Effects of Rapid Reduction of Body Mass on Performance Indices and Proneness to Injury in jūdōka. A Critical Appraisal from a Historical, Gender-Comparative and Coaching Perspective

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Abstract

In contrast with the vast amount of literature on rapid reduction of body mass in male wrestlers there is a particular lack of studies on the effects of “weight cutting” in female athletes who compete in weight class events such as jūdō. The advantages of competing in a lower weight category include increased leverage, relative power, and strength. A competitively active jūdōka attempts to build a long-term career in a single weight class to avoid having to overhaul tactical preparations due to having to face many new opponents. The most influential person on the jūdōka’s weight management behavior appears to be their jūdō coach and training partners. Significant gender differences in the type or magnitude of physiological effects of “weight cutting” are caused by female jūdōka typically relying on different methods (chiefly nutritional restriction and dehydration) when compared to their male counterparts (mostly increased energy expenditure and excessive exercise). Elite jūdōka engage in these unhealthy practices at an increasingly young age (<15 yrs) and are not commonly submitted to any preventive assessment of menstrual function, bone health, and markers of muscle and bone breakdown hence their high frequency and sustained history of musculo-tendinous injuries. While the effects of weight cutting on relative aerobic, anaerobic capacity and strength are limited, it is mainly dehydration, loss of muscle, tendon elasticity, catabolism, and premature osteopenia that contribute to their overall increased risk of injury. Protein and amino acid supplementation may be useful in avoiding severe catabolism and may potentiate lipolysis.

Keywords: Dehydration; Eating Disorders; Estrogens; Female Athlete Triad Syndrome; Judo; Martial Arts; Protein; Weight Loss; Weight Reduction

Introduction

In sharp contrast with most other Olympic sports, training methods in jūdō have little evolved over the past half century, with scientific input being shunned or considered suspect. The reason, most likely is, because for decades jūdō has recruited its competitive athletes from people with lower social and educational backgrounds, such as laborers. In most countries there does not exist an equivalent of the US “certified strength and conditioning professional”; those involved in administering these tasks and the majority of competitive preparation of jūdōka (jūdō player), are predominantly themselves former competitive jūdōka who rely on their own practical experience rather than on cutting edge science and on having expanded those experiences with advanced degrees in relevant subjects [1-3]. In the light of a number of health concerns that have recently been highlighted in jūdō, it is essential that this relevant health information is put into a form that actually reaches jūdō athletes and their coaches despite lacking the scientific preparation that professionals in other Olympic sports may possess. To achieve this, an interdisciplinary and liberal arts approach is suggested rather than the mere clinical
The occurrence of reducing body mass in jūdō and the risks of these practices were first highlighted in February 1994, when the Japanese Mainichi Daily newspaper published a dramatic article about a male junior high school jūdōka who had collapsed after a training bout and had died from a combination of reduction of body mass, hyperthermia and dehydration [4]. Barely two years later, in March 1996, another tragedy occurred when 22-year old South Korean jūdō athlete Chung Se-hoon died in similar weightloss-related circumstances while preparing for the 1996 Atlanta Olympics [5]. At the time, the incidence or the broader topic of weight cycling (repeated loss and regain of body mass) in jūdō, was, however, never reported in the foreign media or by the jūdō professional bodies. Even after various experimental studies [6-8] were launched in the West to further investigate the practice and potential health consequences of “cutting weight” in wrestling or other combat sports, the world of jūdō remained virtually immune from any new health information on the this topic that was discovered in wrestling athletes.

In October 2011, it was reported that between 1983 and 2009 at least 114 deaths in children had occurred during jūdō practice in Japan in schools alone [9-11]. While most of these fatalities were due to traumatic impact causing head injuries (chiefly, acute subdural hematomas), nine were thought to be the consequence of behavioral or environmental factors such as extended practice in hot summer temperatures at high humidity and subsequent dehydration. During 2011 three high school students died as a consequence of school jūdō activities in Japan [9,10,12]; two students died from head injuries and the third fatality was due to acute heat stroke and dehydration. However, dehydration does not only occur as a result of vigorous practice, but is also an intentionally applied method for rapid reduction of body mass known to be used frequently in sports where athletes are divided in weight classes [13-20].

Ironically, when jūdō was created back in 1882, it was conceived as system of physical and mental education with the goal to improve the quality of life and develop skills to contribute to the well-being of man. Despite jūdō’s founder being a member of the Japanese Olympic Committee in the early 20th century, he strongly resisted any effort from others to convert jūdō into a competitive sport with a focus on winning medals. Nevertheless, after Japan’s defeat in World War II, the only way for the Kodōkan Jūdō Institute to relatively easily receive permission from the occupying Allied Forces to quickly restart jūdō practice, was to switch the emphasis from a martial art to a sport, hence, this is how jūdō would evolve in Japan, and also abroad, from that point on [21-23].

The first two Jūdō World Championships (Tōkyō, 1956, and Paris, 1958) were won by Japanese (Natsui Shōkichi and Sone Kōji, resp.) and underscored Japan’s hegemony in what was to become a new Olympic sport, Japan’s symbol of national pride [21]. However, the third Jūdō World Championships held in Tōkyō in 1961 resulted in a shockwave in Japan, when the giant Dutchman Anton Geesink defeated the Japanese in one of their own national sports. Japan realized very well that they did not have a single active jūdōka that likely could beat Geesink. This meant that if only a single Open weight class remained in place, Japan would not win any gold medals. That is the main reason why Japan suddenly pushed towards the creation and implementation of weight classes in jūdō. Only thanks to the creation of four weight classes (light/middle/heavy/open) starting at the 1964 Tōkyō Olympics was Japan able to win three gold medals, and save national honor [21-23]. Geesink, without much resistance, won the prestigious Open category, thus creating a national disaster in Japan. The threat of further loss of Japanese hegemony intensified during the years to come when several strong Soviet Russians entered the field. Four weight classes expanded to six weight classes by the Munich Olympics of 1972, and after another change in 1977 there were eight weight classes at the 1980 Moscow Olympics.

A chronological overview of the weight divisions as historically in use during the World and Olympic Championships Jūdō is provided in Table 1. In some cases changes were implemented in a year during which no world championships or Olympics were organized. Rather, changes in weight classes followed World Championships or Olympics often due to fierce discussion and feelings of having been denied a fair chance to win. Thus it is no surprised that the Japanese wanted changes after Geesink’s 1961 World title, and again after Geesink’s 1964 Olympic Title when it turned out the first changes still were not enough to warrant complete domination by the Japanese. Throughout history, weight class changes in jūdō virtually all came in place due to political reasons rather than given in by anthropometric scientific data.

Optimizing strength-to-mass ratio is critical for jūdōka or any athlete who competes in weight classes. Furthermore, anaerobic power is closely related with increases in fat-free mass and muscle mass [25-26]. The perceived higher chance to win by entering into a lower weight class, after being able to drop a few kilograms of body mass, therefore exerts great attraction on the individual athlete, and is, in essence, the reason why jūdō athletes frequently engage in “cutting weight”. Because of the frequency jūdō athletes have to go through this process (3 ± 5 times per season [27]), “cutting weight” oftentimes evolves into weight cycling.
Table 1. Chronological overview of the weight divisions as historically in use during the World and Olympic Championships Jūdō. Currently, both women’s and men’s jūdō know eight different weight classes (modified after [24]). The dates listed are those of the implementation of the new weight divisions.

It is the purpose of this paper to review the research and scientific evidence about the various consequences of rapid reduction of body mass in female vs. male jūdōka, whilst also reflecting on the history of weight management in jūdō. We also will consider possible ways to reduce the negative effects of rapid reduction of body mass. In order to better prevent and address the potential health consequences of rapid reduction in body mass in jūdōka the practical questions we aim to address bearing in mind the strength and conditioning coaches, jūdō coaches, and jūdō athletes, are:

■ What are the effects of a rapid loss of body mass on anthropometric, psychological, physiological (metabolic, hormonal and immunological), and performance indices in jūdō athletes?
■ Are such potential effects of rapid loss of body mass different between female and male jūdōka?
■ What lessons can be drawn from the information available to prevent debilitating health performance effects while recognizing that the jūdō athlete needs to cut body mass to stay within the limits of his/her weight class?

Methods

Scholarly databases such as MEDLINE, SPORTDiscus, SCOPUS, Google Scholar were searched for all clinical articles related to jūdō and weight loss using the following MeSH terms or Medical Subject Headings: ‘judo’, ‘jujitsu’, and ‘martial arts’ in combination with ‘weight loss’, ‘weight reduction’, and ‘body weight’. Given that jūdō’s origin is Japanese, that the major part of the literature on jūdō is in Japanese, and that many Japanese journals that do not contain English abstracts and that therefore are not included in these databases due to the language barrier, we also conducted individual searches of relevant Japanese scholarly journals corresponding search terms in the native language. Furthermore, all pertinent articles from the bibliographies of these articles were reviewed irrespective of the language they were written in. Abstracts and conference proceedings were considered when no other source of information was available. Articles were then grouped into those that investigated male subjects, female subjects, or both genders without separating them. Articles were further grouped depending on whether they investigated the effects of weight loss on anthropometrical, physiological, metabolic, hormonal, nutritional, immunological, or psychological factors, performance, or traumatology. Results and conclusions were reviewed by two independent reviewers.
There were no studies available on jūdō and weight loss with solid randomized cross-over designs, and only very few well-controlled prospective studies. Lack of uniformity in experimental protocols and variables measured prevented the option of a meta-analytical or systematic review approach.

Management of body mass (“weight regulation”) practices in history

There exist several reports from antiquity, not so much about weight regulation, but certainly about the use of special diets to optimize performance [28-32]. According to the legend, Charmis of Sparta, the victor of the Olympic Games in 668 B.C., used to train on a diet of dried figs [28]. He won the 200 yards sprint, and may have optimized his glycolytic system by benefitting from the fructose that was present in the figs. Perhaps the most relevant case in antiquity is that of Milo of Crotón [Greek: Μίλων], from what is currently Southern Italy. Milo of Crotón was an outstanding wrestler in the 6th century BC and a celebrated figure in the history of Greek athletics, who won the wrestling at seven successive Olympiads, with 26 victories in other great Pan-Hellenic festivals [28,33]. However, most of the legends from ancient Greece, such as those discussed above, generally involved diets for the purpose of increasing performance and not so much for weight control. While there exist several legends —some rooted in mythology— which involved female warriors (e.g. the Amazons), women did not typically participate in the ancient Olympics as athletes. Therefore, there are no commonly known antique legends involving “weight cutting” or dieting in women.

There do not seem to exist reports of any weight divisions in sports in antiquity, and their creation seems to be a fairly recent feature dating back only to the early 19th century, and largely linked to the sport of boxing. The 1823 version of Grose’s Dictionary of the Vulgar Tongue in 1823 mentions that “light weight” is “… a pugilistic expression for gentlemen under twelve stone” [34], hence indicating that the upper limit for a “light weight” in boxing was 76.2 kg. Sportsman’s Slang, published two years later, indicated that “In affairs connected with the ring, persons of 11 stone and under are light weights, and if of nine or less, they receive the appellation of little-ones” [35, p.113]; “11 stone” equals 69.9 kg.

Serious mismatches in size between two boxers potentially led to grave injury for the smaller boxer and often reduced the duration of a contest considerably thereby making it very unsatisfying for the spectators. Also, in order to recognize national and world titles, it became necessary for the results to be comparable, which required the creation of universal standard weight classes that were agreed between participating countries and federations. In 1909 (implemented in 1910), important sets of boxing weight classes were specified by the National Sporting Club of London, followed in 1920 by the Walker Law which established the New York State Athletic Commission (NYSAC) [36]. However, the introduction of weight classes does not seem to immediately have led to any excessive behaviors from participating boxers desiring to cut weight in order to make a certain weight class.

One of the very first cases of weight cutting known in sports history appears to involve the Swedish athlete Ivar V. Johansson (1903–1979). Johansson, a Swedish wrestler, competed in the 1932 Summer Olympics winning gold in the Greco-Roman welterweight competition (-82 kg in those days) [37]. He then, within a 24-hour period, cut more than 10 kg through fasting and sweating in a sauna so that he could enter the Greco-Roman freestyle middleweight (-72 kg) division the next day, which he also won, thereby obtaining a second gold medal and essentially winning two divisions in the same sport during the same Olympics. Johansson also participated four years later in the 1936 Summer Olympics and would win a third Olympic gold medal in the middleweight Greco-Roman wrestling [37]. The origin of excessive weight cutting in female athletes historically, and contrary to its history in males, is not linked to combat sports or individually fighting another athlete in a contact sport. Instead, weight cutting practices in females are typically linked to events such as ballet dancing, gymnastics and ice skating, disciplines where elegance, acrobatics, and one’s own body mass is considered important either in order to create a better strength-to-body mass ratio (ballet, gymnastics) or to facilitate being lifted by a partner (ballet, ice skating), and rowing [38-41], or simply for visual appearances.

Historical appearance of the first scientific investigations of weight regulation practices in jūdō

The phenomenon of “cutting weight” in sports has been known for quite some time and has been well documented in scientific studies and reviews on wrestlers [42,43]. Yet, rapid and gradual reduction of body mass has also become common practice in the, now, Olympic combat sport of jūdō [7,27,44-52]. Reduction of body mass in weight-class events appears to be a problem that is almost unavoidable for many top-competitive jūdōka and wrestlers, as, often, only a single place in their national team is available per weight class. Weight classes in male jūdō were separated, depending on the specific weight class, by 5 to 9 kg under the pre-1998 IJF Rules, and now by 6 to 10 kg under the ‘new’ IJF Sports and Organization Rules, whereas weight classes in female jūdō are separated, depending on the specific weight class, by 4 to 6 kg under the pre-1998 IJF Rules and by 4 to 8 kg under the ‘new’ Rules [53,54] (see Table 1). Obtaining that place in a national team does not only require the neutralization of national concurrent competitors, but also means one must avoid gaining weight. Most competitors continuously balance close to the upper limit of their weight class. The official weigh-in in jūdō is usually

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between 2-4 hours before the event; in major international events sometimes the evening before. Weight class criteria are applied rigorously, and weighing even 100 g over the upper limit, implies disqualification before the actual start of the event. Depending on the type and importance of the event, a training period consisting of months or even years (in case of the Olympics, for example) of hard work and devotion will have been for nothing. It also means an important loss for the team and nation since the disqualified jūdōka cannot be replaced by a reserve one. In order to prevent such disastrous consequences of failing to make weight jūdōka will “do everything” (fluid and food restriction, excessive training, laxatives, etc.) to lose the excess kilograms, if necessary even until right before the weigh-in and subsequent match [55].

A second motivator for “weight cutting” practices in jūdō specifically includes those jūdōka who initially are within the lower weight ranges of their weight class. These jūdōka will generally try to lose a few kilograms to get into a lower weight category, the rationale being that they are used to competing with heavier jūdōka, and believe that this will be a major advantage if they succeed in entering a lower weight category [53-55]. Evidently, that means that they too will now be among those jūdōka who rank near the upper limit of their (new) weight category, which means that henceforth, they will have to continue “weight cutting” because of the reasons explained previously. Particularly in comparison to other weight-class events such as wrestling, it may come across as if jūdōka’s reluctance to switch weight categories would be inspired by psychological issues. This is, however, not so. Differences in jūdō-style between weight classes are substantial (types of techniques used, pace, speed, strength), and the qualities in terms of physiology, anthropometry and technical-strategic approach to succeed in another weight category can be very different. These differences do not only translate in scoring chances but also in injury risk. Some jūdōka moving to a higher weight class may end up continuously getting injured because their body cannot sufficiently adapt to the thoroughly different strategies and physical requirements.

The absence of much scientific literature on reduction of body mass in jūdōka is in sharp contrast with the plethora of papers focusing on boxing [56,57] or wrestling [15,58-71; for a review, see 6]. This is, no doubt, caused due to the high popularity of varsity and intercollegiate wrestling in the United States (where most scientific papers on reduction of body mass in wrestling originate), as opposed to the relatively low local interest in jūdō, and jūdō not being a National Collegiate Athletic Association (NCAA) sport [72-75]. This impression is strengthened by the absence of frequent and well-organized intercollegiate jūdō championships in most countries, except Japan [45-48,52]. Hence, the phenomenon of “weight-cutting” in jūdō had not been seriously researched by Western sports scientists and authors until the early 1990s. Although several Japanese studies on “weight-cutting” predate the 1990s [46,76-79] these were generally unknown to Western scholars before, due to the language barrier and nonexistence of the Internet.

Among the most important findings from these first Japanese studies that focused on the problem of rapid weight loss in male jūdōka we note that Hattori et al. [47] found that 35.2% of their male high-school jūdō subjects engaged in weight-cutting, with 45.6% of that sub-group incurring more than 5% of loss of body mass. However, Muramatsu et al. [48] found that male high-school-level jūdōka, excluding those belonging to the heavy-weight category, on average lost 3-5.8 % of body mass. The same authors also found that among male high-school-level jūdōka the most extreme cases lost as much as 6% of body mass in 3 days through a combination of excessive dieting, dehydration, running, taking baths, wearing extra clothes, and daily hours-long sauna sessions [48]. Furthermore, those engaging in weight-cutting had reduced skin folds, lower abdominal girth, and increased uric acid excretion [77].

In 1993 Fogelholm and co-workers [80] published a paper on the reduction of body mass in male athletes, which included three jūdōka among its subjects, although, unfortunately, their data were not presented separately from those of the seven non-jūdōka (wrestlers). Nevertheless, this was probably the first paper devoted to reduction of body mass to also pay some cursory attention to jūdō. Among their findings these authors noted increased serum magnesium after rapid reduction of body mass, and speculated that this was due to leakage from the muscles following intense work.

However, the first scholarly paper in English to be devoted exclusively to weight cycling in jūdō was the 1993 Canadian study by Waslen et al. [81]. We note that this was almost three decades after the first Japanese report on the existence of “cutting weight” by Ōtaki [79], which had appeared shortly after weight classes firstly were implemented in the 1964 Tōkyō Olympics. The study by Waslen comprised one group of ten male jūdōka, who within a single sports season at least three times reduced their weight by ≥4.0 kg and had done so for ≥3 years; these were compared with a group of non-weight-cycling controls [81]. The study concluded that there were no prolonged metabolic or biochemical effects of weight cycling.

### Regulation of body mass and general problems related to reduction of body mass

According to Jéquier & Tappy [82] regulation of body mass in humans is achieved via genetic, physiological, and behavioral mechanism. Stability of body mass and composition require that energy intake matches energy expenditure and that nutrient balance is achieved [83,84]. Serum leptin reflecting the size of the adipose tissue mass communicates with the hypothalamus that regulated energy intake and expenditure [82].
Hypocaloric dieting and fasting alter the contraction-relaxation characteristics of skeletal muscle and result in low frequency fatigue, reflected in a significant increase in intracellular muscle calcium content (p<0.05), and a significant decrease in muscle enzymes, in particular phosphofructokinase (p< 0.05), succinate dehydrogenase (p< 0.02), and some muscle amino acid levels, such as glutamine (p< 0.025), glycine (p< 0.01), and alanine (p< 0.02), while muscle histochemistry may show type II fiber atrophy (p< 0.025) [85]. Exercise has an important role in effective reduction of body mass as it assists in preventing the normal decline in fat-free mass, muscular power and VO2 max that otherwise might be some of the side-effects of weight-loss induced by diet alone [84,86,87].

Particularly individuals who have some degree of obesity and who have to reduce their body mass are at risk for weight cycling as it requires greater effort for them to maintain lost weight than for those who have to cut weight but have never been obese. Henson et al. [88] measured resting energy expenditure in obese women over a 9-week period of dietary restriction (80 kcal•d⁻¹ or 335 kJ•d⁻¹), and found that during the first 3 weeks, the resting energy expenditure decreased by 13%. Exercise training which started at week 4 was unable to elevate dietary-depressed resting energy expenditure even though it significantly increased VO2 max [88].

Maintaining a reduction in body mass is more difficult if the athlete has been obese than when they have never been obese. Leibel et al. 1995 found that to maintain body mass at a level of 10% or more below initial body mass was associated with a mean reduction in total energy expenditure of 6 ± 3 kcal•kg⁻¹•day⁻¹ (25 ± 13 kJ•kg⁻¹•day⁻¹) of Fat Free Mass (FFM) in the subjects who had never been obese (p< 0.001) and 8 ± 5 kcal•kg⁻¹•day⁻¹ (34 ± 21 kJ•kg⁻¹•day⁻¹) of FFM in the obese subjects (p< 0.001). Resting energy expenditure and non-resting energy expenditure each decreased 3 to 4 kcal•kg⁻¹•day⁻¹ (13 to 17 kJ•kg⁻¹•day⁻¹) of FFM in both groups of subjects. Conversely, maintaining body mass at a level 10% above the usual body mass was associated with an increase in total energy expenditure of 9 ± 7 kcal•kg⁻¹•day⁻¹ (38 ± 29 kJ•kg⁻¹•day⁻¹) of FFM in the subjects who had never been obese (p< 0.001) and 8 ± 4 kcal•kg⁻¹•day⁻¹ (34 ± 17 kJ•kg⁻¹•day⁻¹) of FFM in the obese subjects (p< 0.001) [89].

Scientific investigations of weight regulation practices in male jūdōka

The early Japanese and Western scientific papers about weight regulation practices in jūdō and which we discussed in chronological order in the previous section, exclusively dealt with male jūdō athletes. In the following section we offer a systematic approach to the later studies that focused on reduction of body mass practices in male jūdōka. Specifically we will consider studies that dealt with performance effects, hormonal effects, bone status, immunology, and psychological effects.

In terms of prevalence of weight regulation practices in male jūdōka, Filaire et al. [90] found that 14% of male jūdōka engaged in fasting and other methods, such as, diet pills, diuretics, vomiting and laxatives, while Taguchi [91] also reported finding practices of unbalanced dietary regiments and abuse of nutritional supplements. Any effects of rapid loss of body mass on performance indices are likely to be among those perceived in a dramatic way by the subject. Timpmann et al. [92] found significantly impaired absolute peak power, total work and increased ammonia responses in a group of male combat sports athletes (twelve wrestlers and five karateka) after a regimen of reduced energy and fluid intake and mild sauna used in order to achieve a 5.1 ± 1.1% reduction of body mass over a 3-day period. These findings were not surprising and in line with the pioneering studies of Bosco et al. [93] who 40 years earlier had been studying the effects of hypohydration on isometric strength in athletes. Moreover, Silva et al. [94] in a group of 27 male elite jūdō athletes demonstrated that loss of intracellular water due to loss of body mass was a significant (p< 0.027) predictor of forearm and grip strength. These results also echo the findings of Kraemer et al. [59] for twelve male Division-I collegiate wrestlers, who had lost 6% of total body mass during the week before a simulated 2-day freestyle wrestling tournament, and who had significantly reduced body power and upper body isometric strength as the tournament progressed.

Koral and Dosseville [95] found that after a 4 ± 1.1% loss in body mass and of 10 ± 4.0% loss in percentage of body fat over a 4-week period, male jūdō athletes showed a decrease in vigor over 30 seconds of uchi-komi (literally meaning: “pounding in”, is a training exercise that consists of repetitively and vigorously entering a jūdō technique to hone its key aspects) training, but an increase in scores of mental confusion. No differences were found though in very short bursts of exercise, such as jūdō movements over 5 seconds or squat jumps. No changes at all were observed in the control group. Along the same lines, were the findings of Artioli et al. [96], who looked at anaerobic energy availability and found that even after rapid loss of 5% of body mass over a 5-7-day period, and despite reduced resting glucose levels, performance in a jūdō-specific exercise and a Wingate test improved in jūdōka experienced in weight-cycling, provided that the subjects were given at least 4 hours to recover after each exercise. These findings could, however, not be extrapolated to jūdōka inexperienced with weight-cycling [96].

There are also others who looked at the effects of rapid loss of body mass on aerobic energy, or both aerobic and anaerobic energy. According to Chaouachi et al. [97,98], who observed male Muslim jūdōka during the Islamic fasting period of Ramadan, aerobic performance was not significantly affected, but fatigue scores increased [97]. Filaire et al. [99] found that following a 7-day food restriction (low carbohydrate diet) in male jūdōka, there was a significant reduction in body mass, lower circulating triglycerides and free fatty
acids and decreased left arm strength and scores on the 30-second jumping test. Serum glycerol, total cholesterol, LDL-C, HDL-C and apolipoprotein A-1 and B remained unaltered [99]. These findings were largely in agreement with those of Kurakake [100] obtained in 22 male college judoka who found that nutritional parameters such as triglycerides and free fatty acids decreased pre-contest but rebounded post-contest, and this most prominently in those judoka whose reduction in body mass was equal to or exceeded 6%. These studies suggest varying outcomes with regard to the effects of rapid loss of body mass on peak power. Different experimental designs, stationary vs. dynamic exercises, different muscle groups, etc., might explain these differences. Rapid loss of body mass may express itself in the competitive judo in an impaired performance due to inadequate recovery from subsequent matches spread throughout the day, rather than negative effects being present during a single exercise test.

In attempting to clarify the mechanisms behind the effects of rapid loss of body mass on muscle metabolism, performance or predisposition to injury, one cannot ignore eventual hormonal changes, especially changes in anabolic and catabolic hormones. Between 1999 and 2003 a Spanish group of researchers conducted a variety of experiments in male judoka on the effects of competition and its outcome on serum testosterone, cortisol and prolactin [101-103]. A somewhat similar Brazilian study [104] later reported finding anticipatory salivary cortisol stress responses to competitive bouts of combat in Brazilian jujutsu practitioners. Notwithstanding, as interesting as these studies might be, the authors did not relate their findings to reduction of body mass, nor did they provide any data on body mass and body fat. However, the same year Toda et al. [105] published their findings having found that over a 3-week period of weight loss salivary cortisol levels in 15 university-level Japanese male and body fat. These findings were not surprising in the light of earlier work, in non-athletes, by Russell et al. [85] on the metabolic and structural changes in skeletal muscle during hypocaloric dieting. Taguchi [91] concluded that weight reduction, through a combination of energy restriction and intense exercise, prior to judo competition adversely affected physiological and psychological functioning. In the same context Matsumoto et al. [107] found that male judo collegiate athletes showed higher rates of bone resorption than long-distance runners or swimmers as shown by increased urinary excretion of pyridoline and deoxypyridinoline, hence raising some concerns. However, Andreoli et al. [108] demonstrated that 21 male judoka and 14 karateka had significantly higher bone mineral density and appendicular muscle mass than age-matched nonathletic subjects (18-25 yrs of age). Similarly, Prouteau et al. [109], almost ten years later, examined the effects of weight-cycling on bone metabolic balance and found increased bone formation rates concluding that powerful osteogenic stimuli provided by judo’s unique biomechanical environment may help prevent bone loss associated with reduction of body mass. Their testing involved 54 French elite judoka, both male and female subjects, average BMI 24 ± 2.1 and 22.7 ± 2.4, resp. Analytical data were obtained using DXA and blood analysis of type-I collagen and osteocalcin.

Competitive combat sports such as judo put considerable strain on musculo-tendinous structures so prevention of injury, such as stress fractures, especially in the light of rapid loss of body mass is important. Taguchi [91] also observed in male judoka increased parameters of muscle breakdown and involvement of gluconeogenesis including increased plasma concentrations of insulin, ammonia, urea, and uric acid. These findings were not surprising in the light of earlier work, in non-athletes, by Russell et al. [85] on the metabolic and structural changes in skeletal muscle during hypocaloric dieting. Taguchi [91] concluded that weight reduction, through a combination of energy restriction and intense exercise, prior to judo competition adversely affected physiological and psychological functioning. In the same context Matsumoto et al. [107] found that male judo collegiate athletes showed higher rates of bone resorption than long-distance runners or swimmers as shown by increased urinary excretion of pyridoline and deoxypyridinoline, hence raising some concerns. However, Andreoli et al. [108] demonstrated that 21 male judoka and 14 karateka had significantly higher bone mineral density and appendicular muscle mass than age-matched nonathletic subjects (18-25 yrs of age). Similarly, Prouteau et al. [109], almost ten years later, examined the effects of weight-cycling on bone metabolic balance and found increased bone formation rates concluding that powerful osteogenic stimuli provided by judo’s unique biomechanical environment may help prevent bone loss associated with reduction of body mass. Their testing involved 54 French elite judoka, both male and female subjects, average BMI 24 ± 2.1 and 22.7 ± 2.4, resp. Analytical data were obtained using DXA and blood analysis of type-I collagen and osteocalcin.

Perhaps not so directly relevant in terms of performance, but certainly relevant in terms of health and well-being, a number of authors considered the effects of rapid loss of body mass on oxidative and immunological parameters. Finaud et al. [110] examined the effects of reduction of body mass through energy and fluid restriction on oxidative stress in judoka. These authors found that rapid reduction of body mass induced significant increases in lag phase and plasma uric acid concentration, but not in oxidative-antioxidant status as indicated by maximum rate of oxidation during the propagating chain reaction, by maximum amount of conjugated dienes accumulated after the propagation phase, and by lipidic profile. However, participating in a judo competition produced more extreme values in these parameters than reduction of body mass did, as similar values were found in competitors irrespective of reduction of body mass.
Recall, Chaouachi et al. [97,98] used the Islamic custom of Ramadan fasting as a model to study food restriction and eventual reduction of body mass in fifteen Muslim male elite jūdōka. Over a 3-week period jūdōka lost an average of 1.5 kg of body mass. The authors found small but significant changes in hormonal, inflammatory, and immunological profiles following this period of food restriction [98]. Serum C-reactive protein in male elite jūdōka increased from 2.93 ± 0.26 mgL⁻¹ before to 4.60 ± 0.51 mgL⁻¹ at the end of Ramadan. Haptoglobin and antitrypsin also significantly increased at different phases during Ramadan, whereas homocysteine and prealbumin remained relatively unchanged. Immunoglobulin A increased from 1.87 ± 0.56 gL⁻¹ prior to Ramadan to 2.49 ± 0.75 gL⁻¹ at the end and remained elevated for the next three weeks. Leuko-cyte cell counts remained unaltered all along while serum albumin decreased slightly by mid-Ramadan and then recovered. The authors concluded that a period of food restriction, such a Ramadan, in male jūdōka might cause a variety of minor changes in immunological and inflammatory parameters [98]. Previously, other authors had already observed immunosuppression and increased susceptibility to infections in male jūdōka following reduction in body mass as shown by decreased neutrophil phagocytic activity [111], and reduced serum immunoglobulins and serum opsonic activity [112], for example, in male jūdōka who reduced body mass by 4.2 kg over a 19-day period. About two years after the findings by Chaouachi [98], Shimizu et al. [113] ob-served in six elite male Japanese jūdōka that a two-week program of body mass reduction caused significantly lower (P<0.05) CD3, CD4, CD8, CD28CD4, and TLR-4CD14 cell counts, suggesting that impaired cell-mediated immune function and a higher susceptibility to upper-respiratory tract infection.

Performance during contests certainly is not merely a matter of physiological function. The question arises if, and to what extent, psychological functioning is affected in male elite jūdō athletes who engage in rapid reduction of body mass. According to Filaire et al. [99], vigor was signifi-cantly lower, though tension, anger and fatigue were significantly elevated. After administering the Eating Attitudes Test (EAT-26), the Multi-dimensional Perfectionism Scale, the Body Es-teem Scale, and the Profile of Mood States Inventory in twelve competitively active male jūdō athletes (19.5 ± 0.5 yrs, 67.4 ± 13.4kg, BMI: 21.9 ± 2.2, weight reduction: 3.4 ± 0.2 kg), Filaire et al. [90] found that jūdōka scored significantly (p<0.01) lower in body esteem (weight [p< 0.05] and appearance satisfaction), disordered eating, dieting and bulimia, when compared to controls [90,114].

These studies from the last decade show that the issue of promoting loss of body mass in male jūdōka now has a higher profile, at least among sports scientists. However, jūdō coaches, clubs and federations still do not take the issue seriously in terms of the potential negative health effects [116,117]. In addition, scholars such as the Brazilian group of Franchini [27,44,118-20] continue to explore a variety of aspects related to “weight cutting” in male jūdō athletes. That being said, there exists another body mass-related phenomenon in jūdō which is still virtually undocumented, namely excessive gain of body mass or adipositas athletica [121]. This physical condition, by its nature, is limited to one defined weight-class, namely the heavy-weights (males +100 kg, females +78 kg), and to the Open class. The reason is that maximizing one’s body mass may represent an advantage over lighter opponents in these classes. The phenomenon is better known in Japanese sumō wrestling where the fighters often have colossal body dimensions. Cardiovascular complication and type-2 diabetes are among the most important risks of adipositas athletica [121]. The effect may also be observed though in athletes of other weight-classes who previously had to frequently reduce body mass, but who after ceasing their athletic career and discontinuing excessive physical training and diet, may gain excessive body mass and become obese [121-23]. Given that few judoka are able to con-tinue at a top level by the time they have reached 32 yrs of age, adipositas athletica may start as early as their mid-30s. To the best of our knowledge no research is as of yet available on the long-term health effects of adipositas athletica in jūdōka, either male or female. However, general population studies have repeatedly shown that exercising is the only variable that consistently shows effectiveness in physiological, medical, psychological and behavioral outcomes [87,124].

Scientific investigations of weight regulation practices in Female jūdōka

Weight regulation practices in female jūdōka and the media

With regard to reducing body mass in jūdōka most attention has been devoted to performance indices in male athletes. However, given some of the deleterious health consequences observed in underweight female athletes in some sports (e.g.: gymnastics, ice skating, dis-tance running, etc.) and their dysfunctional eating habits, which scientists have repeatedly alerted the athletic community about [91,125], the question arises whether similar behaviors and consequences exist in female jūdōka, and if so, to what extent?

Europe took the lead with organizing major international jūdō championships for women organ-izing the first EJU European women’s jūdō championships in 1975 in Munich twenty-four years after Europe had organized its first men’s European jūdō championships (21). The first JF Women’s World judo Championships took place New York in 1980 (21), and it is only as recently as 1992 that women’s jūdō finally became a full-fledged Olympic sport, after having been introduced in 1988 as a demonstration sport. Therefore, it took until the early 1980s female jūdō athletes started obtaining international star athlete status and before their eventual specific challenges started attracting the attention of the media (Figure 1).
Figure 1. Composite picture featuring some of the stars of the first world jūdō championships and Olympics for females, which were largely dominated by European countries. From left to right, clockwise: Barbara Classen (Germany), Irene De Kok (The Netherlands), Diane Bell (Great-Britain), Dawn Netherwood (Great-Britain), Jeannine Meulemans, Ulla Werbrouck and Ingrid Berghmans (Belgium), Margit Schmutzer, Gerda Winklbauer and Edith Hrovath (Austria).

Only now it is beginning to dawn in jūdō circles that female jūdōka might engage in exactly the same reduction of body mass practices as their male counterparts. If so, then this is important to realize for those with medical responsibilities in jūdō, in particular considering some potentially more outspoken health effects in females such as menstrual cycle irregularities, osteopenia, and subfertility [38,126,127]. That such practices of reduction of body mass might be prevalent in females became particularly obvious in the case of Heidi Rakels which became widely published in the Belgian and international press [128,129]. This particular case involved a vigorously training and energetic young female Belgian engineering graduate student and jūdōka, who had to take on the challenge of changing weight classes shortly before the 1992 Olympics in order to pursue her only avenue of participating. While under expert scientific supervision to monitor her body fat and body composition, she succeeded in losing not less than 11 kg over a 6-week period through a fierce and ambitious regime of heavy dieting and training [130-132]. As a result of this effort, Rakels, who stood 1.78 m (5’10”), won a bronze medal in the -66 kg category of the 1992 Olympics (Figure 2).
Heidi Rakels (Belgium) proudly showing her bronze 1992 Barcelona Olympic medal women’s judo after she courageously fought her way to the podium following her 11 kg reduction of body mass in 6 weeks to make the -66 kg weight class, instead of her normal -72 kg, for which Belgium had already selected Ulla Werbrouck.

However, although only in her early twenties, she soon after quit judo after having incurred a series of substantial and nonhealing successive musculo-ligamentous injuries and major psychological stress (Table 2).

<table>
<thead>
<tr>
<th>Methods of Body Mass Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Strict diet</td>
</tr>
<tr>
<td>• Strict training regime</td>
</tr>
<tr>
<td>• Severely intense training regime</td>
</tr>
<tr>
<td>• Careful definition &amp; monitoring using hydrostatic weighing</td>
</tr>
<tr>
<td>• Dietary supplements</td>
</tr>
<tr>
<td>• Mental strength: tunnel vision</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-Olympic &amp; Olympic Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>• -11kg in 6 weeks before Olympics</td>
</tr>
<tr>
<td>• Heart Rate: down to 29 bts/min</td>
</tr>
<tr>
<td>• Loss of fat + gain LBM</td>
</tr>
<tr>
<td>• Top condition</td>
</tr>
<tr>
<td>• Initially some dehydration</td>
</tr>
<tr>
<td>• No injuries!</td>
</tr>
<tr>
<td>• Most important: -66kg + Olympic Ticket !</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Immediate Post-Olympic Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Weight increase due to low metabolism</td>
</tr>
<tr>
<td>• Emotional breakdown</td>
</tr>
<tr>
<td>• Menstrual disruption &amp; hormonal dysfunction</td>
</tr>
<tr>
<td>• Wrist fracture</td>
</tr>
<tr>
<td>• Multiple Shoulder dislocations</td>
</tr>
<tr>
<td>• Stress fractures</td>
</tr>
<tr>
<td>• ACL &amp; double PCL ruptures</td>
</tr>
<tr>
<td>• Torn meniscus</td>
</tr>
<tr>
<td>• Bone &amp; muscle integrity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Required Post-Olympic Medical Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Shoulder dislocation (physio, 10/1992)</td>
</tr>
<tr>
<td>• Shoulder dislocation (surgery, 10/1992)</td>
</tr>
<tr>
<td>• Shoulder dislocation (2 surgeries, 01/1993)</td>
</tr>
<tr>
<td>• Shoulder dislocation (surgery, 03/1994)</td>
</tr>
<tr>
<td>• Lower back pain (physio, 12/1994)</td>
</tr>
<tr>
<td>• Left ACL &amp; torn left meniscus (surgery, 03/1995)</td>
</tr>
<tr>
<td>• Left PCL &amp; fractured left patella (cast, 06/1995)</td>
</tr>
<tr>
<td>• Right PCL (physio &amp; brace, 10/2002 &amp; retirement from judo)</td>
</tr>
</tbody>
</table>

(Advertisers: LBM: lean body mass; ACL: anterior cruciate ligament; PCL: posterior cruciate ligament.)

Table 2. Summary of the Belgian judoka Heidi Rakels’ performance and health consequences following her rapid reduction of body mass prior to the 1992 Olympics as publicly disclosed by her in news media and available from her personal website [124-126].
This example illustrates the importance of “weight cutting” in female competitive jūdō, and it were these events described above, which triggered our interest in this problem. The advantages of being able to compete in a lower weight category (increased leverage, power, strength) among female jūdōka, just like among male jūdōka, were generally not questioned. Before the mid-1990s some idea of the implications of “weight cutting” on performance in jūdō probably could have been derived from the vast amount of Western literature on wrestling [133-140; for a review, see 80,141]. Whilst the scientific literature on wrestling bears some relevance for the issue of weight-cutting in jūdōka, one basic problem for scientific study though is that wrestling generally is, or in those days at least, was only practiced by males. Women’s wrestling has had world championships only since 1987, and was added as an Olympic sport, only as recently as 2004. This means that for female jūdōka there did not exist the vast amount of data from a similar discipline that one might extrapolate, contrary to the situation in men’s jūdō. The first study to focus on reduction of body mass in women’s jūdō probably was the 1990 paper by Kasuga et al. [126], which was printed in Japanese and has generally remained unknown in Western jūdō literature to date.

Methods of weight-cutting in male versus female jūdōka

Similarly to what has been observed regarding the anthropometry of male jūdōka, the heavy-weight female jūdōka exhibit significantly different anthropometric and physiological character-istics than those of other weight classes [53,54,78,142] as they do not need to “cut weight” in order to qualify or be allowed to compete. Hence they have far less pressure to reduce their body mass. Jagiello et al. [142] examined the anthropometric indices of junior female jūdōka (17-19 yrs old [18.2 ± 0.7 yrs] body mass ranges from 46-’00 kg [66.1 ± 17.6 kg]). These authors using the Brozek and Keys equation [142] found average total body fat percentages of 20.8% for the light-weight women (-48 & -52 kg), 24.7% for the middle-weight women (-57 & -63 kg), 29.8% for the heavy-weight women (>70 kg), and 23.3% in controls (no SDs were reported). The authors also noted that light-weights were characterized by a non-proportionately small pelvis and a low diameter of the tibia. The percentages of total body fat observed by Jagiello et al. [142] in national elite female jūdōka are higher than the 16.3 ± 3.3% and the 20.9 ± 2.9% averages across all weight classes, heavy-weights excluded found in Olympic female jūdōka by other authors [127,143].

It appears that many female jūdōka, even if having no particular intent to reduce body mass simply through their normal training activity are in negative energy balance. Clarys et al. [144] examined energy intake and total energy expenditure in twelve female (age [mean ± SD]: 20.5 ± 2.3 yrs, mean body mass: 62.8 ± 7.9 kg) and in eight male elite jūdō athletes over a 3-day jūdō camp. Jūdōka (both males and females; no separate data were provided for each gender) trained an average of 201 ± 39 min•d⁻¹. Energy expenditure, as estimated from either personal activity diaries or from SenseWear™ armbands,(bodyMedia®, Pittsburgh, PA) was 3,554 ± 595 kcal (14,870 ± 2,490 kJ) and 3,137 ± 505 kcal (13,125 ± 2,113 kJ), respectively, the high SDs according to the authors likely due to differ-ent training regimens with some athletes engaging in resistance training while others did not. A significantly (p<0.01) negative energy balance was found on days 1-2 according to the SenseWear armband method, and on all 3 days when based of the activity diaries [144].

Female jūdōka appear to practice reduction of body mass even more than their male counterparts. Sasaki et al. [145] when surveying reductions of body mass in junior high-school and high-school male and female jūdōka, found 54.0% of junior high-school and 78.6% of high-school female jūdōka engaging in “cutting weight”. These numbers were significantly (p<0.01) different from those in male jūdōka (35.7% & 51.3%, respectively). About 1.9% of the girls were forced to lose more than 7 kg of body mass, against 3.9% of males [145]. By means of the Rapid Weight Loss Questionnaire [146] researchers from the University of Sao Paulo and Federal University of Sao Paulo found similar worrisome results. Artioli et al. [27] analyzed the responses of 607 male and 215 female jūdō athletes taking part in regional, national and international competitions, in this way offering what so far is probably the most important and extensive study about reduction of body mass practices in jūdōka. The questionnaires included questions on diet history and rapid reduction of body mass habits. Excluding heavyweight athletes, 89% of the participants answered they had previously reduced their body mass to compete. Among athletes in all weight classes, 86% engaged in pre-competition reduction of body mass; most of them lost about 5% of their body weight in a short amount of time, generally within close proximity to when the competitive event was scheduled. There was little difference between male and female jūdōka in extent of reduction of body mass, starting age, and reduction of body mass practices. Most of them reduced body mass two to five times a year, but a considerable proportion among them did so six to ten times per year.

Artioli et al. [27] also found a marked tendency for higher-level athletes to be more aggressive in their reduction of body mass behaviors. According to these authors one reason is that contest jūdōka attempt to build a long-term career in a single weight class. The reason for this is that switching weight classes implies having to face many new opponents which may require having to change all tactical and strategic preparations. Such changes may also cause problems with re-gard to agility, leverage and strength adaptation. Thus they attempt to compete as long as possible in a single weight class which may prompt them to revert to increasingly dramatic measures the older they get or the more weight they need to lose. The authors observed similar aggressive weight management strategies in athletes who had already switched to a higher weight class, probably having been forced to do so because the sacrifices they needed to make in order to still make the lower weight class had become too extreme and were therefore no longer compensated by a reliable advantage.
In a questionnaire-based survey conducted on 580 Brazilian combat sports athletes that included jūdōka, Brito et al. [147] found that 60% used a method of rapid reduction of body mass through increased energy expenditure, 50% made use of saunas and plastic clothing, while only 26.1% had consulted a nutritionist. Methods classified by the World Anti-Doping Agency (WADA) as doping and thus prohibited, such as diuretics, were also used. While previous attention had been devoted elsewhere to the different methods employed by athletes to lose body mass [148], the question arises whether male and female jūdōka use the same, or different, preferred methods to rapidly reduce their body mass. Boisseau et al. [149] examined the extent to which adolescent female jūdō athletes (age 16.1 ± 0.3 yrs) modified food and drink intake during a period of the 3-1 weeks prior to the French National Women’s Judo Championships, and what methods they used. The authors learnt that their female subjects reduced water intake during the weeks prior to competition due to the subjects restricting their overall fluid intake by approximately 8.5%. Accordingly, urinary excretion was reduced by more than half (58%) compared with their excretion two weeks earlier. These findings generally confirmed findings found by earlier studies published in Japanese only and that have remained largely unknown in the Western jūdō world. For example, Muramatsu et al. [48] found that weight-cutting practices as much as 6% of body mass in 3 days to be achieved through a combination of extreme dieting, dehydration, running, taking baths, wearing extra cloths, and daily hours-long sauna sessions. Kasuga et al. [126] found similar results with high-school female jūdōka losing body mass ranging from 2 kg in a single day, up to 6 kg in a week, through similar methods. Results obtained in wrestlers show that when only using diet as a means to lower body mass, then typically, daily energy intake has to be reduced below 100 kJ•kg⁻¹ (24 kcal•kg⁻¹) to achieve a loss of mass of >1.0 kg•wk⁻¹ (Figure 3) [6].

Figure 3. Relationship between dietary energy intake and weekly loss of body mass. An energy intake above 100 kJ•kg⁻¹ (24 kcal•kg⁻¹) resulted in a loss of mass of <1.0 kg•wk⁻¹ (Reproduced from [6, p. 253], by permission of Adis, Ltd., Springer).

Umeda et al. [150] opined that potential significant gender differences in the type or magnitude of physiological effects of “weight cutting” are caused by female jūdōka overall relying on different methods (chiefly nutritional restriction and dehydration) than their male counterparts (mostly excessive exercise), leading to important differential effects on electrolytes [150,151].

The most worrying findings though were perhaps not the occurrence of body mass reduction practices, but the unhealthy way in which these rapid reductions in body mass are achieved, and the increasingly young age at which jūdōka engage in these practices. Overall, these female jūdōka often suffer from low energy availability resulting in decreased growth and development [125]. Another remarkable finding by Artioli et al. [27] was that the most influential person on the jūdōka’s management behavior was their jūdō coach and/or instructor and training partners, a finding that was similar to what other authors had observed in wrestlers [17]. Dietitians, sports physicians, or other medically or scientifically qualified experts, on the other hand were of limited influence, as were parents. This is particularly important given the young age at which these jūdōka are known to start these practices of reducing body mass. According to Artioli et al. [27,152], “weight cutting” practices in jūdōka often were already prevalent at a young age and had started before age 15 (mean age ± SD: 12.6 ± 6.1 yrs). The authors also worried about the great reliance on dehydration methods [11,12]. Also, the magnitude of the reduction of body mass was a concern. These children are still growing, have less perfected protection against hyperthermia, dehydration and electrolyte imbalances, and the females among them have not even reached peak bone mass. Hence, these methods of “weight cutting” represent significant concerns. The International Judo Federation, which is the key body to formulate policies regarding the health of its members, has ignored these problems; instead, it has aggressively pushed towards more competitive events, including those which specifically target children, such as its recent decision to create World Judo Championships for Cadets.
First studies reporting health consequences of reduction of body mass in female jūdōka: menstrual irregularities and increased bone and muscle breakdown

To the best of our knowledge De Crée et al. were the first, in 1991 [153], to discover potential health concerns in female jūdōka. As part of a study looking into fertility problems in young athletes, these authors discovered that two young female jūdōka among their testing subjects suffered from anovulation and oligomenorrhea resistant to pharmaceutical induction of ovulation, and were at risk for developing premature osteopenia [153]. Kasuga et al. [126] in a Japanese questionnaire-based study had also observed menstrual problems among female high-school jūdōka. Over the next years, other authors [154,155] had reported stress fractures and increased muscular injuries in those female jūdōka where hypoestrogenemia was present, often as a consequence of weight cycling. These authors also observed that those athletes who were on oral contraceptives showed less frequent injuries than the others.

In 1996, Nader in The Lancet [156] devoted an editorial comment to a prospective study that had followed a number of female jūdōka preparing for the 1992 Olympics in Barcelona [127]. This work involved investigating how strenuous training, that included reduction of body mass, led to a state of relative hypoestrogenemia, menstrual problems, and increased bone and muscle breakdown particularly during the subjects’ luteal phases. Nader [156] already at that point in time warned that “Female athletes undergoing strenuous training, especially under the duress of weight reduction and the stress of competition, should be made aware of the possibility of estrogen deficiency and its consequences”, consequences which we had documented by data on muscle and bone turnover [127].

Until that point, most knowledge about the effects of body mass reduction on performance in female athletes had been derived from only two studies that had considered a number of sports disciplines only remotely comparable to jūdō, namely female skiers [142] and body-builders [157]. The ranges of reduction of body mass of the subjects from Walberg-Rankin et al.’s report [157] were similar (ranging from 0.3-3.8 kg•wk⁻¹) to those of the female jūdōka reported later by De Crée et al. [127] (see Table 3).

<table>
<thead>
<tr>
<th>Reference</th>
<th>Athlete Level</th>
<th>Age (yrs)</th>
<th>Period</th>
<th>% Body Fat</th>
<th>Loss of body mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>[159]</td>
<td>International</td>
<td>33.8 ± 1.5</td>
<td>Pre-contest</td>
<td>15.2 ± 1.0</td>
<td>Data unavailable</td>
</tr>
<tr>
<td>[160]</td>
<td>National</td>
<td>15.5 ± 0.7</td>
<td>Rest</td>
<td>16.1 ± 3.5</td>
<td>Data unavailable</td>
</tr>
<tr>
<td>[160]</td>
<td>National</td>
<td>19.0 ± 2.6</td>
<td>Rest</td>
<td>15.2 ± 2.0</td>
<td>Data unavailable</td>
</tr>
<tr>
<td>[127]</td>
<td>International</td>
<td>22.1 ± 3.0</td>
<td>Pre-training</td>
<td>16.4 ± 3.3</td>
<td>Data unavailable</td>
</tr>
<tr>
<td>[127]</td>
<td>International</td>
<td>22.1 ± 3.0</td>
<td>Pre-contest</td>
<td>14.2 ± 3.1</td>
<td>-2.2. ± 3.2% fat/8 wks</td>
</tr>
<tr>
<td>[142]</td>
<td>National</td>
<td>18.2 ± 0.7</td>
<td>Rest</td>
<td>20.8 (LW*) &lt;br&gt;24.7 (MW†) &lt;br&gt;29.8 (HW‡)</td>
<td>Data unavailable</td>
</tr>
<tr>
<td>[161]</td>
<td>National</td>
<td>20.0 ± 0.0</td>
<td>N/A</td>
<td>21.5 ± 1.4</td>
<td>Data unavailable</td>
</tr>
<tr>
<td>[143]</td>
<td>National</td>
<td>Rest</td>
<td></td>
<td>20.9 ± 2.0</td>
<td>N/A</td>
</tr>
<tr>
<td>[149]</td>
<td>National</td>
<td>16.1 ± 0.3</td>
<td>Pre-contest</td>
<td>23.3 ± 1.5</td>
<td>-1.4 ± 0.5 kg/2 wks</td>
</tr>
<tr>
<td>[109]</td>
<td>National</td>
<td>19.0 ± 2.4</td>
<td>Rest</td>
<td>23.0 ± 4.1</td>
<td>-4.0 ± 0.3%</td>
</tr>
<tr>
<td>[162]</td>
<td>National</td>
<td>19.0 ± 1.2</td>
<td>Pre-contest</td>
<td>19.2 ± 3.6</td>
<td>Data unavailable</td>
</tr>
<tr>
<td>[162]</td>
<td>National</td>
<td>19.0 ± 1.2</td>
<td>Pre-contest</td>
<td>18.1 ± 3.2</td>
<td>-3.2 ± 12.0 kg/3 wks</td>
</tr>
</tbody>
</table>

*LW: Light-weights; †: Middle-weights; ‡HW: Heavy-weights

Table 3. Comparative overview of measured percentages of body fat and reduction of body mass in female jūdōka as available from chronological literature data (adapted from [158]).
The subjects included in the study by Inger and co-authors lost about twice as much body mass, but their trial lasted 9 weeks [163], while studies from De Crée and co-workers [127] lasted 8 weeks. However, female jūdōka do appear even leaner in comparison than athletes from many other sports [164,165]. Brechtel et al. [166] investigated the prevalence of eating disorders in German female top-level athletes. These authors assessing risk by using the Fragebogen zum Essverhalten (German version of the “Three-factor Eating Questionnaire”) and the Eating Disorder Inventory questionnaires identified that women involved in weight-class combat sports such as jūdō are significantly more at risk for developing eating disorders than those in non-weight-class game and power endurance sports [166].

Indices of bone and muscle breakdown in female jūdōka after reduction of body mass

The urinary amino acids hydroxyproline (OH-Prol) and 3-methylhistidine (3-MH) offer additional valuable information on the catabolic and anabolic state of the body in response to reduction of body mass [167]. Since creatinine (Crt) excretion is a measure of muscle mass, we may use the 3-MH•Crt⁻¹ ratio as an index of fractional breakdown rate of myofibrillar protein. It has been shown that vigorous training may result in the catabolism of up to 400 g of wet muscle daily [127]. Such values indicate rapid wasting of muscle mass, and a subsequent much larger risk of muscular injury. When food balance in training athletes is reached, increases in catabolism must be accompanied by an absolute increase in protein synthesis. However, when protein ingestion is insufficient, the higher muscle breakdown rates will far outweigh the increased protein synthesis [85], as illustrated by the pronounced higher post-reduction of body mass urinary 3-MH • Crt⁻¹ and plasma myoglobin levels [127]. In addition, increased urinary OH-Prol levels observed by the same authors were indicative of an increased bone collagen breakdown. Such outcomes are potentiated by eventually low circulating estrogens found in female jūdōka after reduction of body mass. Therefore, female jūdōka, probably more than male jūdōka, are particularly at risk for incurring musculo-ligamentous and cartilaginous injuries [168,169]. The high peripheral circulation of myoglobin, uric acid, and blood diagnostic enzymes creatine phosphokinase (CPK), lactate dehydrogenase (LDH), and glutamic oxaloacetic transaminase (GOT), associated with hypocaloric reduction of body mass, are indicative of heavy demands on the renal system. Therefore, the combination of heavy training and reduction of body mass may put the jūdōka at risk for developing myoglobinuria and in extreme cases even rhabdomyolysis [65,127]. It is well known from trauma nursing and intensive care medicine that negative nitrogen balance, catabolism and lipolysis gluconeogenesis cause myoglobinuria and, in serious cases, may put the patient at risk of kidney failure. However, more recent studies suggest that that exertional muscle damage produced by eccentric exercise in healthy individuals can cause profound CPK and myoglobin elevations without renal impairment [170].

The above results are in agreement with findings in male collegiate jūdō athletes who too had shown increased rates of bone resorption as reflected by increased urinary excretion of pyridoline and deoxypyridinoline [107]. Prouteau et al. [109], almost ten years later, found increased bone formation rates after reduction of body mass as indicated by DXA and blood analysis of type-I collagen and osteocalcin in 54 French elite jūdōka including both female and male subjects. More than a decade after the pioneering study by De Crée et al. [127], the scientific methods for studying bone health had evolved, and simply had become much more accurate. At the time, those authors still had to rely on urinary alkaline phosphatase and hydroxyproline methods to estimate bone turnover [127], which since have been largely abandoned due to a lack in specificity and replicability. Nevertheless, research simultaneously studying various existing bio-chemical bone markers suggests that the serum C-terminal telopeptide of type-I collagen is not necessarily a more reliable biochemical parameter of bone turnover than the old serum hydroxy-proline technique [171]. Despite those considerations, these results from Prouteau et al. [109] supported the view that despite a reduction of body mass promoting an increased bone breakdown, jūdō in itself proved to be a powerful osteogenic stimulus due its unique biomechanical challenges. Therefore, jūdō might actually help prevent bone loss associated with reduction of body mass.

However, scrutiny of these results still yields some questions which have not been entirely satisfactorily addressed. For example, whilst having determined bone mineral density by DXA, it is unclear if the authors performed DXA more than a single time. In other words, there does not seem to have been any repetitive DXA measurements over the entire testing period bridging the reduction of body mass and weight gain period. If so, then really very little additional information is offered to support the authors’ initial hypothesis of the effects of weight cycling on bone health. A single measurement that measures higher bone mineral density in jūdōka than in controls only reflects the positive results of practicing the discipline over a substantial time, but does not allow any solid conclusions about the specific effects of weight cycling within this time window.

Furthermore, Prouteau et al. [109] noted during their subjects’ first in-weight competition of the season, thus after reduction of body mass, that values of C-terminal telopeptide of type-I collagen (CTX) were significantly increased (p< 0.0001). However, the baseline concentrations of CTX showed significantly higher values only in female jūdōka. Whilst Prouteau et al. seemed to suggest that the effects on bone parameters did not differ between genders, this cannot be concluded with certainty since 35% of their female subjects were taking oral contraceptives, hence were compensating for some of the important hypoestrogenic effects that weight-cycling might cause, and which might affect bone turnover [37]. Therefore, the results offered by Prouteau et al. [109] may in fact be masking an increased
bone turnover in females, which would then be in agreement with previous findings [107,127]. However, without separately reprocessing the data of the female subjects who are not on oral contraceptives while dismissing those of the subject on oral contraceptives as included in the subject group of Prouteau et al. [109], it is not possible to establish with certainty the impact of the subjects’ endocrine status in the overall outcome. In the absence of such additional information it seems to us that the results of the bone scans in this [109] more suggest a long-term positive effect of jūdō practice than offering any information about the effects of the subjects’ weight cycling practice. However, Rouveix et al. [115] found that 25% of the female jūdō athletes to have sustained bone injuries during their career, likely because of being at risk due to their high frequency of eating disorders and menstrual irregularities.

Hormonal and metabolic findings in female jūdōka after reduction of body mass

We had earlier indicated that Degoutte et al. [106], in a study with prospective design, found important effects of “weight cutting” on physiological and endocrine parameters in males, contrary to earlier findings based also on male jūdōka [81]. Degoutte et al. [106] emphasized that simulated competition irrespective of reduction of body mass, also produced significant decreases in plasma levels of testosterone (Figure 4), testosterone-to-cortisol ratios, alkali reserve, and free fatty acids, as well as increased parameters of muscle breakdown and involvement of gluconeogenesis, and increased plasma concentrations of insulin, ammonia, urea, and uric acid [106].

![Figure 4](image-url)

Figure 4. Correlation between plasma testosterone concentrations and percentages of body fat in 19 wrestlers during their competitive period (Reproduced from [172, p. 146], original concept [42], by permission of Éditions De Boeck Université).

In their 1995 study, De Crée et al. [127] found reduced plasma levels of estrone, estradiol, LH, and progesterone after an 8-week intensive training program in female jūdōka that was accompanied by a 2.2 ± 3.2% reduction in body fat and a decrease from 94.7 ± 2.9 to 92.8 ± 4.7% of their estimated ideal body mass. In later work, these authors also reported reduced plasma free testosterone and cortisol levels [116,173]. Hormonal homeostasis is of importance to obtain information on the anabolic or catabolic state of the body, especially in order to allow identifying any increasing risk for injury. An important decrease in circulating plasma estrogen levels in response to strenuous training and reduction of body mass in female athletes subsequently resulting in a disruption of menstrual cycle regularity is a well-known related phenomenon and a predictor for such injuries [38]. The characteristically low levels of estradiol have been linked to an increased bone breakdown and to being prone to musculo-tendinous injuries, and to impaired muscle elasticity [127,168]. The mechanisms involved are still poorly understood, but clearly include: a dysfunction of LH and gonadotropin-releasing hormone (GnRH) pulse frequency, a shortening of the luteal phase, and a disturbed positive feedback mechanism [38,153]. Total frequency of menstrual dysfunction among jūdō athletes has been reported as 58.3%, though only 7.1% of female controls suffered from oligomenorrhea [115].

Baseline cortisol values are known to be higher in trained subjects and have been assumed as a consequence of a long time hypersecretion of corticotropin-releasing hormone (CRH) [38]. Higher cortisol levels are generally associated with increased physical and mental stress in male rowers [174]. Data from male wrestlers, as reported by Roemmich et al. [175], suggested though that acute reduction of body mass in combat sports athletes may actually decrease circulating cortisol levels. The mechanism for this decrease is unknown. Decreased plasma cortisol levels in women as reported indicated by De Crée et al. [173,176] remain equally insufficiently understood. Possibly these lower numbers reflect a decreased anabolism and are directly related to the disruption of the LH oscillator [38,42,175].
The validity of testosterone-to-cortisol ratios in female athletes has remained the subject of controversy [38,174]. Reduced free testosterone-to-cortisol ratios in female elite jūdōka might indicate the need for a longer recovery from strenuous exercise when compared with male athletes [173,176,177]. Apart from reduced performance and increased risk for injuries [156,178], further health and metabolic effects of a prolonged catabolic environment induced by reduction of body mass in female jūdōka, have scarcely been mentioned elsewhere [179-181].

Increases in plasma levels of growth hormone have been observed by Roemmich and Sinning in male wrestlers [67]. These authors also measured associated growth factors. It was concluded that increases in lipolysis and growth hormone levels following reduction of body mass were the consequence of a reduction in growth hormone receptor number and of an in-season relative target cell resistance. However, an intense 8-week training program that was accompanied with re-duction of body mass in female jūdōka in addition to reduced free testosterone produced higher growth hormone levels reflecting an increase in protein synthesis [127]. Women, when compared with men, normally maintain 20-fold higher growth hormone secretory-burst mass at rest and 40-fold less stimulation of pulsatil growth hormone release by exercise than rest. However, in prospective studies with women acting as their own control increases in circulating growth hormone levels have been found to be more pronounced in female jūdōka who, during reduction of body mass, consumed arginine/ornithine supplements [127]. Such supplements are known to have growth hormone-release potential and may directly contribute to increased lipolysis.

Prouteau and co-authors [182] found in both female and male jūdōka that a precompetitive loss of body mass that averaged 4 ± 0.3% resulted in a significant decrease of 64% (p<0.001) in leptin levels and a 31% decrease in insulin (p< 0.0001). A 4 ± 0.5% regain in body mass, however, induced a 276% increase in leptin levels (p< 0.001) and an 18% increase in insulin (p< 0.0001) [176]. As mentioned further in this paper, Casimiro-Lopes et al. [183] have suggested that serum leptin may be mediated by body mineral content (especially zinc and copper) and energy homeostasis, while also reflecting the size of the adipose tissue mass [82].

Umeda et al. [150] investigating eventual gender differences in effects of rapid reduction of body mass in jūdōka found that serum creatinine, uric acid, and hematocrit increased after weight reduction but only in female jūdōka. Female jūdōka, after reduction of body mass, did not show any differences in serum troponin, creatine, uric acid, blood urea nitrogen, creatine kinase, lactate dehydrogenase and IgA, all of which had been found to significantly increase following reduction of body mass in male jūdōka [150]. These authors opined that such potential significant gender differences in the type or magnitude of physiological effects of “weight cutting” are caused by female jūdōka overall relying on different methods (chiefly nutritional restriction and dehydration) than their male counterparts (mostly excessive exercise) [150].

**Aerobic and anaerobic performance indices in female jūdōka after reduction of body mass**

Typical VO₂ max values for female jūdōka in the senior division have been reported around 41.0 ± 6.4 mL•kg⁻¹•min⁻¹ for national-level athletes [51] to 50.9 ± 2.8 mL•kg⁻¹•min⁻¹ and 51.8 mL•kg⁻¹•min⁻¹ in, respectively, Belgian and Polish Olympic team female jūdōka [127,184]. Maximal anaerobic power values in female senior international elite jūdōka have ranged from 9.63 W•kg⁻¹ [185] to 10.9 W•kg⁻¹ [184]. In general, moderate loss of body mass resulting from short-term moderate energy restriction in physically fit women who are not elite athletes exerts positive effects on aerobic performance. Zachwieja et al. [186] observed in eleven physically fit women that a two-week period of moderate dietary restriction (750 kcal•d⁻¹ or 3,138 kJ•d⁻¹) which resulted in a loss of body mass of 1.29 ± 0.16 kg (p< 0.001) resulted in improved muscle endurance and 5-mile running time.

It has been shown that competitive jūdō in females is physiologically vigorous and demanding [90,127,187-190]. Effects of reduction of body mass on aerobic and anaerobic physiological parameters are likely to more immediately and dramatically affect female jūdōka during jūdō contests, than mere blood changes in metabolic and hormonal parameters. Wolska et al. [51] identified four factors which in combination contributed to 89% of the energetic capability of female jūdōka in the seniors division. Relative indices of both anaerobic and aerobic efficiency, in par-ticular anaerobic maximal power (Wₘax•kg⁻¹) and aerobic maximal power, was the greatest (30.9%) contributor to their energetic capacity. The authors referred to these parameters as “anaerobic and aerobic maximal power relative interdependence”. Furthermore, the authors identified absolute maximal anaerobic power (demonstrated in a Wingate test) as the second most (21.6%) contributing factor. The third and fourth most important factors were absolute maximal oxygen uptake (20.2%) and ventilatory equivalent VE/VO₂ (16.3%) or the “effectiveness of lung ventilation”. There were some minor differences in younger groups of female jūdōka such as juniors and cadets where relative critical (oxygen) power also scored among the dominant factors.

Houston et al. [191], to the best of our knowledge, were the first authors to have used muscle biopsies in combat sports athletes (male wrestlers) in association with reduction of body mass, and found that an 8% loss of body mass resulted in significantly reduced glycogen storages [191]. There are very few studies that have used muscle biopsies in female athletes, let alone specifically in combat sports.
The first authors to do so in female jūdōka were De Crée et al. [127] who observed decreases in lower body muscle glycogen similar to what Houston et al. [191] had previously found in male wrestlers. However, muscle phosphagens (ATP and CP) were not significantly altered by reduction of body mass in female jūdōka. As it appears, muscle glycogen seemed to be more sensitive to reduction of body mass than the immediate fuel energy system (high-energy phosphate compounds) in skeletal muscle. To this date no other studies are as yet available which have used muscle biopsies in association with reduction of body mass in elite female jūdōka, and very few if any in other female athletes.

The 1995 study by De Crée et al. [127] provided a wealth of other data about the physiological and metabolic effects of extensive training in elite female jūdōka accompanied by loss of body mass. For example, it was observed that the absolute aerobic capacity of female jūdōka was not significantly altered by reduction of body mass when spread over weeks, which was a finding that agreed with previous data obtained in male wrestlers. Because of the paucity of experimental studies using female jūdōka, we are limited to comparing findings with studies on either male jūdōka or wrestlers. Horswill, in an earlier review on physiological issues in wrestlers had concluded that cardiovascular performance and peak oxygen uptake seemed not to be affected by rapid reduction of body mass [141]. However, in a review, Fogelholm differentiated between the effects of reduction of body mass on aerobic performance depending on the percentage and speed of the reduction of body mass, and the specific choice of wrestling techniques [80]. For example, rapid reduction of body mass between 4 to 5 kg per 12-24 hour by means of diuretics or fasting appeared to have deteriorative effects on aerobic performance [192,193]. Furthermore, the results found by De Crée et al. [127] showing an increase in relative aerobic performance when maximal oxygen uptake was expressed per body mass, were in agreement with earlier findings in male wrestlers by Fogelholm et al. [80].

The lower upper body anaerobic power observed by De Crée et al. [127] after reduction of body mass in elite female jūdōka was in agreement with the two other studies available which presented data obtained by arm-cranking after reduction of body mass in male wrestlers [194,195]. Similarly, the decreased lower body anaerobic capacity which De Crée et al. had observed, and which was shown by the shorter time to exhaustion during uphill sprinting, was in agreement with findings by Maffuli [29], who used the same protocol, though in male wrestlers. However, Houston and colleagues [192] did not find any differences in time to exhaustion post-reduction of body mass in a test that involved male wrestlers running uphill at a speed of 12.9 km•h\(^{-1}\). One can only speculate about the reason for the differences in outcomes between both studies, but it is evident that the speed in Houston’s experiment [192] was 35.5% lower than that of the subjects included in the studies by either De Crée et al. [127] or Maffuli [29]. The type of tests De Crée et al. used for upper body and lower body anaerobic performance were both short-duration one-time all-out tests. However, additional caution must be paid when attempting to draw conclusions relevant for actual jūdō performance in female jūdōka, especially for interval anaerobic exercises, or more specifically, repeated jūdō bouts. This reservation is strengthened by literature findings on male wrestlers [196].

### Strength responses to reduction of body mass in female jūdōka

Explosive strength is particularly important in jūdō, and, to lesser extent, strength endurance and maximal strength [120]. Several analytical techniques have been developed which are believed to offer a more accurate assessment of strength. Using non-isokinetic tests to measure isometric elbow strength per unit of muscle cross-sectional area (CSA), Ikai and Fukunaga could not find any differences in strength per unit CSA between trained male jūdōka and untrained men [197,198]. However, studies that made use of isokinetic equipment to measure elbow strength, expressed as peak isometric torque per unit CSA (the same parameter the present study used for analysis), have clearly demonstrated that resistance training increased maximal force [199]. However, very few studies are available that have used these techniques in jūdō athletes, either male or female, to assess the effects of reduction of body mass and parameters of physical strength.

De Crée et al. [127,173] showed that arm strength (torque) to muscle cross-sectional area (CSA) ratio in female jūdōka is high, when compared with literature data of trained females from other disciplines [199]. In addition, since only absolute arm strength (torque) per unit CSA was decreased following reduction of body mass, whereas the arm torque per unit CSA and per unit lean body mass (LBM) was increased, it is concluded that theoretically a jūdōka might benefit from “weight cutting” to compete in a lower weight class (Table 4).

<table>
<thead>
<tr>
<th>Percent of Total Loss in Body Mass</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>25%</td>
<td>70%</td>
<td>85%</td>
</tr>
<tr>
<td>Protein</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Water</td>
<td>70%</td>
<td>20%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 4. Typical proportional composition of reduction in body mass over a 3-week period of caloric restriction in athletes (From [30], by permission of Lippincott Williams & Wilkins).
However, whether a female jūdōka would still have the energy to actually mobilize that strength repeatedly as required within and between several vigorous jūdō matches with relatively quick succession, is a question of an entirely different nature but one that is equally important. To the best of our knowledge, no study in female jūdōka has either succeeded, or even attempted, to address these two questions. It is also difficult to derive the answer from studies using subject groups from other sports disciplines, or those based on data obtained from subjects of different gender.

There is a large gap in the scientific literature regarding muscle strength before, and following, reduction of body mass in female jūdōka. In fact, the data are largely absent even for male jūdōka, hence leaving nothing available to consider than data obtained in male wrestlers. Indeed, several such studies exist that used either non-isokinetic [29,200] or isokinetic [189,201] equipment to test leg strength, or non-isokinetic techniques to measure upper limb strength [192,202]. However, it is difficult to make meaningful comparisons between these studies, even if they did measure the same parameters. Often these studies mention conflicting findings which probably resulted from having used different reduction of body mass regimens (for a detailed comparison, see [6] or [141]). Houston et al. [191] and Webster et al. [139] found in male wrestlers a decrease in dynamic leg strength (peak torque values), as measured by isokinetic equipment [139,191]. Conversely, Viitasalo and colleagues [203] and most older studies which used variable types of equipment, had not been able to find any differences in static leg strength following reduction of body mass [203]. Results for static strength of the upper limbs, specifically the elbow, have been provided in a single paper only. Indeed, Maffuli [29] found significant relative increases in maximum isometric strength of the upper limbs in two male sambo wrestlers following an 8% reduction of body mass, though isometric endurance was reduced by 7%. Clearly, there is insufficient basis to extrapolate these results to predict strength outcomes following reduction of body mass in female jūdōka.

Effects of reduction of body mass on electrolytes and trace elements in female jūdōka

Data on electrolytes and trace elements in female jūdōka following reduction of body mass are limited. Although Fogelholm and co-workers [80] already, in 1993, had reported increased serum magnesium concentrations after rapid reduction of body mass in male jūdōka and wrestlers, it was not known if the same would be true in women. Even the cause of the increased serum magnesium was unclear, despite authors speculating that it might be due to leakage from the muscles following intense work [80]. Furthermore, Umeda et al. [150,151] investigating the effects of cutting weight in both male and female jūdōka, observed important decreases on serum electrolytes in both genders. However, plasma copper was found to not have changed after a period of severe training and correlated positively with plasma leptin (r= 0.66, p= 0.05) and with percentages of body fat (r= 0.80, p= 0.007) [204]. It is for this reason that suggestions have been made that plasma zinc, copper, and energy homeostasis may be involved in regulation of plasma leptin [183].

Immunological responses to reduction of body mass in female jūdōka after reduction of body mass

Suzuki et al. [205] found significantly decreased phagocytic activity per cell and increased oxidative burst activity of neutrophils in eight competitively active female jūdōka when compared to controls. Chishaki et al. [206] in 25 female university jūdōka investigated serum enzymes (myogenic enzymes, immunoglobulins and complements), neutrophils counts, reactive oxygen species production capability, and phagocytic activity after mild dehydration and loss of mass vs. severe dehydration and loss of mass. Neutrophil count was increased significantly both groups, but the changing ratios of IgA, IgG and C3 observed in the mild dehydration group were significantly higher than those in the severe dehydration group. In the severe dehydration group, post-practice PA/neutrophil had decreased significantly. The authors also found significant positive correlations severity of dehydration or reduction of body mass and changing ratios of IgA, IgG, IgM, C3, C4 and reactive oxygen species production capabilities, whereas no significant association was seen with phagocytic activity and/or serum superoxide dismutase activity [206]. These results suggest that dehydration resulted in immunosuppression, including decreased neutrophil function. The finding decreased neutrophil phagocytic activity was similar to what was previously observed in male jūdōka by Kowatari et al. [111].

Psychological responses to reduction of body mass in female jūdōka after reduction of body mass

Psychological data of the effects of reduction of body mass in jūdōka are available chiefly from male test subjects. Filaire et al. [207] in male jūdōka found that abnormal eating attitudes are more prevalent in those athletes who are characterized by body dissatisfaction and low levels of emotional intelligence, and less prevalent in those with good stress tolerance, emotional self-awareness, and positive general mood. The same research group found similar findings in female jūdōka [115]. Degoutte and colleagues [106] found that in a group who had been asked to lose approximately 5% of body weight mainly through food restriction (<4 MJ•d⁻¹) significant alterations in the subjects’ mood occurred with increasing fatigue and tension and decreasing vigor. The authors concluded that reduction of body mass through a combination of energy restriction and intense exercise prior to jūdō competition adversely affected psychological func-
tioning. Arieli and Constantini [125] in a case study reported weakness, fatigue and feelings of depression in a female jūdōka, with low energy availability due to heavy dieting and weight loss. However, not all psychological findings following reduction of body mass in female jūdōka are thought to exert negative effects on actual performance. For example, it is suggested that the psychological impact of the significantly increased hostility and aggression factors associated with reduction of body mass in jūdōka, might contribute to a substantial degree towards an increased performance or mobilization of strength [12,208].

Yoshioka et al. [162] are the only authors to date to have specifically investigated into gender differences in psychological responses to reduction of body mass in jūdōka. These authors found that, interestingly, total mood disturbance scores as assessed by the Profile of Mood State questionnaire, increased after reduction of body mass only in male, but not in female jūdōka. Furthermore, only in female jūdōka was reduction of body mass accompanied by a decrease in anger and depression scores. The authors suggested that in females psychological stress may be caused by anxiety engendered by the overall concept of reduction of mass preceding any eventual reduction of mass, whereas in males it may be caused by the actual reduction of body mass.

Role of dietary protein within methods of weight-cutting practiced by female jūdōka

Boisseau et al. [149] in nine female jūdō athletes (age 16.1 ± 0.3 yrs) observed an average reduction in body mass of 1.1 ± 0.5 kg and 2% of fat-free body mass over a two-week period prior to the French National Women’s Judo Championships, while percentages of fat mass remained unaltered. The authors also examined the nutritional intake and dietary composition. They calculated nitrogen balance from reported daily protein intake, urine nitrogen excretion, and estimated fecal and integumentary nitrogen losses. Expressed in g•d−1 mass remained unaltered. The authors also learnt that their subjects reduced water intake during the weeks prior to competition due to the subjects restricting their overall fluid intake by approximately 8.5%. Accordingly, urinary excretion was reduced by more than half (58%) compared with their excretion two weeks earlier. Despite these differences, nitrogen balances apparently were not significantly different the week prior to competition when compared to two weeks earlier. This was likely due to both protein intake and exercise intensity over that two-week period having remained largely unaltered [149].

The authors concluded that food and drink restrictions induced a combined negative effect on physical and psychological capacities of young, adolescent female jūdōka [149]. In determining these strategies jūdōka are driven by passing the weigh-in, which is generally held early in the morning for regional and national competitions, and on the evening before for large international contests. Jūdō athletes then try to replenish body fluids, electrolytes, and glycogen in the brief period (1–3 hr) between the weigh-in and the competition [149]. Knowledge of physiology and physiological effects is generally poor, as is dietary supervision [41]. If such supervision exists at all, it is generally by basic dieticians or people with a basic professional degree such as a bachelor’s degree in physical education, but rarely by experts with large scientific and research experience involving top-athletes. Reestablishing fluid homeostasis and replenishing muscle glycogen might well take 24–48 hr or even longer to accomplish. Because the effects of these practices are likely subject to interindividual differences they will, to a different degree, adversely affect the jūdōka’s energy reserves, fluid and electrolyte balances, and accordingly negatively affect performance. These findings in female jūdōka are similar to the practices of unbalanced dietary regiments that Taguchi [91] had previously reported in male jūdōka.

Performance effects of reduction of body mass in female jūdōka after protein supplementation

Several authors have indicated that, in weight-class sports, during food restriction, athletes have to increase the carbohydrate and protein ratio to prevent the otherwise unavoidable negative effects on body composition and performance [49,172,209]. A high percentage of energy from dietary protein through its satiety and energy inefficiency related to the change in body composition limits gain or regain of body mass. Protein is more satiating than carbohydrate and fat both in the short term and in the long term [50]. High-protein diets affect loss of body mass positively only under ad libitum energy intake conditions hence also implying a decreased energy intake. In this way dietary protein improves both body composition and metabolic profile [50]. A hypoenergetic diet that provided twice the RDA for protein was more effective in retaining a positive nitrogen balance in male weight lifters who attempted to achieve low body fat, than a diet that contained a higher carbohydrate content while limited to the RDA for protein [210].

However, the use of protein supplementation for athletes attempting to lose weight has also been the subject of considerable controversy [211,212]. A frequently heard argument is that relatively little protein is consumed as fuel for muscular work. Therefore, many authors...
do not appear to encourage protein supplementation in athletes. Similarly, the use of high dose simple amino acids, such as the growth hormone-releasing arginine and ornithine finds little support. Despite some of these negative reports, Elam [213] found a significant increase in lipolysis in men enrolled in a strength and weight training program while taking 1 g•d⁻¹ of arginine and ornithine each. Furthermore, compelling new arguments exist that considerably more protein can be used by the human body through the alanine-glucose cycle, when exercising in a glycogen-depleted state [127,211,214]. “Weight cutting” while training for 4 to 6 hours a day practicing jūdō, resistance or interval exercises, evidently puts severe demands on the glycogen system [215-217], as has been evidenced by reduced glycogen contents in muscle biopsies [127]. None of the studies discrediting the use of protein or amino acid supplementation have studied such athlete populations during comparable activities, or in any kind of elite female athletes [218-219].

With regard to the usefulness of protein supplementation in jūdōka the only existing studies to date have exclusively used male jūdōka; also, these studies did not specifically look at the combination protein supplementation/reduction of body mass. Laskowski and Antosiewicz [220] found that when twelve (male) jūdōka were divided into two groups, with one group receiving daily soy protein supplements at 0.5 g•kg⁻¹ of body mass, after 4 weeks of jūdō training their performance in a VO₂ max and a Wingate test was significantly better than in the group not on protein supplements. Moreover, if the group stopped taking protein supplements, but continued training for another 3 months, all differences with the other group disappeared. The authors concluded that those data indicated that supplementing normal diet by soy protein supplements (0.5 g•kg⁻¹ of body mass daily) is beneficial for a jūdōka for his aerobic and anaerobic performance.

Practical Applications

We conclude that weight-cutting can lead to objectively measurable advantages in jūdōka. However, actual weight-cycling also has been proven to significantly slow down resting metabolic rates and obstruct future reduction of body mass [88,89,221-228]. Therefore, continuous weight cycling should be discouraged. Proper hydration is essential to avoid a deterioration of performance, prevent hypovolemia and suboptimal thermal regulation, and relieve increased renal stress [229] from muscle and bone breakdown substances, and subsequent risks for developing myoglobinuria and rhabdomyolysis [13,17,127]. Franchini et al. [44] further recommend that athletes should be administered hydration tests to have their weigh-in validated. In addition, these authors propose that the time between weigh-in and matches should be minimal (<1 h), number of weigh-ins should be limited to a single time [44]. Supervision by properly qualified expert medical personnel is recommended for female elite jūdōka feeling a need to reduce or maintain a reduced body mass. Performance coaches should strongly discourage that prepubertal or adolescent female jūdō athletes strive for or maintain a body mass below normal. Validated questionnaires are now available to help identify jūdōka who are particularly at risk for loss of body mass-related pathologies [146]. Accurate assessment of percentages of body fat by hydrostatic weighing or DXA and follow up of menstrual status and bone health are recommended for girls and women (or men) in jūdō at risk for maintaining suboptimal body mass [230]. Furthermore, female jūdōka who need to lose a substantial amount of body mass should be meticulously monitored for estradiol, testosterone, cortisol, myoglobin, and markers of muscle (3-methylhistidine) and bone breakdown to prevent an imbalance of catabolism over anabolism, which may result in frequent and important injuries involving muscles, tendons, ligaments, and bone. Female jūdōka who need to reduce body mass are more likely to avoid a substantial impairment of performance capacity (especially strength and anaerobic power) when taking protein and growth hormone-releasing amino acids, which may also potentiate fat loss [50,217].

In summary, referring to our initial practical questions for the strength and conditioning professional involved with jūdō, jūdō coaches, and jūdō team physicians, and based on the findings of this review paper, it is recommended that:

• They encourage their jūdō athletes not to engage in weight-cycling as the process reduces the success of effectively losing body mass and maintaining that loss.
• They are aware that male and female jūdō athletes may revert to different methods of rapid loss of body mass, and have a role in educating them about the negative effects of rapid loss of body mass through dehydration on jūdō performance, and discourage the use of this method.
• They are aware that effects of rapid loss of body mass may be of a physiological or psychological nature.
• They are aware that although many of the effects of rapid loss of body mass are similar in female and male jūdōka, female jūdōka who show Female Athlete Triad-like symptoms (eating disorders, oligomenorrhea or amenorrhea, and musculo-tendinous injuries or osteopenia) may be particularly at risk for negative health consequences.
• They are aware of a potential role of a balanced nutrition and nutritional supplements in limiting impairment of jūdō performance when having to lose body mass.

In the previous paragraphs we have elaborated about the problems in jūdō caused by its weight classes. This review may assist jūdō coaches to improve their training prescription and, consequently, maximize their athlete’s performance. However, none of the above
recommendations in the end will properly solve what has become one of the many fundamental problems in present day competitive jūdō, i.e. the preoccupation with weight classes and ensuing problem of rapid and excessive weightloss. It is noted that kendō (Japanese sword play, lit.: “the way of the sword”), a related budō martial art that is not an Olympic discipline, does not have weight divisions, and hence does not have weight cycling. The continued sportification of jūdō over the past 70 years, no doubt, has made it increasingly deviate from its noble pedagogical and moral objectives as defined by its founder [22] leading to questions such as whether rapid and excessive weight loss qualifies as a way of cheating that should be outlawed, given its performance-enhancing intent and potentially negative effects on health [230-233].

The resolution to deal with the problems in jūdō caused by its weight classes clearly lies at the organizational level with the International Judo Federation, who could learn some useful lessons from the rules of collegiate wrestling in the United States, which have been revised several times to take into account similar health concerns. Franchini et al. [60] have suggested, as an alternative, that each jūdōka’s minimal allowed weight should be determined at the start of the season, and one should not be allowed to compete in weight classes that require >1.5% loss of body mass. This is, however, not watertight since nothing prevents the athlete from already being underweight at the beginning of the season. A more solid remedy would be for jūdō to revert back to its origin. Returning to the pre’962 system with only an Open division and no further weight classes would discourage athletes who are middle-weight and lower to participate out of fear for injuries, and for not having a realistic chance to medal. The other alternative would be to establish floating weight divisions created by a computer algorithm immediately prior to the contest by taking into account the number and spread of registered participants. Such a system would make reduction of body mass undesirable by making predictions impossible as whether one would rank near the top or bottom of a weight class.

Notes

For absolute rigor, long Japanese vowel sounds have been approximated using macrons (e.g. Kōdōkan) in order to indicate their Japanese pronunciation as closely as possible. However, when referring to or quoting from Western literature, the relevant text or author is cited exactly as per the original source, with macrons used or omitted accordingly.

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