies by Yang et al. (2017), Brito et al. (2012). During this period, those subjects wishing to change weight class were asked to adopt their individual weight loss methods. During this period selected for the intensive program of judo practice, the training volume was 11 sessions (S_1, S_2, …, S_{11}) at a rate of 3 hours in the morning (9 a.m. - 12 p.m.) and 2 hours in the afternoon (3 p.m. - 5 p.m.), for a total of 28 hours, Monday to Saturday morning. A session was made up of 3 parts: warm-up + physical preparation (general and specific), technical-tactical training and successive randoris (fights), recovery + debriefing.

Table 1. Anthropometric data of subjects before the rapid weight loss program.

	All group (n = 21)	−66 kg (n = 10)	−90 kg (n = 7)	+100 kg (n = 4)
Age (years)	22.3 ± 1.5	20.5 ± 0.8	21.7 ± 2.1	24.7 ± 1.6
Height (cm)	175.68 ± 1.86	173.41 ± 2.05	175.23 ± 1.41	178.41 ± 2.12
Weight (kg)	82.23 ± 1.86	62.01 ± 0.14	81.35 ± 1.06	102.58 ± 0.37
BMI (kg/m^2)	26.79 ± 0.48	21.00 ± 0.03	26.58 ± 1.04	32.78 ± 0.36

BMI: Body mass index.

The physical preparation began with 5 minutes of cardiovascular activation exercises, followed by a joint and muscle warm-up (10 minutes), a specific judo warm-up (10 minutes) and specific judo weight-training exercises (20 minutes). The technical-tactical training, meanwhile, was based on: uchi-komi (duration: 20 - 25 minutes), tandoku-reiku; ne-waza (ground work). As for the fights whose number varied from 5 to 7 per judoist with various partners, their duration was in accordance with the recommendations of the International Judo Federation (IFJ) and their intensity was around 80% - 95% of the HR_{max}. Recovery consisted of muscle and cardiorespiratory relaxation exercises, as well as meditation exercises based on Zen Buddhism. On the first day of the experiment, height and body mass measurements were taken 45 min before the S_1 session, followed by the heart rate at rest (HR_0). Subsequently, haematological and HR measurements were taken at the end of the technical-tactical period, precisely after the phase of judo fights. The same procedure was followed during session S_{11}. Regarding the parameters of interest associated with the performance mortice, the subjects were subjected to the test of Almansba et al. (2007) for the determination of the quantity and the quality of execution of a technical judo gesture.

2.3. Anthropometric Measurements

Body mass was measured to the nearest 100 g using an electronic balance (Omron Health Care), with the subjects wearing only shirts without shoes. Standing height was measured to the nearest 0.1 cm using a stadiometer (Seca Instruments Ltd, Hamburg, Germany). Body mass index (BMI) was calculated using the formula: Weight (kg)/[Height (m)]^2.

2.4. Physiological Measurements

They boiled down to heart rate (HR). A polar Pro Team dock (Polar Electro OY, Finland) was used to record heart rate. Apart from its collection during sessions S_1 and S_{11}, it was also recorded after the warm-up.

2.5. Blood Collection and Analyses

Blood samples were assessed pre-sequence S_1 and immediately after S_1, as well as immediately after S_5 and S_{11} sequences. On the day of sequence, the judoists arrived at the place of experimentation after an overweight fast between 10:00-12:00. A resting blood sample was taken after the subjects had been standing for at least 15 min, after which the participants consumed a light standardized meal and drink at rest for 2 h. The meal consisted of 1.7 g white bread and 0.3 g of a low-fast spread; both values are per kilogram of body mass (Redman et al., 2007). Consumption of coffee, tea, alcohol and other beverages containing coffeine 3 h before testing was not permitted. In addition, all subjects did not perform any exercise for the last 72 h. Venous blood was sampled from an elbow vein into sodium-heparin tubes (BD Vacutainer, USA) to measure basal blood parameters included: red blood cell concentration (RBC), hemoglobin concentration (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC) and were measured using an automated analyzer (MS9-Melet Shoesing Laboratories, Osny, France) according the manufacturer's protocol. Changes in Hb concentration and Hct levels were used to calculate in plasma volume changes (ΔPV) according to Dill and Costill's (1974) formula:

$$\%\ \Delta PV = 100 \times \left[Hb_0 / Hb_1 \times \left(1 - Hct_1 \times 10^{-2}\right) \Big/ \left(1 - Hct_0 \times 10^{-2}\right) \right] - 100$$

where 0 refers to resting values (before the period of judo fights) for Hct and Hb, and 1 refers to the subsequent values for Hct and Hb after the period of judo fights.

Capillary blood was additionally sampled from the earlobe at rest, and after S_1 and S_{11} sequences into heparinized capillaries (EKF Diagnostics GmbH, Germany) to measure lactate concentration by an enzymatic-amperometric sensor chip system (Biosen S-line, EKF diagnostic sales, GmbH, Germany).

2.6. Physical Fitness

Energy expenditure during a judo session was evaluated from the heart rate (HR) recorded at the end of each session. It was measured using a telemetry device (Polar Pro Team dock), with continuous recording. We have used the highest and lowest HR during each phase of training in order to quantify the level of cardiac demand of each. The Almansba et al. (2007) fitness test to which the subjects were subjected, is a field test that takes place over 6 bearings. It has 3 phases: isometric phase, shuttle phase, and recovery phase as shown in **Table 2**.

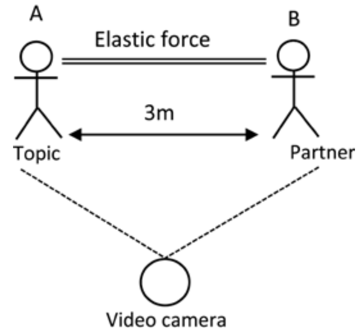
During the isometric phase, the judoist exerts a pulling force on a jacket of a judogi attached to a rubber band with a resistance of 50 kg. The goal of each subject during the test is to perform as many uchi-komi as possible while maintaining the highest possible quality of execution. **Figure 1** illustrates the installation of the required equipment within the test site for the conduct of the test.

Points A (partner) and B (marker on the ground) are located 3 meters apart, between which the subject goes back and forth for the dynamic phase. During the test, for each of the six bearings are recorded: the number of uchi-komi performed, and the height H (in cm) at which uke's center of gravity (who undergoes the movement) is located, determined from a video analysis (JVC GC-PX10 HD camera) as the difference H between the maximum height h_1 and the initial height h_0 of the center of gravity. For this, luminescent pellets have been placed on the judogi jackets to materialize the position of the center of gravity.

Table 2. Protocol of the performance test of Almansba et al.

	Bearing 1	Bearing 2	Bearing 3	Bearing 4	Bearing 5	Bearing 6
Isometric phase	3"	6"	9"	12"	15"	18"
Shuttle phase	20"	20"	20"	20"	20"	20"
Recovery phase	4"	6"	8"	10"	12"	

Source: Almansba et al. (2007).



Source: Almansba et al. (2007).

Figure 1. Performance test hardware installation.

Thus, the Almansba test made it possible to determine the number of uchi-komi with projection performed by Tori (globally and by level) and the height of the center of gravity of the projected partner (uke) at the end of each level (thus translating Tori's fatigue). The measures of these performance indicators were taken before the blood samples collection: 1) during sessions S_1 and S_{11} according to the weight categories and the level for the uchi-komi; 2) bearings 1 to 11, and sessions 1 and 11 for the height of the center of gravity of uke.

2.7. Statistical Analysis

All anthropometric and haematological variables (RBC, MCH, MHCH, Hb, Hct, ΔVP) of the study were assessed at the start of the program, at the end of the technical-tactical and period of each serie of fights, second set and third set, as well as between sessions 1 and 11. Regarding the variables associated with performance in the test of Almansba et al., they were: heart rate; number of uchi-komi performed at each level; height of the center of gravity at each session. A few parameters were evaluated in the judoists according to their profile. Data are expressed either as frequencies and percentages, or as mean ± SD. The normality of the data distribution was verified using the Shapiro-Wilk test. The comparison of two means used Student's t test; In the event of normality, the Wilcoxon test was applied. Spiegel's test was used to compare two percentages. The data were analyzed using an Anova (time × group) to compare the end-of-effort HR values, from the warm-up period to the fighting phase through the period of physical preparation. On the other hand, it was the end of sessions S_1, S_5 and S_{11} for 3 performance indicators of Almansba and al., and haematological parameters. If statistically significant, Tukey's post hoc test was used to locate the level of difference. Sokal and Rohlf (1995) was used to compare 3 percentages. $p < 0.05$ was used as the statistical significance level.

3. Results

3.1. Weight Data and Weight Loss Practices

Among the 21 subjects selected, only 16 of them lost a weight between 4% - 5.5% (**Table 3**). These were 7 subjects who were in the −66 kg to −60 kg category (i.e.

Table 3. Weight variations of subjects included in the study.

Subject	From −66 to −60 kg		From −90 to −81 kg		From +100 to −100 kg	
	Pi (kg)	Pf (kg)	Pi (kg)	Pf (kg)	Pi (kg)	Pf (kg)
1	61.5	58.6	82.3	78.7	103.5	98.1
2	62.7	59.5	81.7	77.6	103.1	97.7
3	62.3	59.8	82.5	78.2	102.6	97.4
4	61.8	58.5	82.2	78.7	101.9	97.6
5	62.1	59.2	81.8	77.5	---	---
6	61.7	58.1	---	---	---	---
7	62.2	59.2	---	---	---	---
Mean (kg)	62.0	59.0	82.1	78.3	102.7	97.7
SD (kg)		0.6		0.6		0.3
ΔP (kg)		3.1		3.9		5.2
ΔP (%)		4.9		4.8		5.0

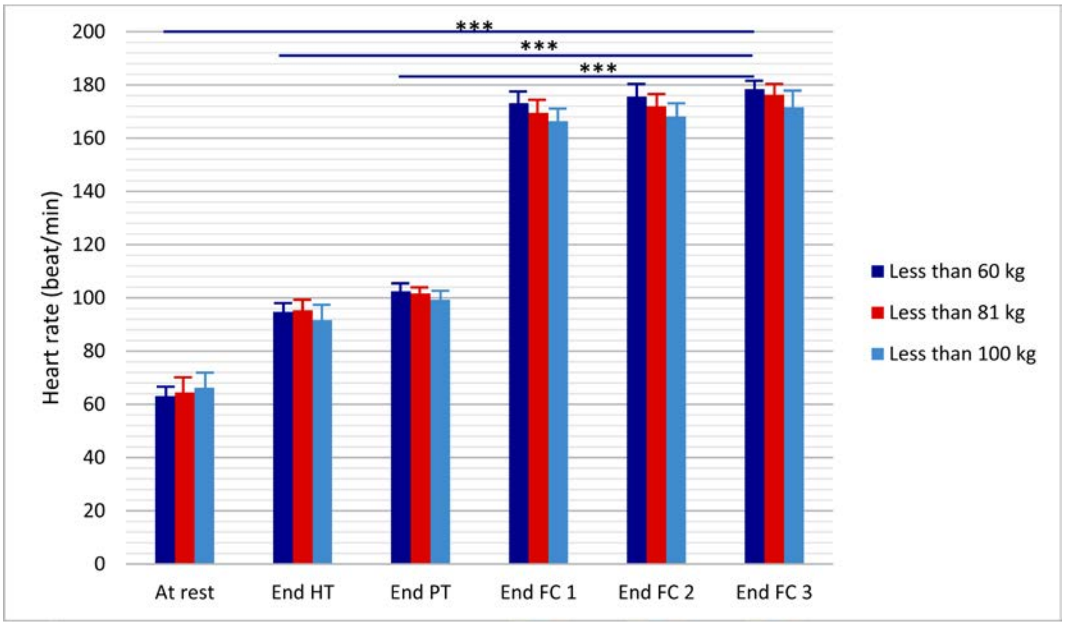
Abbreviations: Pi, initial weight before the weight loss program; Pf, final weight at the end of the program; ΔP, weight variation induced by the program; SD, standard deviation

70% of cases), 5 subjects in the −90 kg to −81 kg category (7.4% of cases) and 4 out of four subjects from +100 kg to −100 kg category (100% of cases). The mean weight loss was 3.1 kg in the −60 kg category (range: 2.5 kg - 3.6 kg); it was 4.0 kg in subjects weighing less than 81 kg (range: 3.5 - 4.3 kg), and 5.2 kg for less than 100 kg (range: 4.3 - 6 kg). Among the weight loss practices combined with increased energy expenditure in judo, the data collected from interviews with the judoists revealed, in decreasing order of importance: restriction of food intake, 61% of quotes; drastic restriction of specific intakes, 35%; restriction of water intake, 20% for an average intake of 0.5 L during the program; the increase in energy expenditure combined with the practice of long jogging, 17%; laxatives and diuretics, 3%.

3.2. Energetic Cost

Figure 2 illustrates the change in heart rate at the start of the program during the different training sequences within each weight category. The resting HR values were: 63.1 ± 2.4 bpm in the −60 kg judoists, 64.5 ± 2.2 bpm in those under 81 kg and 60.3 ± 1.8 bpm in the less than 100 kg. The energy expenditure requested in the fights decreased between sessions S_1, S_5 and S_{11}; the highest HR_{max} was noted during session S_1: 173.1 ± 10.2 bpm in judoists with −60 kg versus 169.5 ± 13.0 bpm in those weighing -81 kg and 166.4 ± 10.6 bpm for judoists under 100 kg. HR_{max} values after weight loss were higher than those found before the program.

Heart rate varied throughout each training phase. During the warm-up, the highest HRs were between 70% - 90% of the subject's HR_{max}. Throughout the warm-ups, HR was not less than 70% of HR_{max}. During the technical-tactical



Legend: End HT, at the end of the warm-up; End PT, at the end of physical preparation; End FC1, at the end of the first series of fights; End FC2, at the end of the second series of fights; End FC3, at the end of the third series of fights.

Figure 2. Evolution of exercise heart rate in the three weight categories in session 1.

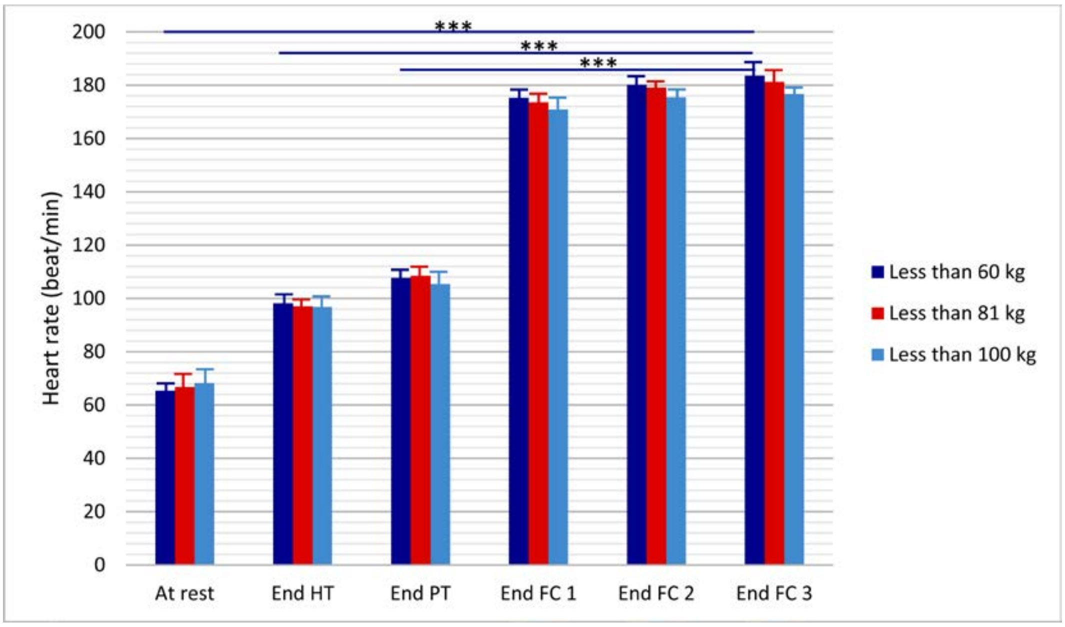
period, the highest HRs were between 80% - 100% of the HR_{max}, the lowest between 80% - 90% of the HR_{max}. Following the judo fights, the HR_{max} were close to the subject's HR_{max}: 180 bpm (98% of HR_{max}). Therefore, the movements undertaken during these confrontations resulted in a cardiac solicitation of 80% to 100% of the HR_{max}; the lowest (60% of HR_{max}) were noted during periods of recovery often linked to the award of numerous penalties (faults) from the partner or the subject himself.

At the end of the 11th session and following the subjects' weight loss, the raw heart rates increased compared to those noted in session S_1 in the new weight categories (**Figure 3**). A significant difference was during the different phases of the training sessions: 66.8 ± 1.8 bpm at rest *vs* 97.4 ± 3.5 bpm at the end of the warm-up *vs* 180.5 ± 4.9 bpm at the end fight [$F(2, 18) = 1656.93$; $p < 0.001$]. High HR values were found in subjects less than 60 kg, followed by those noted in subjects less than 81 kg.

3.3. Motor Performance

The difference in the number of uchi-komi performed by subjects for all weight categories was significant for four of the 6 bearings, from third bearing, respectively: $p = 0.035$, $p = 0.011$, $p = 0.007$ (**Figure 4**). The highest number of uchi-komi was found before the implementation of the program. Corollarly, the total number of uchi-komi achieved by all subjects was noted at the start of the intensive judo program combined with weight loss.

The same was true for the change in the average height H at which uke's center of gravity was located during the execution of the movement (**Figure 5**). The



Legend: End HT, at the end of the warm-up; End PT, at the end of physical preparation; End FC1, at the end of the first series of fights; End FC2, at the end of the second round of fights; End FC3, at the end of the third series of fights.

Figure 3. Evolution of exercise heart rate in the three weight categories in session 11.

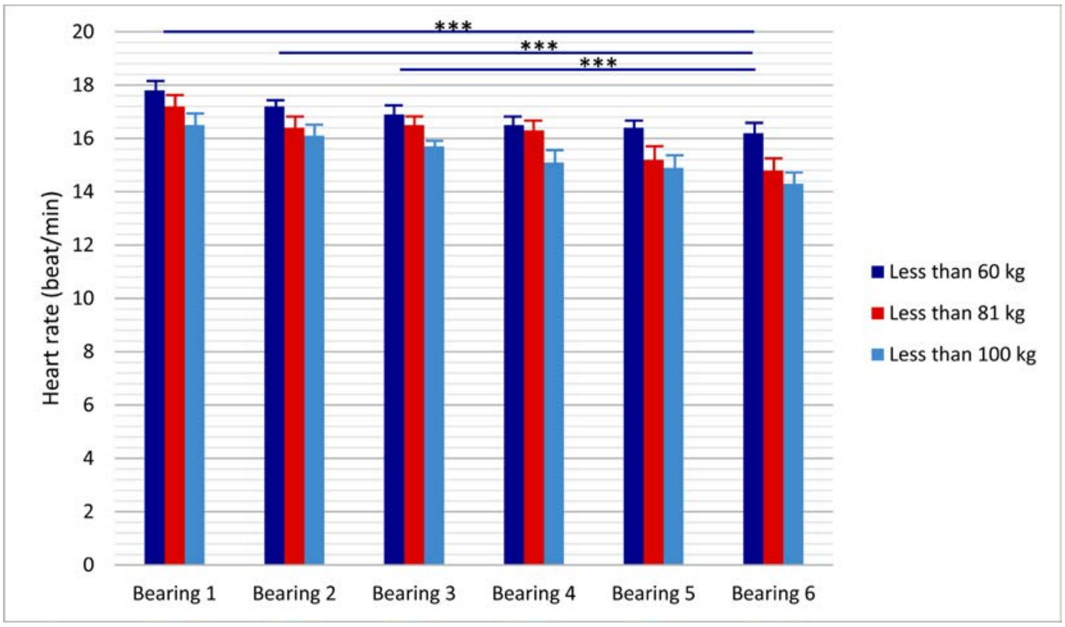


Figure 4. Evolution of the average number of uchi-komi per bearing in all subjects during the program.

difference between the mean heights for each bearing, recorded in the sessions 1 and 11, was significant, from bearing 1 to the eleventh session: $p = 0.041$ from bearing 1 to bearing 4, $p = 0.023$ from bearing 1 to bearing 5 and $p = 0.007$ from bearing 1 to bearing 6.

3.4. Evolution of Haematological Values

The evolution of basal blood parameters is presented in **Table 4**. The hematocrit

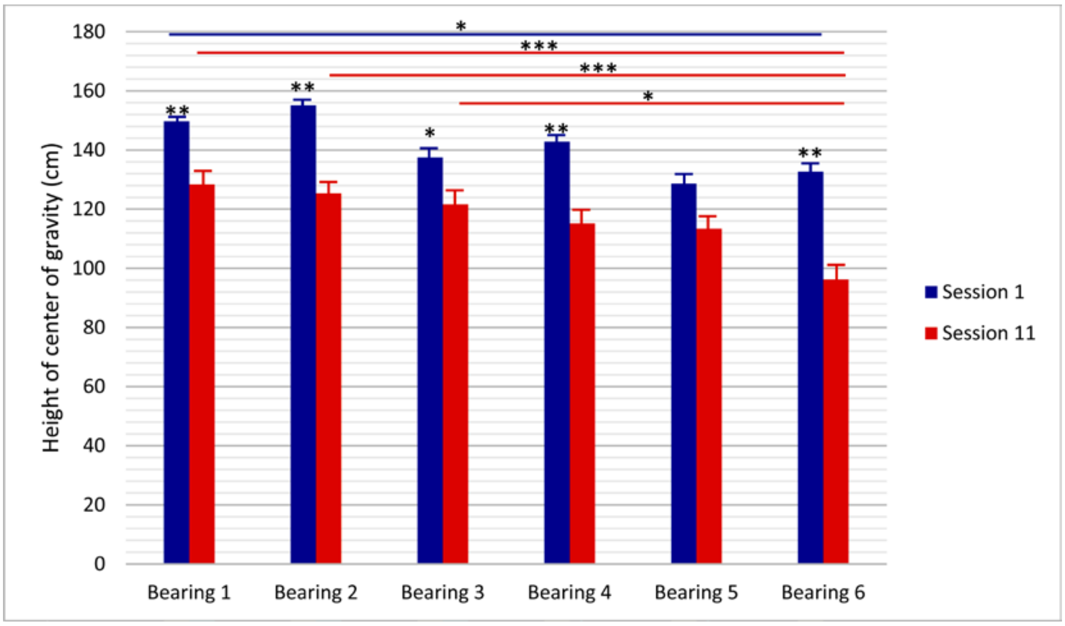


Figure 5. Evolution of the height H of the center of gravity in bearings in the 3 weight categories during the program.

Table 4. Haematological and biochemical data of all subjects.

	Before RWL (n = 16)	After JFS_1 (n = 16)	After JFS_{11} (n = 16)	*P*
RBC ($*10^6$/µL)	5.84 ± 0.35	5.35 ± 0.23	5.22 ± 0.16	<0.001
Hb (g/dL)	17.91 ± 0.82	15.92 ± 0.57	15.28 ± 0.74	NS
Hct (%)	49.74 ± 1.64	47.26 ± 1.34	43.52 ± 2.06	<0.001
ΔVP (%)	100	118.05 ± 5.20	131.48 ± 3.70	<0.05
MCV (fl)	84.92 ± 2.73	85.37 ± 2.81	85.70 ± 3.15	NS
MCH (pg)	30.38 ± 1.65	29.52 ± 1.76	30.16 ± 1.83	NS
MCHC (g/dL)	35.66 ± 1.08	34.64 ± 0.95	35.22 ± 1.60	NS
Peak [La] (mmol/L	1.73 ± 0.12	9.61 ± 0.74	8.32 ± 2.54	NS

Abbreviations: JFS, judo fight sequence; RBC, red blood cell, Hb, hemoglobin; Hct, hematocrit; PV, plasma volume; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; Peak [La], highest lactate concentration; RWL, rapid weight loss.

concentration was significantly lower at the 11^{th} judo fight sequence compared at rest before rapid weight loss ($p < 0.001$), but a significant difference was found compared to values of 5^{th} sequence. We also note a significant variation in plasma volume after the bouts of session 11 in the direction of hemodilution ($p < 0.05$). Other basal blood parameters were not affected by the intervention if we compared our values between JFS_1 to JFS_{11}.

4. Discussion

To our knowledge, the effects of rapid weight loss on judo-energy profile, specific performance and haematological parameters in Subsaharan African environment has been not investigated so far. The major findings of our study indicate that RWL increases heart rate during fights, decreases motor performance in judo (number of uchi-komi executed during a field event, body placement) and haematological values compared to baseline values. Weight loss practices are at the heart of the judo practice in competition, the proportion of fighters having regular recourse to them being very important (Artioli et al., 2010). Rapid weight loss, that is to say carried out in less than 10 days, is also significant (Franchini et al., 2012). There are many methods which are identified by Brito et al. (2012) and are not always in agreement with the search for optimal performance. In our study, one of the methods identified is the restriction of food intake (61% of respondents during the interviews). Among the other methods cited, we find the drastic restriction of nutritional intake (35% of respondents), or even total the last days of weight loss; this suggests an exhaustion of energy reserves. Thus, the increase in energy expenditure (17%) during training sessions, associated with the practice of long joggings, goes completely against the sharpening process (reduction in training volume, maintenance or increase in intensity with the aim of improving performance) which is sought after in the pre-competitive period. Finally, the methods dictated by a restriction of water intake (20% of our respondents) coupled with a search for excessive sweating (5% of citations) can lead, if they are practiced excessively, to a state of dehydration, obviously bad for performance. In fact, some responses, which are very much in the minority, report long and/or almost total restriction with a mass loss objective well above 2%, which beyond the risk of performance, represents generally a health risk (Artioli et al., 2016).

Regarding the energy expenditure during the different phases of a training session and evaluated using the HR_{max} reached, our results show that the anaerobic energy expenditure and cardiac solicitation in real judo practice situations are important throughout weight loss. Our results in judoists subjected to combined training with a RWL show at the end of the warm-up average values of 117 ± 10 bpm, with range of 97 bpm - 123 bpm (**Figure 2**). The interest of the telemetric study of the HR in the evaluation of energy expenditure during training in combat sports is underlined by several studies (Guillerme, 2014; Francescato et al., 1995; Majean et al., 1990). Among the studies that we found in the literature concerning judoists, Ahmaidi et al. (2005) report a mean frequency of 150 ± 10 bpm during the warm-up phase, a value higher than that found by Selinger (2014) 143 bpm for HR between 132 - 151 bpm without specifying the level of the judoists, their physical condition, the conditions and the level of stake. At the end of the judo fights, the HR_{max} recorded in our study were 180.5 ± 4.9 bpm at session S_{11} against 171.4 ± 5.2 bpm at session S_1 (i.e. a difference of 5%; $p < 0.05$, **Figure 3**). In the only study that we identified in the literature in combat sports athletes subjected to RWL, that of Yang et al. (2018) devoted to taekwondo, the authors note at the end of the series of fights (5 fights per series and a number of 3 series) values of: 179.6 ± 10.9 bpm at the end of the first series (maximum: 193.3 ± 8.3 bpm), 176.8 ± 8.7 bpm in the second set (maximum: 188.6 ± 5.4 bpm) and 185.8 ± 3.2 bpm in the third set (maximum: 196.2 ± 5.0 bpm); i.e. a variation of 4.8%. Ahmaidi et al. (2015), in judoists not subjected to a RWL report at the end of 3 min of fight for 3 series (each including 3 fights) of HR_{max} of: 125 ± 9 bpm for series 1, 161 ± 10 bpm for series 2 and 163 ± 8 bpm for series 3; i.e. a mean increase of 23%.

Regarding the number of uchi-komi before and after RWL during the sessions (**Figure 4**), it decreased significantly. For Almansba et al. (2007), uchi-komi number is the main variable determining test performance. Also, quantity is inseparable from quality. And we also observe that the height H to which uke's center of gravity is raised, which can be considered as representative on the one hand of the quality of technical execution, but also on the other hand of the general anaerobic alactic power of each technical repetition also decreases significantly at the end of the test (**Figure 5**). The gradual and significant decrease in the number of uchi-komi performed by Tori and the height of Uke's center of gravity, from session 1 to session 11, therefore suggests a deterioration in muscle strength due to a greater level of physical fatigue. As a result of dehydration, therefore a weight loss. This difference could be explained by the fact that for high intensity activity during the performance test lasting 30 minutes 40, the body mainly uses the process of anaerobic glycolysis. This system uses water to help synthesize energy, to resynthesize pyruvate into glucose. Water is used by the aerobic system to perform the same role. An organism with limited water may decrease the ability of anaerobic, lactic and aerobic glycolytic processes to produce energy, and thus negatively affect performance (Carlton & Orr, 2015). Our results, which thus show, as in taekwondo, an alteration in the processes of the metabolic systems, undoubtedly reflect the decrease in the intensity of movements including the times of rest and stops of the performed movements (Santos et al., 2011; Bridge et al., 2013; Hausen et al., 2017). Our observations strongly agree with the fact that the aerobic system is used during long-duration moderate intensity movements, while the lactic anaerobic system is less required (Mader, 2003). Similar results are reported by Marcon et al. (2010) in judo which show that the aerobic system is used frequently (66%) during fights. However, only the evaluation of fat and muscle mass throughout the program can make it possible to objectify these statements, even if it is reported that the more intense the calorie restriction, the greater the loss of muscle mass in the loss of body mass (Leibel et al., 1995). As muscle atrophy results in a significant loss of contractile proteins (Horswill et al., 1990), muscle strength decreases (Walberg et al., 1988) consequently in proportion to this loss (Narici et al., 1989).

As for the haematological parameters, these give some indication of body dehydration status. For example, MCHC significantly describes the cellular viscosity of blood within RBC (Bull et al., 1996), and the increase in hematocrit reflects the negative influence of blood viscosity. In our study, the alteration of these parameters (**Table 4**) is associated with the reduction in motor performance because the increase in viscosity reduces peripheral blood flow and cardiac output (Connes et al., 2013; Brun et al., 2012; Mcardle et al., 2010). The increase in hematocrit in athletes, especially in our judoists, may be due to the extensive loss of body water during intensive training and water restrictions (Brun et al., 2000). Concerning the significant increase (13.4%) of plasma volume changes, our observations join those of Vaccaro et al. (1976) through the physiological alterations that can induce a loss of water greater than 4% of the body mass, which lead to significant changes in physical ability. However, they are contrary to those of other authors who observe hemoconcentration and for whom body water loss > 3% body mass does not affect plasma volume (Yang et al., 2017; Francesconi et al., 1987; Armstrong et al., 1998). The discrepancy between our results and those of the literature is mainly explained by the protocol and the nutritional disorders linked to the poor living conditions of most of our subjects. Regarding the protocol for example, in our study the subjects are judoists who performed, in addition to physical preparation exercises and technical-tactical training, 30 to 50 fights of 3 - 5 minutes each and divided into 5 1/2 days. On the other hand, the subjects of Yang et al. (2018) are taekwondo athletes and the duration of RWL is 3 1/2 days. Blood samples were taken after the series of fights in sessions 1 and 11 in our work, while they were taken 16 hours after competition day in Yang's study. In this case, athletes recovered their body water and carbohydrates storage. In addition, the time between each serie of fights taekwondo bouts was 1 hour compared to 5 minutes for us, the duration of a fight being 2 minutes *versus* 3 - 5 minutes in our study. The hypervolemia observed in our work can then be explained by an increase in the level of intravascular water probably due to retention of both proteins and electrolytes under hormonal control. Indeed, after endurance exercises such as those implemented in our training schedule, the intravascular protein mass increases, thereby inducing hypervolemia. The mechanism responsible for the content is not yet entirely clear. However, when the total protein concentration increases by food manipulation for 4 days, the plasma volume does not change (Leiper et al., 1988). This implies that proteins are not the only ones responsible for the expansion of plasma volume.

In addition, during physical exertion, changes in renal perfusion and hormonal variations promote fluid retention. Thus, the increase in plasma volume and that of extravascular fluids is favored by limiting fluid loss: 1) through redistribution of blood in favor of the working muscles; 2) thanks to the activation of the renin-angiotensin-aldosterone system (Milledge et al., 1982; Makni Krichen et al., 2009) which induces a retention of Na^+, and thereby a displacement of fluids towards the circulation (Leiper et al., 1988); 3) by stimulating the hormones responsible for the hydroelectric balance (ADH, FAN, aldosterone, renin); 4) and also through metabolic water production through the oxidation of fatty acids and carbohydrates and the release of water from glucose stored in muscle and liver (Pastene et al., 1996).

Our results show also that the hematocrit was higher at the end of session S_1 compared to session S_{11} (**Table 4**). Hematocrit is affected by a variety of factors including hydration status and the above-mentioned mechanisms, which could exert an influence on values. Besides MCH, MCHC and hematocrit, other blood values were also no affected by the intervention. In regard of RBC deformability, MCV is of special interest. A decrease in RBC might be caused by food restriction during RWL.

Numerous studies associated a reduction in RBC to decrease in blood glucose and thus reduced a reduced ATP level (Henkelman et al., 2010; Grau et al., 2013). A study of Yang et al. (2015) indicated that food restriction and reduced glucose levels reduce nitric oxide production in RBC which in turn reduces RBC deformability. It remains to be investigated whether RWL facilitates oxidative/nitrosative stress which was show to reduce RBC. Finally, our results show a significant increase in lactatemia from the first to the eleventh session, S_1 - S_{11} (**Table 4**). The predominance of the anaerobic lactic component during training sessions is thus verified by the high concentrations of blood lactates, exceeding 10 mmol/L. The higher values are for judoists less than 100 kg. These observations are in line with field analyzes by Chance et al. (1987) which show that enduring judoists possess superior aerobic qualities, underlining once that the resynthesis of phosphocreatine (PC) is linked to the oxidative metabolism. On the other hand, there is a more significant intervention of anaerobic glycolysis during the transitional phase of adaptation to each workload in judoists with an explosive profile. These have a less efficient mitochondrial system, the resynthesis of PC is slower; this does not allow them to maintain high power for long, from where they usually win their fights at the onset of assaults.

Thus, analysis of our results leads us to draw some recommendations for judo competitors and coaches as part of an overall sports preparation. Indeed, our results show that judoists are not recommended to cut weight before competitions. Before a judoist decides alone or in agreement with his trainer to undertake a rapid weight loss regimen to change weight category, it is advisable to seek the advice of a doctor and a dietitian in order to study the feasibility, ins and outs of such a maneuver. In all cases, it is better to favor gradual or progressive loss over emergency or rapid loss through dehydration, so as not to lose 1 kg/week to limit the loss of muscle strength. If the quick method is being considered, you should avoid losing more than 4% of your body mass. To do this, from a nutritional point of view, the judoist must eat in the following caloric proportions: 60% to 65% carbohydrates; 15% to 20% proteins; 20% lipids, to curb the inevitable involutions of body composition and motor performance. An intake of 4 g/kg/d of carbohydrates is necessary. The lipid intake should not be lowered below 20%, because essential fatty acids remain essential for the proper functioning of the body and therefore for health. Hence, it is imperative to have the nutritional value of the main foods commonly consumed in the Congo. After the weigh-in, a carbohydrate load (i.e., meal containing 200 - 300 g of CHO) is recommended. In terms of training, the final preparation of the judoist (last month) must respect the general principle of training by reducing the content of the session, and therefore their duration. If an endurance activity must be undertaken for the purpose of weight loss, certain principles should be observed: sessions should not exceed 30 minutes, and small accelerations at the end of the session are advisable. For example, in the last 10 days of the diet, two short training sessions (30 to 40 min) are done twice a day or are combined with one long session (1 1/2 to 2 hours) of judo training. Depending on the state of fatigue, a single session may be sufficient (especially for rapid weight loss). Despite the slight impact on physical capacity, rapid weight loss has negative effects on several health parameters. In addition, competitive performance may be impaired, since other factors (e.g., mood profile and cognition) associated with competitive performance (no objective in this study) are impaired. In sum, RWL should especially be avoided if the judoist will knowingly have less than 3 hours to refeed and rehydrate after the weigh-in. Indeed, if the dehydration is greater than 4% of the body mass and if the time between weighing and the start of the competition is less than 5 hours, the athlete's physical capacities are in all cases altered, even if in the meantime a fluid intake more than covered the loss. Therefore, only relevant weight loss strategies can maintain the performance capabilities of the judoist. On the other hand, the transgression of certain principles such as those mentioned above is enough to alter these performance capacities and (or) his health.

However, it is important to note some limitations of this study. The first limitation is the assessment of energy expenditure. It would have been desirable to separately determine the aerobic, anaerobic lactic and anaerobic alactic systems by the consumption of O_2 during a session, combined with measurements of maximum lactate concentration and the fast of excess oxygen uptake after exercise (EPOCFAST), as suggested by a recent study of Yang et al. (2018). However, the implementation of these methods is proving difficult in the context of the poor technical facilities of our biological analysis laboratories. A second limitation is related to the fact that the magnitude of the performance deleteriousness of the subsequent water loss to the rapid weight loss could be minimized by the fact that the performance test used in this work is not perfectly representative of competition in judo. Indeed, it representatively simulates a judo fight, in an isolated way. However, performance in competition requires a series of combats to achieve a ranking. In this case, the very significant decrease in performance at the end of session 11 is accentuated if the test consisted of a sequence of fights. It would therefore have been desirable to set up a protocol that is truly representative of a competition. For example, a protocol requiring the performance test used here to be completed 6 times, each test performed being separated by a 20 to 30 minutes rest period, as is the case in official competitions. Therefore, it can be suggested that rapid weight loss is even more deleterious to competition performance than the results would suggest. The third limitation is inaccuracies of measurement which might also explain the high hematocrit results and might thus represent a possible limitation of the study. Finally, the fourth limitation of our study relates to information on rapid weight loss practices used by our subjects who relied only on their statements, without rigorous verification; this does not authorize the generalization of the conclusions obtained to the entire population of Congolese competitive judoists.

It is suggested that future investigations on judo RWL effects who must take these limits into account verify if repeat RWLs of structured training protocols and includes sparring fights and official fights, lead to different results in the season.

5. Conclusion

Our results suggest that RWL in judo at about 4% - 5.5% of body mass has a negative effect on the body, even if a period is allowed for rehydration; each variable determining performance having varied negatively. For this, it is necessary to favor longer and progressive weight losses, so as not to associate the possible negative consequences, and not to disrupt the training process. It would also be interesting to respond to the problem represented by the general ignorance of competitive judoists and coaches, especially in black African circles, in terms of nutrition by making them aware of the importance of this aspect for sporting performance. It is in this context that to protect judoists health situation, African Judo Federations through the African Judo Union, particularly Congolese Judo Federation should be considered a random control of body weight in the morning of the competition day to ensure no discrepancy of body weight between weigh-in and competition day.

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Author's Contribution

Study concept and design: MOULONGO JGA and MASSAMBA A; Acquisition of data: MOUSSOUAMI SI, MOUSSOKI JM, MASSALA KITANGA FN, and MOULONGO NGWALLAT JAP; Methodology: MASSAMBA A and PACKA TCHISSAMBOU B; Investigation: MOULONGO JGA, BUESO NZAMBI GA, ATA ASIOKARAH NF, and DIAGNE OSSEY M; Analysis and interpretation of data: MASSAMBA A, MOULONGO JGA, and PACKA TCHISSAMBOU B; Drafting of manuscript: all authors; Critical revision of the manuscript: all authors; Statistical analysis: MASSAMBA A; Administrative, technical, and material support: MOULONGO JGA, MASSAMBA A, ATA ASIOKARAH NF, and MASSALA KITANGA NF; Study supervision: MASSAMBA A.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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