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Review

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A scoping review of rapid weight loss in judo athletes: prevalence, magnitude, effects on performance, risks, and recommendations

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[Purpose] Combat sports, such as judo, are weight categorized. Weight control was established to promote fair disputes among individuals. However, combat sports athletes adopt rapid weight loss (RWL) to obtain an advantage over smaller and lighter opponents. This scoping review article presents the prevalence, magnitude, and methods of RWL and its effects on physical and competitive performance, health risks, and psychological effects. Specific recommendations for attenuating the effects of RWL are also presented.

[Methods] Studies were retrieved from Web of Science, PubMed, and Scopus databases. Four hundred and forty-six articles were identified, of which fifty-three were considered eligible for this review.

[Results] The results showed that the prevalence of RWL was between 40% and 92.9% and that athletes reduced their body mass by approximately 5%. Although the literature suggests that RWL impairs the performance and psychological well-being of athletes, these results were obtained when recovery time was not provided.

[Conclusion] No negative effects on performance were observed when the recovery time was >4 h. However, health risks due to RWL practices should be considered, and RWL should be avoided.

[Keywords] weight cutting, martial arts, combat sports, health

INTRODUCTION

In judo, athletes are separated into weight categories to avoid discrepancies in size and strength between opponents and create a more balanced and fairer dispute. The athletes' body mass is measured before the competition to ensure that they are within the lower and upper limits of their weight category. However, athletes often reduce their body mass prior competitions to gain an advantage over potentially smaller and weaker opponents[1,2]. This process is often referred to as rapid weight loss (RWL) and is characterized by a reduction in body mass, usually one week before the competition[3]. This reduction is typically in the range of 2–10% of the body mass of the athlete (even though larger reductions have been reported), with most it achieved in the last 2–3 days prior to weigh-in[4]. The methods frequently used during this process include food and fluid restriction, increased exercise, exercising while wearing plastic suits, use of laxatives, vomiting, and saunas[2,5,6].

Adoption of the RWL methods can result in lethal outcomes. In 1996, a South Korean judo athlete died owing to methods used for RWL. That year, he was a strong candidate to win an Olympic medal in the ≤65 kg weight category, while presenting approximately 74 kg in the days before his death[7]. Currently, evidence of the negative effects of RWL on combat sports performance exist[3,7]. Despite this, a recent systematic review concluded that combat sports athletes frequently engage in RWL of a magnitude similar to of judo athlete who died[8]. In addition, combat sports athletes view RWL as a practice of mental toughness that provides competitive success[9].

However, whether athletes who adopt RWL obtain advantages in matches and whether this process is associated with good performance remains unclear. Despite these controversial results, evidence indicates that RWL impairs both aerobic and anaerobic performances[1]. Given the intermittent nature of judo, both aerobic and anaerobic pathways are important for competition success[10]. Impaired aerobic performance after RWL can be a consequence of dehydration, lower plasma volume, and elevated heart rate at a given exercise intensity[11]. Conversely, a decrease

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in anaerobic performance is possibly due to reduced buffering capacity and glycogen depletion[12].

Furthermore, 7 days of food restriction, due to RWL methods, reduced physical and psychological performance in judo athletes compared with an equivalent period of body mass maintenance[13,14]. Conversely, Artioli et al.[2] did not observe any influence of food-restriction-induced RWL on the performance of judo athletes. Fortes et al.[15] investigated the effects of RWL using the Special Judo Fitness Test (SJFT). The results demonstrated that the athletes who adopted RWL did not change their SJFT index, whereas the control group improved this parameter. In addition, the total number of throws in the SJFT in athletes who adopted RWL decreased, whereas an increase was observed in the control group. These studies assessed the maximal isometric handgrip strength[13,14] or used judo-specific tests[2,15]. These controversial results may be associated with methodological heterogeneity in the RWL process (i.e., variation in the methods used to reduce body mass), the interval between the weigh-in and the performance test, including recovery interventions used during this period, and the test used to assess performance (i.e., physical ability assessed by the test and test specificity regarding judo).

Despite controversial results in terms of physical performance, this practice can affect health[16,17]. Previous studies have reported that RWL increases the probability of contracting infectious disease[16]. Additionally, this process can lead to eating disorders, because the low-energy methods utilized can affect emotional intelligence[17].

Given the use of RWL procedures by judo athletes and the margins for weight regain, further research is needed to better understand this process. In addition, despite recent reviews on this topic[3,7], aspects of eating disorders, emotional well-being, and health risks involved in this process, and recommendations to minimize them can be added. Understanding these factors associated with RWL can provide information for federations and other stakeholders to implement rule changes aimed at safeguarding the health of athletes against adverse events. Therefore, this scoping review aimed to determine the prevalence, magnitude, and effects of RWL on the performance and health of judo athletes and provide recommendations to minimize risks and optimize this process.

METHODS

The review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-analyses Extension for Scoping Reviews (PRISMA-ScR) statement guidelines[18]. The protocol for our review was registered in the International Prospective Register of Systematic Reviews (PROSPERO; Registration No. CRD42021259536). A systematic search of the literature was performed using the PubMed, Web of Science, and Scopus databases through December 2021 to identify original research articles. An update was performed considering the period from January 2022 to January 2024. The following keywords were used in combination: "judo" and "weight loss." The analysis was restricted to original research articles published in peer-reviewed journals (excluding grey literature indexed in non-scientific databases as abstracts of scientific events). Articles published in English or Portuguese were included in this review.

The inclusion and exclusion of articles were determined using the Participants, Intervention, Comparison, Outcomes, and Study Design (PICOS) criteria for the title, abstract, and/or full text of articles (Table 1).

Two authors independently performed searches and abstracting; after which the references were loaded onto the Rayyan platform for selection. After selecting articles on the Rayyan platform, full-text articles were downloaded. In the blind phase on the Rayyan platform (selection by title and abstract) and the full-article phase, 83 (71.5%) and 43 articles (81.1%), respectively, were agreed upon for inclusion in the review. Discrepancies of 28.5% and 18.9% were resolved using the timing of weight loss applied in the study for decision making. Two discussions were conducted to decide article selection: one regarding the selection on the Rayyan platform and the other for the full articles. The data collection process is illustrated in Figure 1.

RESULTS

Four hundred and forty-six articles were identified, including 148 in the Web of Science, 114 in Scopus, and 184 in PubMed. An additional article from another source was also included. After removing duplicates, 291 articles remained. Based on the title and abstract reading, 175 articles

Table 1. PICOS (participants, interventions, comparison, outcomes, and study design).

PICOS components	Detail
Participants	Judo athletes
Interventions	RWL must be achieved up to seven days before the weigh-in. The extent of RWL had to be approximately 3% or higher than the athlete's body mass.
Comparisons	Judo athletes who had reduced body mass rapidly compared with a group that did not do it or, the same athletes in both conditions, within a period of up to seven days before the competition.
Outcomes	Prevalence and magnitude of rapid weight loss; Effects on performance (maximal strength, muscle power, strength-endurance, anaerobic and aerobic performances); Physiological parameters.
Study design	Observational, descriptive, crossover double blind, randomized, and non-randomized studies

RWL: Rapid weight loss

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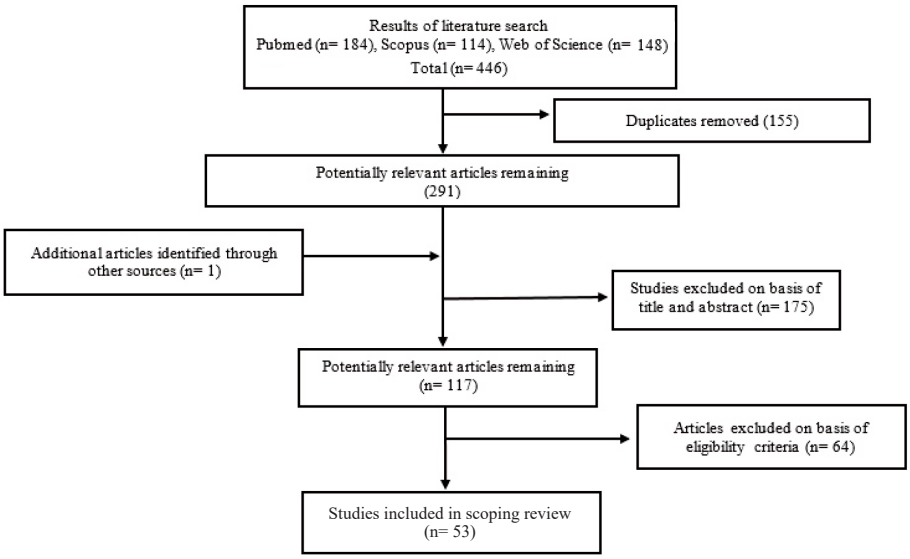

Figure 1. Selection process for research articles included in this scoping review.

were excluded for the following reasons: long duration of weight loss, no involved weight loss, <3% variation in body mass, and several modalities. One hundred and seventeen articles were retrieved for complete reading, of which 53 were considered eligible for this scoping review. Considering the main scope of the included studies, 27 articles investigated the prevalence, magnitude, or procedures due to the RWL, 13 articles examined the effects of RWL on performance, and 13 articles reported risks due to RWL. The collected data are presented in Tables 1–4, including information about the references (authors), sample (size and sex), procedures for weight loss, recovery time between weigh-in and assessment, variables assessed, and the results.

Prevalence, magnitude, and procedures

In general, the literature showed that when heavyweight athletes were excluded from the analysis, the prevalence of RWL was approximately 89%[2,5,19,20]. Brito et al.[21] did not observe significant differences in the prevalence of RWL between competitor levels: regional (59.8%), national (72.9%), and international (40%). Conversely, Malliaropoulos et al.[22] found that male international judo athletes had the highest prevalence of RWL (92.9%) compared to national (78.8%), regional (74.1%), and club-level athletes (58.3%). These conflicting results can be attributed to differences in the number of athletes. Brito et al.[21] reported a lower number of international athletes (only four), whereas Malliaropoulos et al.[22] did not report the total number of international-level judo athletes. When examining prevalence across different weight categories, Malliaropoulos et al.[22] reported no significant differences, particularly when heavyweight athletes were excluded. In the context of sex-based comparisons, Artioli et al.[2] found no statistically significant differences between males (84.1%) and females (84.8%). In contrast, senior athletes had the highest prevalence of RWL (73.5%) followed by junior athletes (53.3%) and cadets (52.2%)[17]. Artioli et al.[2] found a difference between competitors using the Rapid Weight Loss Questionnaire. This score indicated the severity of the RWL process (i.e., the higher the value, the more aggressive and dangerous the RWL process). Notably, state- (25 points), national- (28 points), and international-level (31.5 points) judo competitors obtained higher scores than regional-level (17.5 points) competitors. In addition, international competitors obtained higher scores than state-level competitors.

Athletes frequently reduced approximately 5% (ranging between 3 and more than 10%)[2,20,21,24-26] of their body mass close to the competition (i.e., 3–7 days before the competition)[23,26,27]. Moreover, studies indicated that the use of RWL methods increased closer to the day of the competition[21,28,29]. This suggests that most of the body mass reduction occurred in the days before weigh-in. The most utilized methods in this process were increased physical exercise, food and fluid restrictions (especially carbohydrate restriction), and sauna or plastic clothing[2,21,30-33]. Additionally, more aggressive and dangerous methods were reported (e.g., use of laxatives and diuretics)[21].

Regarding comparisons based on sex, Yoshioka et al.[24] indicated that no differences existed between males (3.4%) and females (4.9%) in terms of the magnitude of body mass reduction. However, Escobar-Molina et al.[17] found that males showed a higher frequency (47.1%) of >5% reduction in body mass than females (27.3%). In the context of age groups, Escobar-Molina et al.[17] observed that senior athletes had a higher frequency (47.1%) of >5% reduction in body mass than cadets (28.3%) and junior athletes (30.0%).

Studies that investigated the magnitude of RWL following the 5% tolerance rule established in 2013 demonstrated that athletes reduced their body mass by 5.8–6.8%[34,35]. Therefore, a longer recovery period between the weigh-in and beginning of the competition and/or the tolerance rule may encourage athletes to reduce their body mass by >5 %.

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Overall, despite the controversy among the studies, the literature provides valuable results regarding the prevalence and magnitude of RWL practices among judo athletes. These results suggest that RWL is a common strategy employed by athletes across different levels of competition. Recent studies have explored the impact of regulatory measures such as the 5% tolerance rule on RWL practices. These studies reported a higher magnitude of RWL[34,35] than previous results[2], which indicated a body mass reduction of approximately 5%. Further studies are needed to determine the effectiveness of these rules on RWL behavior in athletes.

Effects of rapid weight loss on judo-specific tests performance

Table 2 presents the studies that evaluated performance using judo-specific tests. Concerning performance in judo-specific tests, Abedelmalek et al.[36] found that RWL impaired SJFT performance, while Fortes et al.[15] reported a lack of performance increase during training for those in the RWL group compared with the control group[15]. Similar results were found by Ceylan et al.[37], who demonstrated that RWL, at a magnitude of 5%, affects performance in both the SJFT and the judogi grip strength-endurance test. Two tests were conducted: the dynamic strength-endurance test, in which the athlete held the suspended judogi with the elbow fully extended and performed elbow flexion (number of movements), and the isometric strength-endurance test, in which the athlete had to maintain the position with the elbow fully flexed for as long as possible. However, no negative effects were reported when recovery was achieved[38-40]. These varying results are possibly influenced by the distinct time of recovery between the weigh-in and assessment.

The reduction in carbohydrate ingestion due to RWL methods can decrease the blood buffering capacity[13,41]. Acidosis due to the combination of RWL and low carbohydrate intake decreases muscle hydrogen ion efflux, which can accelerate fatigue. Furthermore, anaerobic performance can be impaired by low-carbohydrate diets. Low carbohydrate ingestion can decrease glycolysis and, consequently, impair high-intensity exercise performance[13,41]. In the study by Artioli et al.[2], recovery time was provided between weigh-in and performance assessment. During this time, athletes ingested large amounts of carbohydrates, which could partial-

Table 2. Summary of the studies that evaluated performance utilizing judo-specific tests.

References	Sample	Procedures to RWL	Recovery period	Variables assessed	Results
Fortes et al.[15]	n = 42 national level male judo athletes RWL = 21 WS = 21	RWL: 10% of body mass reduction during two weeks; Methods: use of rubber suits, fasting, laxatives and sauna) WS: Maintain body mass	No recovery provided	SJFT	The WS group ↑ the SJFT index and total number of throws; The total number of throws ↓ in the RWL group.
Artioli et al.[38]	n = 14 regional level (or above) male judo athletes RWL = 7 WS = 7	RWL: 5% body mass reduction WS: No body weight reduction Methods: Energy restriction and hypohydration-inducing	4 h	JC and Wingate tests	↔ JC performance
Ceylan et al.[37]	n = 9 male international-level judo athletes	Rapid weight loss: 5% reduction in body mass Control group: No reduction in body mass	1-hour recovery	JGST SJFT	↓ JGST and SJFT
Koral et al.[39]	n = 20 national and international judo athletes (10 female and 10 male) RWL = 10 WS = 10	RWL: 2 - 6% of body mass reduction WS: Maintained the body mass or lost less than 2% Methods: hypohydration-inducing	No recovery provided	SJ and CMJ; Repetitions of favourite judo movements (during 5 s and 30 s)	The body mass decrease by 3.9%; RWL ↔ the SJ and CMJ; RWL ↓ the performance during the 30 s favourite judo movements
Ceylan etal.[40]	n = 18 male international-level judo athletes	Rapid weight loss: 5% reduction in body mass Control group: No reduction in body mass	15 hours of recovery	SJFT	↔ SJFT

SJ: Squat jump; CMJ: Countermovement jump; RWL: Rapid weight loss group; WS: Weight stable group; JC: Judo combats; JGST: judogi grip strenght test; SJFT: Special judo fitness test; HRWL: High rapid weight loss; LRWL: Low rapid weight loss; ↑: Improved; ↓: Decreased; ↔: no effect

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ly restore muscle glycogen stores. In contrast, in the studies by Fortes et al.[15] and Abedelmalek et al.[36], carbohydrates were not ingested after weigh-in.

An increase in HR can be partially attributed to increased blood viscosity, which can decrease the cardiac output and HR recovery for a given work output. In addition, RWL possibly negatively affected the aerobic pathway[15,42]. Another important factor is the recovery time. Fortes et al.[15] and Abedelmalek et al.[36] did not include recovery time between weigh-in and performance assessment. In contrast, in the study by Artioli et al.[2], athletes had 4 h to recover between the weigh-in and test. At this point, the athletes could recover their body mass and fluid loss.

Reale et al.[43] analyzed body mass regain after weighing and showed that athletes who had a larger recovery of body mass had the highest percentage of victory. This was initially interpreted as an indication that these athletes had a larger magnitude of RWL before the competition. However, the magnitude of RWL before competition could not be estimated from the body mass regain between the weigh-in and beginning of the competition[8]. Conversely, a study by Nascimento et al.[44] did not find differences in the number of medals between athletes who reported using RWL procedures and those who reported not using these procedures. However, this study only used questionnaires, and athletes reported the number of medals. Further research is needed to determine whether athletes who adopt RWL procedures and regain a higher amount of body mass are more successful than those who do not undergo these procedures or regain less body mass. Furthermore, analyzing additional variables to represent performance is necessary.

These findings highlight the complex relationship between RWL practices and performance in judo athletes. While some studies demonstrated clear negative effects of RWL on performance, others indicated potential mitigating factors, such as recovery time and carbohydrate intake. However, current judo rules provide sufficient recovery time for athletes. Therefore, further studies are needed to standardize the recovery time, as stipulated in official competitions.

Effects of rapid weight loss on maximal isometric strength

Table 3 presents studies that assessed the effects of RWL on maximal isometric strength. These studies provided conflicting data, with negative[13,14] or negligible effects[26,45]. These controversial results can be explained by different methodologies (e.g., dominant or non-dominant hand and competitive level of athletes). Degoutte et al.[13] reported a decrease in maximal isometric left handgrip strength after RWL in national-level judo athletes; however, whether this was the non-dominant or dominant hand remained unclear. Conversely, Filaire et al.[14] measured both hands of national judo athletes. Their results showed that RWL impaired maximal isometric strength of only the left hand. Morales et al.[45] and Coufalová et al.[26] investigated the maximal isometric handgrip strength of national and international athletes for both hands. They found that RWL did not affect the maximal isometric handgrip strength in either hand. Although the studies used different national- and international-level judo athletes and the hand dominance in each group was not clear, their results suggested that RWL is more likely to affect the maximal isometric left handgrip strength in national-level judo athletes. In addition, Morales et al.[45] included two groups: the RWL and Progressive Weight Loss (PWL) groups. The RWL group reduced body mass by >3% during one week, whereas the PWL group decreased body mass by <3% during the same period. In contrast, in the studies by Degoutte et al.[13] and Filaire et al.[14], athletes reduced their body mass by approximately 5%. Therefore, the difference in the percentage of body mass reduction may explain the differences between the results of these studies.

Clarys et al.[46] utilized a test that mainly recruited the biceps and forearm muscles. A curl bar was pulled towards the trunk by flexing the elbows to an angle of 90°. This test was performed with different intensities: (1) fixed at 60% of the maximal isometric strength for 10 s; (2) maximal effort for 3 s; (3) 60% for 7 s; (4) maximal effort for 3 s; (5) 60% for 7 s; and (6) finishing with a maximal effort for 10 s. This test was used to simulate the immobilization technique used in ne-waza (groundwork combat). In addition, this study analyzed two groups: high RWL (≥3% body mass reduction) and low RWL (<3% body mass reduction), without a control group. The low RWL group did not show any isometric strength impairment. In contrast, the high RWL group exhibited decreased isometric strength. This procedure may have an advantage over the measurement of handgrip strength only, given the judo-specific muscle mass involved[46]. Given that grip strength is a crucial determinant of success in judo, further studies with standardized methods are required to assess grip strength. Additionally, reporting of both the non-dominant and dominant hand strengths could be implemented.

During RWL, athletes decreased fat mass and fat-free mass[28,47,48]. A reduction in the fat-free mass can impair muscle strength and power[45]. A decrease in fat-free mass is frequently achieved through a combination of energy restriction and intense exercise training[48]. Additionally, because of the methods adopted during the process, such as dehydration, a decrease in extracellular or intracellular water concentration can occur[27,49]. Specifically, cellular volume plays a crucial role in orientation of cell metabolism, with cellular swelling promoting anabolism, and cellular shrinkage promotes catabolism. These changes, due to RWL, decrease muscle strength. Furthermore, a decrease in intracellular water can impair magnesium concentration[49]. As magnesium is a potent component of muscle performance, its reduction can decrease maximal strength. Matias et al.[49] found that athletes with decreased intracellular water levels showed decreased isometric strength. Additionally, the indirect effects of RWL on body composition and intracellular water concentration further elucidated the multifaceted nature of its influence on muscle performance.

Effects of rapid weight loss on muscle power

Studies addressing the effects of RWL on muscle power

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have used squat jumps, countermovement jumps, or protocols involving intermittent jumps (Table 3)[14,46]. Generally, the RWL does not affect muscle power. Studies have shown that the RWL does not affect anaerobic power[2,50]. Regarding anaerobic capacity, Degoutte et al.[13] and Artioli et al.[2] observed no changes in performance after RWL. However, Ohta et al.[50] found a decrease in the mean power after RWL.

Filaire et al.[14] evaluated vertical jumps using squat jump (SJ) and counter movement jump (CMJ) tests before and after RWL. The athletes also performed successive maximal jumps (CMJ) during periods of 7 s and 30 s. Notably, RWL did not affect SJ or CMJ height or mechanical power during the period of 7 s. However, a significant decrease in work output was observed during the 30-s jumping test. The decrease in work output was possibly associated with the altered acid-base balance after the RWL period. A low-carbohydrate diet may lower the blood's buffering capacity[41]. When combined with weight loss, reduced carbohydrate intake can decrease the efflux of hydrogen ions from muscles, potentially leading to faster fatigue during muscular contractions[14]. The reason for the lack of a decrease in the 7 s jump test is not clear. However, in the 7 s jump test, the phosphagen stores can be highly important. Furthermore, after 4 days of weight loss achieved by food restriction, ATP

Table 3. Summary of the studies that evaluated performance utilizing strength and power tests.

References	Sample	Procedures to RWL	Recovery period	Variables assessed	Results
Coufalová et al.[26]	n = 9 national level male judo athletes	Days of body mass reduction: 5 Methods: exercise and decreased energy intake. The athletes reduced 4.6% of their body mass.	No recovery provided	Arm, leg and trunk MIS	RWL ↓ MIS trunk strength
Isacco et al.[64]	n = 20 national level male judo athletes RWL = 10 WS = 10	RWL: 3% of body mass reduction Methods: restrictive diet WS: maintain body mass	2 h	Performance in a simulated competition HR during simulated competition MIHGS 30-s horizontal isometric rowing test	RWL ↓ MIHGS in both groups
Degoutte et al.[13]	n = 20 national level male judo athletes RWL = 10 WS = 10	RWL: 5% of body mass reduction during one week; Methods: energy and fluid restriction. WS: Maintain body mass	2 h	MIHGS 30 s isometric horizontal rowing test	RWL ↓ MIHGS
Filaire et al.[14]	n = 11 national level male judo athletes	4.9% of body mass reduction Methods: Food restriction	No recovery provided	MIHGS SJ and CMJ Test of 7 s and 30 s jumping.	RWL ↓ MIHGS and total work output during the 30 s test
Clarys et al.[46]	n = 22 regional to international level judo athletes (15 male and 7 female)	HRWL: higher than >3% of BM reduction LRWL: less than 3% of BM reduction Methods: Energy restriction	No recovery provided	RT MIS Intermittent jump test	HRWL ↓ the MIS
Ohta et al.[50]	n = 10 national level male judo athletes	All subjects reduced 3.6% of their body mass Methods: Food restriction	No recovery provided	Grip (right); Dorsal back strength Isometric elbow flexor strength (right) VJ Peak power and middle power for 40 s.	↔ Muscle strength and high power ↓ Mean power

MIS: Maximal isometric strength; MIHGS: Maximal isometric handgrip strength; RT: Reaction time; MITTS: Maximal isometric trunk traction strength; MIHGS: Maximal isometric hand grip strength; HR: Heart rate; VJ: Vertical jump; SJ: Squat jump; CMJ: Countermovement jump; RWL: Rapid weight loss; HRWL: High rapid weight loss; LRWL: Low rapid weight loss; WS: Weight Stable group

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and creatine phosphate concentrations were not altered in the muscles[51]. This may explain the lack of alteration in the 7-s jumping test. Furthermore, previous studies have reported that RWL through body fluid loss (diuretic effects) does not impair the maximal strength or neuromuscular system for activating dynamic and static force production [52-54].

Clarys et al.[46], who also investigated the effects of RWL on muscle power, used an intermittent jump test with five series of 20 maximal squat jumps, with 1 min rest between each series. This study analyzed two groups: high RWL (≥3% of body mass reduction) and low RWL (<3% of body mass reduction). They found that the RWL did not affect the average jump height in either group.

Artioli et al.[2] and Ohta et al.[50] indicated no effect of RWL on anaerobic power. These results may be due to the recovery time provided after RWL (4 h) or the low body mass reduction during the week of competition (i.e., approximately 3%). Similar results were found for anaerobic capacity. Previous studies found no effect of RWL on performance[2,13,49].

Health risks associated with rapid weight loss

Table 4 presents studies that evaluated health-related risks in response to RWL. Four studies focused on the immunological effects of RWL, particularly its effects on upper respiratory tract infections (URTI). Hiraoka et al.[55] examined the effects of RWL on secretory immunoglobulin A (SIgA) and incidence of URTIs. This study investigated two groups: <5% and >5% of RWL. Notably, SIgA decreased close to the competition (3 and 1 days before the competition). SIgA is a potential marker of protection against URTIs[56]. However, these results were found only in the group with >5% of RWL. In addition, in the experimental group, one incidence of URTI was observed, whereas no such incidence was found in the control group. These results suggest that the magnitude of RWL can be a key factor to induce deleterious effects on the immunological status of judo athletes. Shimizu et al.[57] investigated the effect of RWL on URTI symptoms, utilizing 7 days of food restriction. After this period, the participants reduced their body mass by 3.6%. The results showed that RWL increased URTI symptoms. Also utilizing food restriction, Kowatari et al.[58] assessed the leukocyte, neutrophil, lymphocyte, and phagocytic activity. They utilized 20 days for the body mass reduction; however, the assessment was performed only one week prior to the competition. The results showed that the phagocytic activity decreased after the body mass reduction. These studies reveal a consistent pattern of RWL-induced immunosuppression, characterized by decreased levels of SIgA and increased incidence of URTI symptoms. The findings suggest the importance of considering the magnitude of RWL, as more substantial reductions (>5%) appear to pose a greater risk to immune function.

Abedelmalek et al.[36] investigated the effects of RWL on cortisol, testosterone, and proinflammatory cytokines. Both groups performed an exercise protocol with or without caloric restriction. After exercise accompanied by caloric restriction, cortisol and proinflammatory cytokine levels were higher than in the no-caloric restriction condition. Examination of cortisol, testosterone, and proinflammatory cytokines provides valuable information on the hormonal and inflammatory responses associated with RWL. The observed elevations in cortisol and proinflammatory cytokines following exercise accompanied by caloric restriction suggest a potential link between RWL and heightened inflammatory activity, which may further compromise immune function and increase susceptibility to infections. Considering that these RWL methods are adopted near the competition (1–3 days before the competition)[21], athletes may risk their overall performance.

One study investigated the effects of RWL on muscle damage[59]. Biomarkers such as creatine kinase (CK) and aldolase (ALD) were measured in 18 male judo athletes. This study observed changes in muscle damage markers during the weight maintenance (1–4 days) and RWL (5% of RWL in 5–7 days) periods. Muscle damage markers showed no significant changes during the weight maintenance period. In contrast, during the RWL period, CK and ALD levels increased. These results may be associated with the method used for the RWL process (e.g., increased exercise intensity).

One study investigated the effects of weight cycling on the bone metabolic balance. Prouteau et al.[60] evaluated bone markers, including C-terminal telopeptide of type I collagen (CTX), and the uncoupling index (UI) was calculated to determine the relative balance between bone formation and resorption processes during bone remodeling. Before the RWL phase, bone markers were similar between judoists and controls. In addition, the UI showed a positive value, indicating a bone metabolic balance favoring bone formation. During the RWL period, a 4% RWL was accompanied by a 33% increase in CTX levels. Negative values in favor of resorption were reported for the UI. However, in the body mass gain phase, these results were reversed, as body mass gain restored a positive UI in favor of bone formation. In addition, bone mineral density was not altered by weight cycling[60,61]. The mechanisms underlying this increase in resorption have not yet been elucidated. Given that Proteau et al.[60] assessed weight gain 3 weeks after the competition, determining whether these effects on bone metabolic balance remained after the competition was not possible. Further research is required to clarify this and the possible mechanisms underlying these results. The observed increases in CK and ALD during the RWL phase highlight the physiological strain imposed by RWL, particularly on skeletal muscle. Additionally, alterations in bone markers and the (UI suggest a disruption in bone metabolic balance, with implications for bone health and remodeling processes.

Regarding dehydration, which can occur due to methods used during RWL, Bialowas et al.[62] demonstrated that athletes were in a state of dehydration from 5 days before the competition to the day of the competition. Although the authors did not find an association between dehydration and performance in competitions, dehydration can be detrimental to athletes. In addition, future studies should investigate the effects of dehydration on other parameters, such as psychological aspects. The chronic effects of RWL on health

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status also need to be investigated as athletes frequently reduce their body mass several times during a season.

Eating disorders and emotional aspects

Two studies investigated the relationships among RWL, eating disorders, and emotional aspects (Table 4). Filaire et al.[16] assessed psychological parameters, lifestyle (e.g., historic weight reduction), eating attitudes, and emotional intelligence. A 70% prevalence of was found in athletes using RWL procedures. Furthermore, 30% of the athletes presented with disordered eating habits. In addition, judo athletes with disordered eating habits had lower scores on happiness, empathy, and emotional self-awareness subscales (emotional intelligence test). Additionally, the study highlighted the pervasive nature of disordered eating habits within the judo community, warranting further investigation into their underlying causes. Escobar-Molina et al.[17] investigated eating disorders and added anxiety ratings. Their research revealed intriguing sex-based disparities, with female athletes exhibiting higher levels of anxiety and greater susceptibility to eating disorders than their male counterparts. Despite the prevalence of RWL practices among senior athletes, this study noted their adeptness in managing the associated psychological stressors, suggesting the presence of coping mechanisms or resilience factors within this demographic. Interestingly, the prevalence of RWL was lower in females than in males.

Further studies investigating the relationship between RWL and eating disorders are necessary, especially among female athletes. The prevalence of eating disorders in female athletes is higher than that in male athletes[17], and this population may be at risk of developing the female athlete triad[63]. In judo, when athletes repeatedly reduce their body mass during the season through low-energy diets, future studies should investigate whether those who engage in weight cycling are at a higher risk of developing eating disorders. In addition, further studies could explore the longitudinal effects of RWL on the mental health of athletes by tracking changes in eating behaviors and emotional resilience over time. Moreover, investigating the efficacy of intervention strategies, such as mental health support programs, in mitigating the adverse effects of RWL could offer valuable insights into athlete well-being and performance optimization.

Effects of rapid weight loss on the psychological well-being of judo athletes

Table 5 presents studies that reported the effects of RWL on psychological well-being. Regarding the psychological well-being of judokas, three studies investigated the effects of RWL on this parameter. All studies utilized the Profile of Mood States (POMS). Only one study provided a recovery period between the weigh-in and assessment; however, the

Table 4. Summary of studies that evaluated health-related risks to the athletes.

References	Sample	Procedures to RWL	Recovery period	Variables assessed	Results
Hiraoka et al.[55]	n = 30 university judo athletes (22 male and 8 female) LWL = 10 HWL = 10 WS =10	LRWL: <5% of body mass reduction HRWL: >5% of body mass reduction WS: Maintained the body mass Methods: Water restrictions, judo exercise, and sauna.	No recovery provided	Saliva collection; Screening test of URTI; SIgA	RWL ↓ volume of the saliva near of competition RWL ↑ the incidence of the URTI
Shimizu et al.[57]	n = 6 elite male judo athletes	Methods: Dietary energy restriction, fluid restriction and sauna 3.6% of body mass reduction	No recovery provided	Screening test of upper URTI.	RWL ↑ the URTI symptoms.
Roklicer et al.[59]	n = 18 national male judo athletes crossover study	Days of rapid weight loss: 3 days Methods: Increased physical activity, plastic suit training, caloric deficit and reduced fluid intake. 5% of body mass reduction	No recovery provided	Biomarkers of muscle damage (CK and ALD)	RWL caused changes in CK and ALD
Kowatari et al.[58]	n = 22 college male judo athletes VLEI = 6 LEI = 6 Control = 6	Days: 20 days, but there is date of 5 days and 1 day before competition Methods: energy restriction VLEI: 3.3% of body mass reduction LEI: 2.7% of body mass reduction	No recovery provided	Leukocyte Neutrophil Lymphocyte Neutrophil oxidative burst and phagocytosis assays	RWL ↓ phagocytic activity
Abedelmalek et al.[36]	n = 11 male judo athletes Competitive level not provided	Baseline condition: normal diet Caloric restriction: 7 days of caloric restriction Approximately 4.2% of body mass reduction	No recovery provided	Cortisol Testosterone Proinflammatory cytokines	↑ Proinflammatory cytokines and cortisol

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References	Sample	Procedures to RWL	Recovery period	Variables assessed	Results
Filaire et al.[16]	n = 20 national judo athletes and 25 controls	Methods: Food restriction 4.9% of body mass reduction	No recovery provided	Psychological parameters and lifestyle EAT-26 EQI BIAS-BD	30% of the athletes, presenting disordered eating; Judoists with disordered eating had lower scores in the subscales of happiness, empathy and emotional self-awareness.
Escobar-Molina et al.[17]	n = 144 national judo athletes (66 females and 78 males)	% of body reduction not provided	No recovery provided	STAI-T; FCQ-T; RS; EAT-40	Seniors presented higher use of weight loss methods; Females showed higher anxiety and more eating disorders symptoms
Prouteau et al.[60]	n = 48 elite judo athletes (male = 22; female = 26) control group (n = 20)	Food restriction	No recovery provided	Bone markers and biological parameters (Cortisol; CTX and UI)	The weight loss increase the cortisol and CTX; UI reverse the positive status pre weight reduction in favor the resorption
Bialowas et al.[62]	17 male judo athletes	Dehydration	15-17 hours of recovery	Urine specific gravity	The athletes were in a state of dehydration before weigh-in, on the day of the competition, and after warm-up.

SigA: Secretory immunoglobulin A; URTI: upper respiratory tract infection; CK: creatine kinase; Aldolase (ALD); CTX: C-terminal telopeptide of type I collagen; UI: Uncoupling index; EAT-26: Eating Attitudes Test; EQI: Bar-On Emotional Quotient Inventory; BIAS-BD: Body Image Assessment Scale – Body Dimensions; EAT40: Eating Attitude Test; FCQ-T: Food Craving Questionnaire-Trait; RWL: Rapid weight loss; LRWL: Low Rapid Weight Loss Group; HRWL: High Rapid Weight Loss Group; WS: Weight Stable group; ↑: Improved; ↓: Decreased; ↔: no effect.

Table 5. Effects of rapid weight loss on the psychological well-being in judo athletes.

References	Sample	Procedures to RWL	Recovery period	Variables assessed	Results
Fortes et al.[15]	n = 42 national male judo athletes RWL = 21 WS = 21	RWL:10% of body mass (5% per week) reduction WS: maintained their body mass	48 h	POMS	RWL ↑ the tension, anger, depression, and fatigue. ↓ vigor
Filaire et al.[14]	n = 11 national male judo athletes	7 days food restriction 4.9% of body mass reduction	No recovery provided	POMS	RWL ↑ the tension anger, fatigue and confusion. ↓ vigor
Degoutte et al.[13]	n = 20 national male judo athletes RWL = 10 WS = 10	Methods: Energy and fluid restriction RWL: 5% of body mass reduction during one week WS: Maintained the body mass	No recovery provided	POMS	RWL ↑ tension, anger and fatigue. ↓ vigor
Fortes et al.[65]	n = 42 national male judo athletes RWL = 21 WS = 21	RWL: 10% of body mass (5% per week) reduction WS: maintained their body mass	No recovery provided	GPAI	RWL ↔ GPAI score ↑ GAPI score in the control group

POMS: Profile of Mood States; GPAI: Game Performance Assessment Instrument; RWL: Rapid Weight Loss Group; WS: Weight Stable Group; ↑: Improved; ↓: Decreased; ↔: no effect.

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results were not different. In general, RWL increased several negative aspects (including tension, depression, anger, and fatigue) and decreased one positive aspect (vigor)[13-15]. Isacco et al.[64] investigated the effects of RWL in five successive simulated bouts. This study found that POMS was affected in matches 4 and 5 in athletes who reduced their body mass. Furthermore, these athletes reported a higher rate of perceived exertion. Pinto et al.[6] showed that athletes reported fatigue (34%), irritability (29%), and anxiety (29%) during the RWL process, as well as a perception of a decrease in performance.

Fortes et al.[65] investigated the effect of RWL on decision-making abilities by employing a game performance assessment instrument (GPAI) to evaluate judo-specific movements. Although the control group exhibited improvements in GPAI scores, no discernible changes were observed in the RWL group, underscoring the potential cognitive ramifications of RWL in judo athletes.

These findings highlight the profound influence of RWL on psychological well-being, as evidenced by alterations in mood states, decision-making capabilities, and subjective experiences of athletes. However, gaps in the current literature necessitate further exploration to elucidate the extent to which these psychological effects affect the success of athletes in official competitions. Future studies should incorporate recovery periods between weigh-in and competition to provide a more nuanced understanding of the interplay between RWL, psychological well-being, and athletic performance.

RECOMMENDATIONS

Owing to the risks associated with RWL, this practice is not recommended. However, if athletes are going to decrease their body mass, some points should be considered to minimize the negative effects on performance and health.

- A low-carbohydrate diet, when combined with training and a small reduction in energy intake for 7 days can induce body mass reduction without strength and power performance impairments[66];
- A reduction in fiber intake (48–96 h pre-weigh-in) can induce body mass reduction. The reduction of fiber intake can reduce the amount of water drawn into the intestinal space and fecal bulk, favoring the reduction of body mass during the RWL process[67].
- Passive sweating can be used as an additional method near competition (0–24 h pre-weigh-in)[67]. Because judo allows recover time (nearly 15 h), athletes can ingest the same amount of fluid lost during RWL during this recovery period, with a limit of 5% above the weight category imposed by the rules.
- Maintaining a balanced diet during weight loss is important. For example, if the athletes are following a strategy with a low-caloric diet, maintaining an adequate protein intake (1.8–2.7 g/kg of body mass) is necessary[68]. In addition, despite the limited number of studies on strategies for recovery after weigh-in, increasing carbohydrate ingestion after the weigh-in can help maintain the performance of the athletes and restore glycogen stock (high-carbohydrate consumption should be considered, e.g., 5–10 g/kg/day[69])
- Considering the risk of developing eating disorders, a multidisciplinary team should monitor this phenomenon throughout the season, particularly among athletes with a high level of energy restriction. Self-report questionnaires such as the Eating Attitudes Test and Eating Disorders Inventory can be used for evaluation[63].

CONCLUSIONS

The prevalence of RWL in judo athletes is high. In addition, athletes frequently decrease their body mass by approximately 5%; however, a significant number of athletes decrease their body mass by >5% (46.2% of males and 27.3% of females). Although some studies have found a negative effect of RWL on the performance and psychological well-being of judo athletes, these studies did not include sufficient recovery time between weigh-in and performance assessment as in official competitions. In fact, when an adequate recovery time was provided, RWL did not impair judo-specific performance. Nonetheless, certain problems are associated with RWL, such as the chance of infectious diseases, which could impair the physical capacity of athletes. However, an increase in the time between the weigh-in and competition can encourage athletes to adopt a process of weight loss and subsequent weight gain. Given these considerations, future studies should explore the multifaceted implications of RWL in judo athletes by incorporating factors such as recovery time, psychological factors, and long-term health outcomes. This study outlines the effects of RWL in judo and could serve as a basis for future investigations aimed at enhancing methods and providing information for athletes engaging in RWL practices.

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