Biology of Sport, Vol. 24 N°2, 2007

GENDER DIFFERENCES IN RESPONSE TO WEIGHT CYCLING IN ELITE JUDOISTS

S. Prouteau[1,2], G. Ducher[1,2], C. Serbescu[1,2], L. Benhamou[1,2], D. Courteix[1,2]

[1]Bone Tissue Architecture and Physical Exercise, (ATOSEP Laboratory), University of Orleans, Orleans (45), France; [2]Institute of Prevention and Research in Osteoporosis (IPROS) - INSERM Unit 658 - Orleans Regional Hospital, France

Abstract. Background: Existing reports on the effects of weight cycling in weight class sports used indirect and cumbersome techniques to estimate soft tissue alterations and did not address gender differences. Novelty and aim of the present study was to provide an accurate quantification of soft tissue alterations and to analyze gender differences in response to weight cycling in elite judoists. Methods: Forty-eight elite judoists (males n=22, females n=26) were tested at Early-Season (ES), prior (Pre-C) and after (Post-C) competition. Each time, body composition was assessed by Dual-Energy X-ray Absorptiometry (DXA) and Sargent test and handgrip strength tests were performed. Training history and lifestyle data were collected by questionnaires. Weight-Cyclers (C) and Non-Cyclers (NC) were identified by a statistical typological classification test. Results: Gender had no influence on the typological classification into C or NC. C in both gender significantly altered lean and fat masses at pre-C and Post-C ($p<0.0001$). Weight loss was for 68% lean mass in men, and 54% in women. In men, Pre-C lean mass loss induced prolonged impaired performance despite Post-C weight regain ($p<0.05$). Conversely, females at post-C revealed increased muscle mass at the expense of fat and did not suffer performance alterations. Conclusion: DXA should be used to set realistic weight goals and to select the weight class most appropriate to the athlete's stature and physique. The leanness pertaining to male athletes put them at greater risk than their female counterparts. Accurate follow up of body composition alterations is recommended to optimise training and prevent injuries. ***(Biol.Sport 24:91-104, 2007)***

Key words: Judo - Weight cycling - Body composition alterations - Physical performance

Reprint request to: Stephanie Prouteau, IPROS-INSERM U 658, C.H.R Orleans - 1, rue Porte Madeleine, B.P 2439, 45032 Orleans CEDEX 1, France

Tel: 33 (0)2.38.74.40.67; Fax: 33 (0)2.38.74.40.24;

E-mail: stephanie.prouteau@chr-orleans.fr

Introduction

Judo is the most widely known martial art, and after football, the second most practiced sport worldwide. In terms of national organizations, judo is the largest sport in the world, with 183 member nations in the International Judo Federation and millions of participants. However, scientific studies on judo are very scarce. Competitive judo is performed in strict weight categories, leading many competitors to lose and regain weight repeatedly during the season [2]. Ideally, judoists should select the weight class most appropriate to their stature and body composition. However, many undergo severe weight reduction to compete in a lower-weight class, trying to gain a competitive edge over their opponents. Weight cycling is a common practice in judo, despite evidence establishing that associated health risks outweigh the benefits of the outcome [11]. However, studies on judo, wrestling and boxing include mainly male athletes and gender specific responses to weight cycling have not been questioned yet.

Most of the previous studies on weight loss practices in weight class sports estimated lean and fat mass amounts from skinfold measurements and regression equations [14], or total body potassium calibrations [10]. Many of these methods carry shortcomings and are nowadays considered cumbersome. In contrast, precision error of DXA is very low [7]. Aim of this study was to provide accurate quantification of the effects of weight cycling on soft tissue composition in male and female judoists and to analyze how these changes relate to physical performance measures and injury occurrence.

An accurate assessment of body composition alterations, as well as information on gender-specific responses to weight-cycling would be a valuable contribution to coaches and health personnel in order to optimise training, monitor weight categories, preserve health and prevent injuries.

Materials and Methods

Subjects: Fifty-four elite judoists from the French national training camp of Orleans (France) volunteered to participate in this study. Four judoists dropped out of the study. Reasons were a too tight schedule caused by frequent trips abroad for competitive needs, or transfer to another University. Two further judoists got excluded because of severe injury sustained during training. All judoists were national standard athletes (men: n=22, women: n=26), who had been training for 13±4 years. Weekly training volume had been constant over the past three years with an average of 9.5 (±3) hours per week. There were no differences between

male and female judoists regarding any of these training variables. This study analysed the first weight cycle of the judo season.

Testing schedule: The judoists were tested three times: First, at Early Season (ES, in October), aimed at testing the judoists at their natural bodyweight. The second measure was scheduled 24 h (48 h in three judoists leaving for competition abroad), prior to the first 'in-weight' competition of the season, labelled as 'Pre-competitive' (Pre-C, in March). Three weeks after Pre-C testing, the third measure took place, labelled as 'Post-competitive' (Post-C).

This research project was undertaken after approval from the regional Human Ethics Committee of the University of Tours (Medical School), which is the Institutional Review Board for all biomedical studies conducted in our region (Région Centre, France). All participants in this study gave written informed consent. None of the subjects reported taking any medications, diuretics, protein supplements, or creatine monohydrate. Exclusion criteria were failure to comply with the entire protocol and suspension of training for more than 2 weeks.

Physical performance measures: Two validated performance tests were chosen in order to measure basic physical performance alterations. Hand-gripping strength and power output of the legs both relate to judo motor activity and have the advantage of not inducing any fatigue the eve of the competition. Prior to the physical tests, standardized instructions explaining the procedures and a demonstration of the proper technique, were given to each participant. The order of all the measurements was always 1) Height and weight measurements, 2) Assessment of body composition by DXA, 3) Sargent test, 4) Hand-grip strength test.

Subjects were weighed barefoot, in underwear, on a balance-beam scale (SECA 709, Hamburg, Germany). Body mass index (BMI) was calculated from ES height and weight measurements. BMI at birth was obtained from medical records. All of the measurements described hereafter were performed between 8.30 and 9.30 am. The subjects were required not to have eaten nor exercised before presenting to the laboratory.

Vertical jump: Vertical jumping performance in centimeters was obtained following the procedure described by Sargent [12]. Although all of the athletes were familiar with this test, three attempts were given due to the skill component. The best jump was used for analyses.

Handgrip dynamometer: Grip strength was measured in kilograms with a hand-held dynamometer equipped with a strain gauge (Scaime ZF 200 kg – n°30141). Measurements were taken with the subject seated on a chair. The upper extremity was positioned in neutral adduction and flexion, with the elbow flexed to 90

degrees and the forearm in a mid-prone position. The wrist was maintained in a neutral position by the device. One warm-up trial was made with each hand in order to adjust the grip for hand size. The subjects were then asked to perform three maximal efforts for each hand, separated by 30-seconds resting periods. The best score was recorded as maximum grip strength. Results of right and left grip strength were added and the average value was used for analyses. The device was calibrated monthly with weights ranging from 0 to 100 kg. The short-term precision of the device was calculated according to the formula given by Glüer *et al.* [6]. The root mean square coefficient of variation was 0.56%.

Assessment of body composition: Total and regional Bone Mineral Content (BMC), Bone Mineral Density (BMD) and soft tissue composition were measured by Dual-energy X-ray Absorptiometry (DXA), following recommended procedures [3,7]. Regional bone measurements included the lumbar spine (L1 to L4) and the non-dominant hip. Soft tissue composition comprised fat mass and lean mass, the latter being an accepted surrogate measure for muscle mass [18,19]. The instrument used was a Hologic QDR 4500 (Hologic Inc., Waltham, USA) with the Enhanced Array Whole Body software package QDR for Windows, version 11.2. All the scans and analysis were performed by the same operator in order to limit inter-observer variability. The coefficient of variation in our lab is 0.84% for BMD, 1.2% for BMC, 3.9% for fat mass and 0.48% for lean tissue mass measurements.

Physical activity and lifestyle: The judoists were questioned regarding weight loss methods and history of physical training. Confirmation of the judoists' training loads was obtained from medical records and training logs. Female judoists were interviewed regarding their menstrual status, age of menarche (first menses) and use of the oral contraceptive pill. All questionnaires were administered by the same researcher.

Statistical analyses: The Gaussian distribution of the variables was tested with a Shapiro-Wilk test. In order to accurately assign the judoists into their respective "cycling" or "non-cycling" group, a typological classification was performed using the method of aggregation around a mobile centre. The variables entered into this multivariate analysis were the amount of weight lost and consecutively regained. Influence of gender on the typological classification was tested with a chi-square test. Between-groups comparisons of physical and training variables were made with one-way ANOVA. To establish main effects over the season, weight, body composition and performance measures were analysed by repeated measures of ANOVA. Statistical significance was set at $p<0.05$. All statistical analyses were performed by PCSM® statistical software (Optima-Deltasoft, France).

Results

Table 1
Descriptive characteristics of the judoists at early season (mean ±SD)

Characteristics	Men (n=22	Women (n=26)
Age (yrs)	21±3	19±2
Weight (kg)	73.5±8.0	60.2±9.0
Height (cm)	174.9±4.9	162.8±7.3
BMI	24.0±2.0	22.6±2.4
Lean Mass (g)	61562±5778	43728±5048
% Body Fat (DXA)	11.6±3.6	23.0±4.0
Total Bone Mineral Content (BMC, in g)	3313.2±386.5	2412.4±320.8
Total Bone Mineral Density (BMD, in g/cm²)	1.40±0.10	1.21±0.07

Physical characteristics: The physical characteristics of the judoists at the beginning of the study (Early-season) are described in Table 1. The typological classification test identified the judoists as cyclers (C=19) or non-cyclers (NC=29). Gender had no influence on the typological classification into C (men: n=9, women: n=10) or NC (men: n=13, women: n=16). Weight fluctuations in the C group ranged from 1.5 to 5.5 kg. Average Pre-C body weight loss was 4%±0.3 followed by a Post-C weight regain of 4%±0.5.

Table 2
Comparison of the physical characteristics of male C and NC at early season (mean ±SD)

	Cyclers (n=9)	Non-cyclers (n=13)	p value
Body weight (kg)	77.7±8.2	70.7±7.6	p<0.05
Lean mass (kg)	64.9±5.5	59.3±4.9	p<0.05
Fat mass (%)	11.6±4.0	11.6±3.5	NS
Bone mineral content (BMC, in g)	3528±342	3164±353	p<0.05
Bone mineral density (BMD, in g/cm²)	1.45±0.1	1.37±0.08	p<0.05

Male C had significantly greater ES weight, BMC, BMD and lean mass than their non-cycling counterparts. No further variable distinguished both groups. These results are shown in Table 2. There was no significant difference in females between the C and NC groups.

Weight and body composition were significantly altered over the course of the season in the C group ($p<0.0001$) while remaining unchanged in the NC group. At Pre-C, in the C group, lean mass reflected 68% of pre-competitive bodyweight loss in males and 54% in females.

With post-C weight regain, initial ES lean mass was recovered in males, and exceeded ES values in women. Conversely, fat mass further decreased from Pre-C to Post-C in women, while it increased in male without returning to initial ES values. Body composition results at ES, Pre-C and Post-C are given in Fig. 1.

BMI at birth was no different between genders, but significantly higher in the C group than in the NC group (13.7±0.9 vs. 12.9±0.8; $p<0.01$).

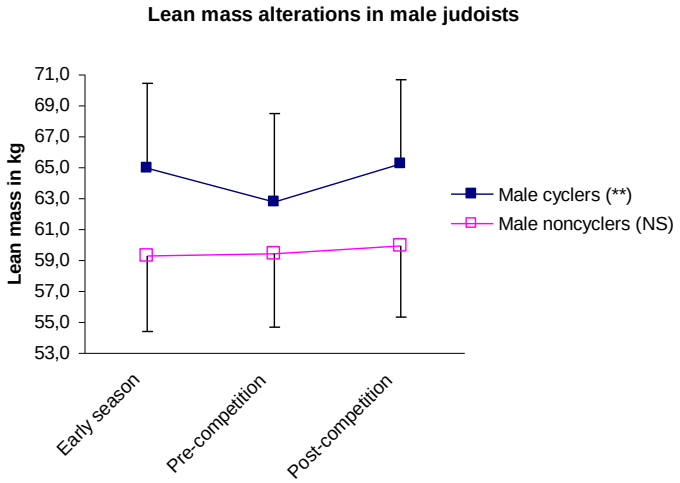

Fig. 1a
**significant difference ($p<0.0001$) ; NS, ($p>0.05$)

Physical performance tests: Vertical jumping data for 15 subjects and handgrip strength data for 3 subjects were not collected due to injuries, which restricted strength testing procedures. Among the eighteen athletes who got injured during the course of their season, fifteen were weight cyclers and six were non-cyclers. Variations in performances over the season are given for the judoists having completed all of the three testing periods.

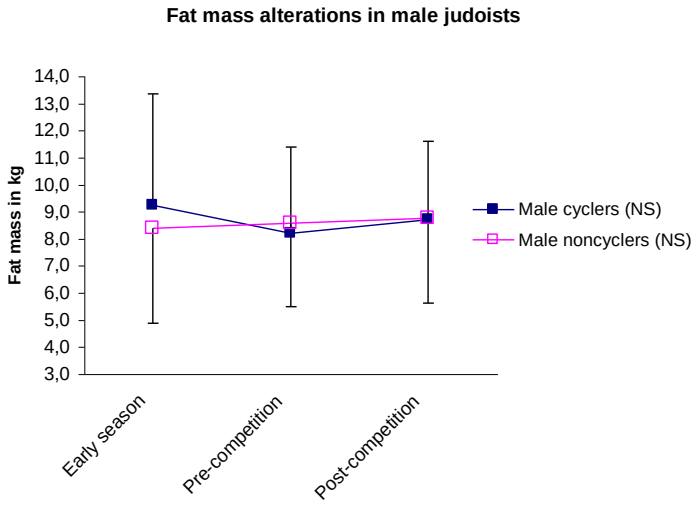

Fig. 1b
NS, (p>0.05)

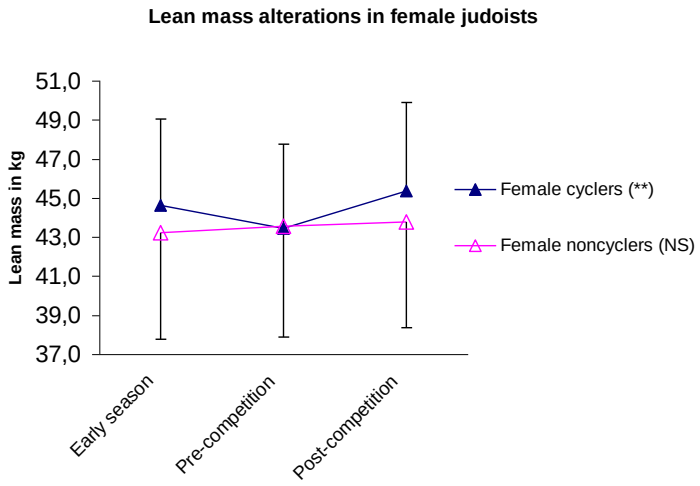

Fig. 1c
**significant difference (p<0.001)
NS, (p>0.05)

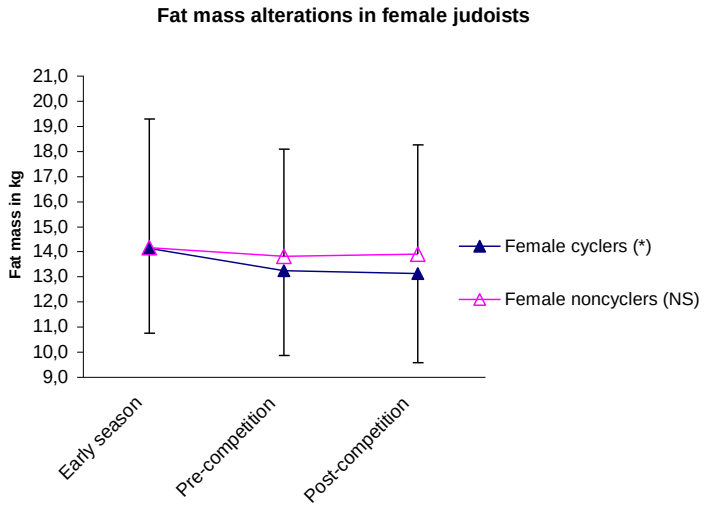

Fig. 1d
*significant difference ($p<0.005$)
NS, ($p>0.05$)

Compared to baseline values at ES, male C experienced a significant decrease in their jumping performances at Pre-C ($p<0.05$) and at Post-C ($p<0.05$). Their hand-grip strength decreased similarly, but without reaching significance ($p=0.06$). Jumping performances and grip strength remained unaltered in female C and NC. These results are shown in Fig. 2.

Life style questionnaire: Eight females of the NC group and four females of the C group were taking oral contraception, hence no menstrual irregularities could be identified in these judoists. Among the fourteen athletes not taking OC, three judoists from the C group were amenorrheic. It is noteworthy however, that female C experienced their menarche later than NC (13.5±1.3 vs. 12.2±1.3 years; $p<0.05$).

The method used to achieve weight goals was food restriction in the week leading up to the contest. None of the judoists reported using any dehydration methods, and they were educated as to the associated health hazards. The judoists of the national training camp benefited an educational program to enhance health awareness and prevent ill practices.

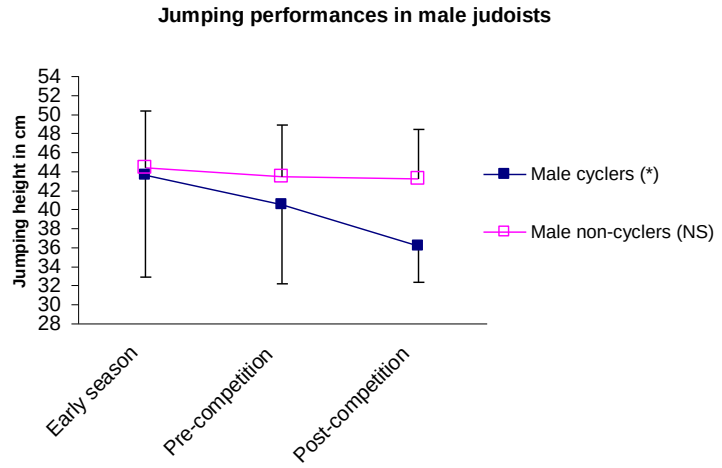

Fig. 2a
*significant difference ($p<0.05$)
NS, ($p>0.05$)

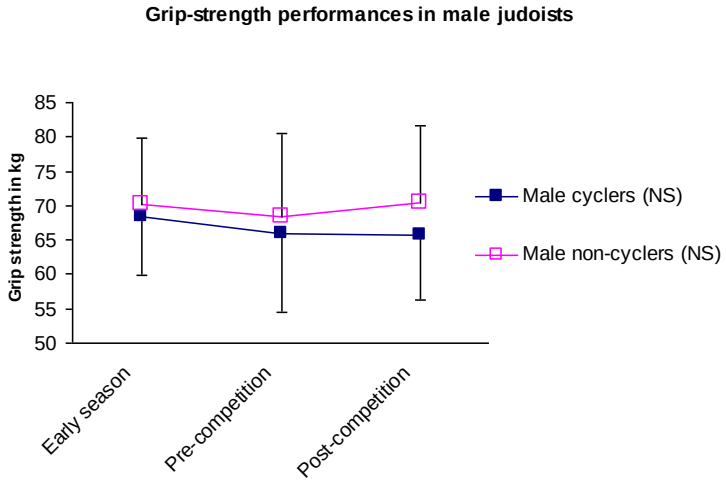

Fig. 2b
NS, ($p>0.05$)

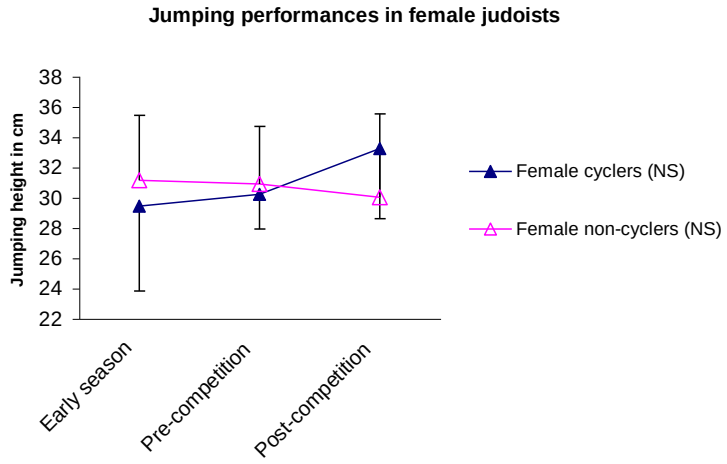

Fig. 2c
NS, (p>0.5)

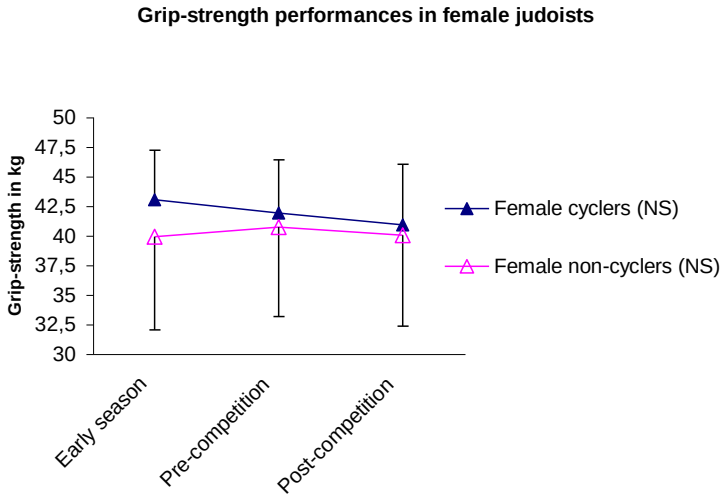

Fig. 2d
NS, (p>0.05)

Discussion

This study showed that weight cycling altered lean mass, rather than fat mass, and that lean tissue is affected to a far greater extend then what was previously thought using other indirect techniques of body composition assessment [10,14]. Lean mass alterations are linked to physical performance alterations and increased rate of injury. These ill effects last despite initial weight recovery. Male C lost a greater amount of lean mass than their female counterparts. Accordingly, physical performances in males were durably decreased, whereas performances were not diminished in female judoists. Male judoists had relatively low body fat, explaining that weight loss affected mainly lean mass. Despite the fact that weight reduction occurred within a week, and hence too rapidly to optimise lipolysis, it may also be difficult to further reduce fat stores in already lean athletes [8].

Controversy remains about the effects of weight loss on physical performance, as impaired [9], unchanged [13] and improved performances have been reported [16]. In cause for this lack of consistency, the rate of weight loss, the kind and amount of soft tissue lost, number and training characteristics of the subjects. In the present study, weight loss was associated with decreased performance and a carry-over effect.

Approximately 68% of the body weight loss reflected lean mass, which is well above the 22% suggested by Webster *et al.*, [20] to be an optimal figure. Thus, even though the male cyclers were at a relative advantage over their non-cycling counterparts due to their greater ES lean mass, this advantage was lost with pre-competitive weight loss. The protective effect of exercise on the maintenance of lean body mass during diet-induced weight loss [1,15] did not occur in the judoists. Their leanness and high level of physical fitness, but also the rate of weight loss, are most likely in cause for this effect.

With Post-C weight regain, male judoists recovered half of their initial ES fat mass and returned to initial ES lean mass values. Conversely, female judoists further decreased their fat stores and regained lean mass exceeding ES values. This discrepancy between genders could be explained by the fact that in women, competitive training might have triggered muscle development at the expense of fat, allowing them to fulfil their lean mass potential. This trend was not seen in men, as male judoists probably already possessed at ES the necessary muscle mass to perform in judo. Muscle mass in men is under strong hormonal influence, (i.e., testosterone), while this is not the case in women, who might actually easier loose lean mass with decreased training loads (i.e., summer break). We cannot exclude either, that male judoists might simply have been more active than their female

counterparts over the summer break, thus maintaining their muscle mass from one season to another.

Despite post-competitive muscle mass recovery, physical performances continued to decrease. This carry-over suggests that weight loss triggers prolonged fatigue, which is not reversed with subsequent weight regain. Among the plausible causes, proteolysis and alterations of the contractile components of the muscle cell, but also general fatigue caused by diet and glycogen depletion. This theory is consistent with the high rate of injuries affecting weight cyclers during this study. Hence, striving to achieve a realistic weight goal over a prolonged period, as opposed to severe food restriction in the week leading to the contest, might favour performance, not only on the short term by allowing the judoist to compete with replete energy stores, but also on the long term, by preserving muscle mass, preventing injuries and fatigue [4,17].

Female C experienced menarche later than NC. However, since we do not have information on training intensity and body composition during their teens, this data is only observational in nature.

C in both genders displayed a higher BMI at birth. This is an interesting finding, since it might partly account for the 'yoyo-effect' and the difficulty of maintaining a stable weight. This remains speculative at this point, but there is convincing evidence from the literature to suggest that a high BMI at birth is related to patterns of metabolism and body composition later in life [5]. Further research in weight-class sports would help determining if there is such a link and to what extend weight-class sporting activities might reveal, or restrain the amplitude, of such fluctuations.

Conclusion

Evaluation of body composition is of valuable contribution to coaches and health personnel, as a regular assessment of soft tissue composition in elite judoists is needed to set realistic weight goals and to select the weight class most appropriate to the athlete's stature and physique. In this study, weight cycling was associated with considerable loss in lean mass, decreased performance and high rate of injuries. The degree of leanness pertaining to male athletes puts them at greater risk than their female counterparts. Hence, weight maintenance is recommended to preserve health, avoid injuries and achieve performance goals.

References

1. Ballor D.L., E.T.Poehlman (1994) Exercise-training enhances lean tissue mass preservation during diet-induced weight loss: a meta-analytical finding. *Int.J.Obes.Relat. Metab.Disord.* 18:35-40

2. Brownell K.D., S.N.Steen, J.H.Wilmore (1987) Weight regulation practices in athletes: analysis of metabolic and health effects. *Med.Sci.Sports Exerc.* 19:546-556

3. Chan G.M. (1992) Performance of dual-energy X-ray absorptiometry in evaluating bone, lean body mass and fat in paediatric subjects. *J.Bone Miner.Res.* 4:369-74

4. Costill D.L., M.G.Flynn, J.P.Kirwan, J.A.Houmard, J.B.Mitchell, R.Thomas, et al. (1988) Effects of repeated days of intensified training on muscle glycogen and swimming performance. *Med.Sci.Sports Exerc.* 20:249-54

5. Eriksson J., T.Forsen, J.Tuomilehto, C.Osmond, D.Barker (2001) Size at birth, childhood growth and obesity in adult life. *Int.J.Obes.Relat.Disord.* 25:735-40

6. Glüer C.C., G.Blake, Y.Lu, B.A.Blunt, M.Jergas, H.K.Genant (1995) Accurate assessment of precision errors : how to measure the reproducibility of bone densitometry techniques. *Osteoporos.Int.* 5:262-70

7. Haarbo J., A.Gotfredsen, C.Hassager, C.Christiensen (1991) Validation of body composition by dual energy X-ray absorptiometry (DEXA). *Clin.Physiol.* 11:331-41

8. Hills A.P., N.M.Byrne (2004) Physical activity in the management of obesity. *Clin. Dermatol.* 22:315-8

9. Houston M.E., D.A.Marrin, H.J.Green, J.A.Thomson (1981) The effect of rapid weight loss on physiological function in wrestlers. *Phys.Sports Med.* 9:73-78

10. Koutedakis Y., P.J.Pacy, R.M.Quevedo, D.J.Millward, R.Hesp, C.Boreham, et al. (1994) The effects of two different periods of weight-reduction on selected performance parameters in elite oarswomen. *Int.J.Sports Med.* 15:472-477

11. Oppliger R.A., H.S.Case, C.A.Horswill, G.L.Landry, A.C.Shelter (1996) American College of Sports Medicine position stand. Weight loss in wrestlers. *Med.Sci.Sports Exerc.* 28(6):ix-xii

12. Sargent D.A. (1921) The physical test of a man. *Am.Phys.Educ.Rev.* 26:188-194

13. Serfass R.C., G.A.Stull, J.F.Alexander. (1984) The effects of rapid weight loss and attempted rehydration on strength and endurance of the handgripping muscles in college wrestlers. *Res.Ques.Exerc.Sports* 55:46-53

14. Steen S.N., R.A.Oppliger, K.D.Brownell (1988) Metabolic effects of repeated weight loss and regain in adolescent wrestlers. *JAMA* 260:47-50

15. Svendsen O.L., C.Hassager, C.Christiansen (1993) Effect of an energy-restrictive diet, with or without exercise, on lean tissue mass, resting metabolic rate, cardiovascular risk factors, and bone in overweight postmenopausal women. *Am.J.Med.* 95:131-40

16. Viitasalo J.T., H.Kyrolainen, C.Bosco, M.Alen (1987) Effects of rapid weight reduction on force production and vertical jumping height. *Int.J.Sports Med.* 8:281-285

17. Walberg J.L., M.K.Leidy, D.J.Sturgill, D.E.Hinkle, S.J.Ritchey, D.R.Sebolt (1988) Macronutrient content of a hypo-energy diet affects nitrogen retention and muscle function in weight lifters. *Int.J.Sports Med.* 9:261-6

18. Wang W., Z.Wang, M.Faith, D.Kotler, R.Shih, B.Heymsfield (1999) Regional skeletal muscle measurement: evaluation of new dual-energy X-ray absorptiometry model. *J.Appl.Physiol.* 87:1163-1171

19. Wang Z., M.Visser, R.Ma, R.N.Baumgartner, D.Kotler, D.Gallagher, et al. (1996) Skeletal muscle mass: evaluation of neutron activation and dual-energy X-ray absorptiometry methods. *J.Appl.Physiol.* 80:824-831

20. Webster J.D., R.Hesp, J.S.Garrow (1984) The composition of excess weight in obese women estimated by body density, total body water and total body potassium. *Hum.Nutr.Clin.Nutr.* 38C:299-306

Accepted for publication 15.02.2006

Acknowledgments
The authors express their special thanks to the coaching staff and athletes of the Pole FRANCE Orleans for their valuable collaboration