Bone Density in Elite Judoists and Effects of Weight Cycling on Bone Metabolic Balance

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ABSTRACT

PROUTEAU, S., A. PELLE, K. COLLOMP, L. BENHAMOU, and D. CORTEIX. Bone Density in Elite Judoists and Effects of Weight Cycling on Bone Metabolic Balance. *Med. Sci. Sports Exerc.*, Vol. 38, No. 4, pp. 694–700, 2006. **Purpose:** Weight cycling has been shown to exert negative effects on bone metabolism and bone mass, whereas weight-bearing activity is positively associated with bone mineral density (BMD). Bone health in judoists and effects of weight cycling on bone metabolism have not previously been investigated. To examine potential disrupter and stimulators of bone integrity, this study analyzed bone parameters at baseline and the effects of the first weight cycle of the season on bone metabolic status in 48 male and female elite judoists. **Methods:** Body composition and lumbar, femoral, and total body BMD were evaluated by dual-energy x-ray absorptiometry. Cortisol, osteocalcin, C-terminal telopeptide of type I collagen (CTX), and bone uncoupling index (UI) were measured in judoists at normal body weight, after weight reduction, and after regaining weight. As a comparison, a control group of moderately active students was included at baseline. Training, menstrual status, and calcium intake were assessed by questionnaires. **Results:** Euweighted judoists displayed high BMD and an increased rate of bone formation. Precompetitive weight loss averaged 4 ± 0.3% of body weight and induced an acute rise in cortisol (81%, $P < 0.05$) and CTX (33%, $P < 0.0001$), with a metabolic imbalance in favor of bone resorption. A 4 ± 0.5% weight regain restored a positive UI in favor of bone formation. Metabolic responses were not dependent on gender. BMD was unaltered by weight cycling. **Conclusions:** Increased bone formation rate pertaining to judo athletes lent protection from alterations in bone metabolic balance associated with weight cycling. This observation suggests that powerful osteogenic stimuli provided by judo's unique biomechanical environment may help prevent bone loss associated with weight loss. **Key Words:** BONE MINERAL DENSITY, BONE BIOCHEMICAL MARKERS, WEIGHT LOSS AND REGAIN, JUDO

Judo is an Olympic combat sport with a competitive weight class system. To gain a competitive edge over their opponents, many judoists seek to certify for a weight category that is below their usual body weight, thus undergoing cycles of losing and regaining weight.

Effects of weight cycling in weight class sports has been the focus of much research in the past, and negative outcomes of energy restriction on metabolism, endocrine, and immune function have been reported (17,21,24). However, the effects of weight cycling on bone metabolism have never been investigated. Moreover, to our knowledge, no report on bone health in weight class sports is referenced in the literature. Small disturbances in bone metabolism may have notable effects on bone mass and, ultimately, skeletal integrity (23).

According to current knowledge, exercises involving high intensity and high strain rates are more osteogenic than low-intensity endurance-type activities. Specifically, unusual strain distribution and versatile loading patterns promote increased bone mineral more than do exercises that involve regular loading patterns (9). However, the exact characteristics of an optimal stimulus for mechanically induced bone formation are not known. In practical terms, effective exercise regimens should consist of high mechanical forces and/or high rates of force application produced in versatile movements, with sufficient frequency and short duration. As these specific strain-related variables are integrated into judo's dynamic loading conditions, this sport might have optimal osteogenic potential.

Effects of weight cycling on bone markers in healthy adults have not yet been described in the literature, but repeated weight loss and history of dieting have been shown to be inversely correlated with bone mineral density (BMD) in postmenopausal women (2). In contrast, weight-bearing physical activity is known to stimulate osteogenesis (6). In the light of these two opposite influences, we studied regional and total body BMD, calcium intake, and bone metabolic status in highly trained male and female elite judoists and examined the effects of the first weight cycle of the sporting season on bone metabolic responses.

The aim of this study was to examine whether bone metabolism is altered by rapid weight loss and, if so, to what extent this process may be reversed with regaining weight. A further hypothesis was that weight cycling might

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potentially compromise skeletal integrity of weight class sports participants.

METHODS

Procedures. This longitudinal study encompassed three testing periods spread over a competitive judo season: first, when the judoists were at their normal weight (early season (ES)); second, after weight loss (precompetition (Pre-C)); and third, after regaining weight (postcompetition (Post-C)). Judoists who did not have to lose weight to enter their competitive weight class underwent the same testing procedures as weight cyclers. Anthropometry, bone mass, body composition, and biochemical parameters were assessed at each testing period.

Subjects. Fifty-four elite judoists of the French national training camp of Orleans (France) volunteered to participate in this study. Four judoists dropped out of the study. Reasons were failure to meet testing schedules due to frequent trips abroad for competitions or transfer to another university. Two additional judoists were excluded because of severe injury sustained during training. All judoists (age 20 ± 3.0 yr) were national standard athletes (men: N = 22, BMI: 24 ± 2.1; women: N = 26, BMI: 22.7 ± 2.4), with a training history of 13 ± 4 yr. Weekly training volume had been constant over the past 3 yr, with an average of 9.5 ± 3 h·wk^{-1}. Strengthening exercises were integrated in the form of routine circuit training during warm-up. These exercises lasted no more than 15 min and consisted of push-ups and abdominal exercises. The judoists did not engage in resistance training. There were no differences between male and female judoists regarding any of these training variables. Weight cycling is undertaken 10 times during the competitive season, which lasts from March to July. This study analyzed the first weight cycle of the judo season.

A control group (N = 20) was included in this study at ES, as comparisons to this group enabled qualitative appraisal of the specific physical and biological characteristics pertaining to judo athletes. The control group consisted of moderately active students who were recruited in order to match the judo group in age and BMI. Controls performed, on average, 2 ± 1.5 h of physical activity weekly. None of them were engaged in any competitive sport, nor did they train for one type of sport in particular. Physical activity in this group was not organized in a strict manner and consisted of hiking, swimming, occasional cycling to school, and ball games.

This research project was undertaken after approval by 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 (Region Centre, France). All participants received verbal and written description of the research protocol. Each subject gave written informed consent. None of the subjects reported taking any medications, diuretics, protein supplements, or creatine monohydrate. Exclusion criteria were fracture occurrence within the past 24 months, failure to comply with the entire protocol, and interruption of training for more than 2 wk.

Testing schedule. The judoists were tested three times. The first, at ES (in October), tested the judoists at their natural body weight. 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 (Pre-C, in March). Three weeks after Pre-C testing, the third test took place (Post-C).

Measurements in the control group were made in October.

Assessment of bone mass and body composition. Total and regional bone mineral content (BMC), BMD, and soft-tissue composition were measured by dual-energy x-ray absorptiometry (DEXA) with a Hologic QDR 4500 (Hologic Inc., Waltham, MA). Regional bone measurements comprised the lumbar spine (including L1–4) and the nondominant proximal femur (including femoral neck, greater trochanter, and intertrochanteric region). Soft-tissue composition comprised fat mass (FM) and lean body mass (LBM). According to the World Health Organization (27), the T score represents the BMD of the individuals compared with the normal peak value of young adults. All scans were performed and analyzed by the same operator to limit interobserver variability. The coefficient of variation (CV) in our lab was 0.84% for BMD, 1.2% for BMC, 3.9% for FM, and 0.48% for LBM measurements.

Blood sampling and analysis. The subjects were instructed to refrain from performing strenuous exercise (intense training session) 48 h prior to the lab visit, to avoid any kind of physical activity on the morning of blood sampling, and to follow the same pretesting procedures before each visit. After an overnight fast, resting blood samples were obtained from antecubital venipuncture in a sitting position. Blood was drawn strictly between 8:00 and 9:00 a.m. Identical testing procedures were rigorously controlled for at each testing period. Blood samples were centrifuged, and plasma was pipetted into aliquots adequate for analysis of each bone marker and hormone. All samples were then immediately frozen at −80°C until time of analysis. C-terminal telopeptide of type I collagen (CTX) assays were performed with the enzyme-linked immunosorbent assay (ELISA) CrossLaps® kit (Nordic Bioscience Diagnostics, Denmark). Intra- and interassay CV were 5.2 and 6.7%, respectively, and the detection limit was 0.010 ng·mL^{-1}. Osteocalcin (OC) measurements were made with the N-MID Osteocalcin ELISA® kit (Nordic Bioscience Diagnostics). Intra- and interassay CV were 2.6 and 4.7%, respectively, with a detection limit of 0.5 ng·mL^{-1}. Cortisol concentrations were measured by ELISA (Immuno-Biological Laboratories, IBL Hamburg, Germany). Intra- and interassay CV were 5.6 and 6.9%, respectively, and the detection limit was 2.5 ng·mL^{-1}. Total plasma protein concentration was determined by the Biuret method, with a measurement error of < 2%. All concentrations were determined as the average of duplicate determinations. To minimize the effects of assay variability, samples from each subject were analyzed in the same assay.

Physical activity and lifestyle. The judoists were questioned regarding their training and weight cycling history. Confirmation of these variables was obtained from medical records and training logs. Calcium intake was estimated using a food frequency questionnaire (8). Female judoists were interviewed regarding their menstrual status, age at menarche (first menses), and use of oral contraceptive pills. Amenorrhea in this study was defined as absence of menses for at least six consecutive months before the beginning of the study. All questionnaires were administered by the same researcher.

Statistical analyses. Normal distribution of the data was tested by the Kolmogorov–Smirnov test. To accurately assign the judoists to their respective weight cycling (WC) or nonweight cycling (NC) group, a typological classification was performed using the method of aggregation around a mobile center. The variables entered into this multivariate analysis were the amount of weight lost and subsequently regained. Influence of gender on the typological classification was tested with a chi-square test. Statistical differences between groups were determined by an unpaired *t*-test. Between-group comparisons of anthropometric, biochemical, and training variables were made with one-way ANOVA. Data were analyzed for the main effects of group and time and the interaction of group × time with a 2 (group) × 3 (test period) repeated-measures ANOVA. A Newman–Keuls *post hoc* analysis was used to locate statistical significance when an ANOVA was significant. ANCOVA was used to adjust BMD values for LBM, and regression analyses were used to evaluate associations among different variables. Statistical significance was accepted at $P < 0.05$. All statistical analyses were performed by PCSM® statistical software (Optima-Deltasoft, France).

An uncoupling index (UI) was calculated to assess the relative balance of the formation and resorption processes of bone remodeling, as previously described (14). First, the mean ± SE of the baseline CTX and OC values were determined in each subject. Using the values of the control group, OC and CTX *Z* scores [(subject value − $\text{mean}_{\text{baseline}}$)/$\text{SD}_{\text{baseline}}$] were calculated for each subject. Then the UI was calculated by subtracting the *Z* score of the resorption marker from the *Z* score of the formation marker. A positive UI indicates bone remodeling unbalanced in favor of bone formation, whereas a negative UI reflects an imbalance favoring bone resorption. Data are presented as mean ± SE unless specified otherwise.

TABLE 1. Baseline physical characteristics (mean ± SD).

	Male		Female	
	Judoists (*N* = 22)	Controls (*N* = 8)	Judoists (*N* = 26)	Controls (*N* = 12)
Age (yr)	20.9 ± 3.4	20.1 ± 1.0	19 ± 2.4	19.5 ± 0.9
Weight (kg)	73.6 ± 8.3	72.5 ± 10.2	60.3 ± 9.1	56.5 ± 7.0
BMI	24 ± 2.1	23 ± 3.1	22.7 ± 2.4	21.3 ± 1.9
LBM (kg)	61.6 ± 5.8	59.0 ± 6.5	43,7 ± 5,1*	38.3 ± 4.6
FM (%)	11.6 ± 3.6	14.2 ± 4.4	23 ± 4.1*	28.1 ± 5.1
Total BMD ($g \cdot cm^{-2}$)	1.40 ± 0.1*	1.28 ± 0.06	1.21 ± 0.07*	1.10 ± 0.07
Lumbar BMD	1.28 ± 0.13*	1.12 ± 0.11	1.14 ± 0.08*	0.99 ± 0.08
Hip BMD	1.29 ± 0.11*	1.18 ± 0.12	1.10 ± 0.11*	0.97 ± 0.01
T score (%)	119 ± 8.1*	108 ± 5.1	113 ± 7.1*	100 ± 6.7

Values are presented as mean ± SD.
* Significant difference judoist vs controls ($P < 0.05$).

RESULTS

Identification of Weight Cyclers

The typological classification test classified the population into WC ($N = 19$) or NC ($N = 29$). Gender had no influence on the typological classification into WC or NC. WC experienced a 4 ± 0.3% body weight loss at Pre-C followed by a 4 ± 0.5% weight gain at Post-C. Weight fluctuations in WC ranged between 1.5 and 5.5 kg. In contrast, NC maintained a stable weight throughout the season. Prior to this study, WC had been weight cycling for 3.2 ± 1.5 yr. Unless specified otherwise, the results revealed no significant difference between genders and led to the pooling of male and female data.

Baseline Characteristics

Anthropometry. As determined by chi-square test, there were no gender differences between judoists ($N = 48$) and controls ($N = 20$), as well as within judo athletes, between WC and NC.

Judo athletes and controls were similar in age, weight, and BMI, but judoists presented significantly greater BMD at all sites. Male judoists and controls had similar soft-tissue composition, but female judoists displayed higher LBM and lower FM than controls. Within each gender, the differences in BMD between judoists and controls remained significant even after normalization for LBM. Table 1. summarizes the initial physical characteristics of the participants.

Bone markers and biological parameters. In both genders, OC levels were significantly higher in judoists than controls. Concentrations in CTX and cortisol were similar in male judoists and controls, but in females, higher in judoists than in controls. Total plasma protein concentrations revealed no significant differences between groups or gender. Baseline values of bone markers, cortisol, and total plasma proteins are provided in Table 2.

Uncoupling index. Value of the UI was significantly greater in judoists compared with controls (0.3 ± 0.15 vs 0.0 ± 0.26; $P < 0.05$). The positive value of the UI in the judo group indicates a bone metabolic balance in favor of bone formation.

Lifestyle questionnaire. Weight loss was undertaken over the week preceding the competition. The method used to achieve competitive weight goals was restriction of food intake.

Estimated daily calcium consumption was higher in judoists than controls ($P < 0.05$), and within groups, greater in males than females (judo, men: 1403 ± 527 mg, female: 1015 ± 424 mg, $P < 0.05$; controls, men: 1045 ± 225 mg, female: 814 ± 271 mg, $P < 0.05$). No association emerged between calcium intake and BMD at any site. Age at menarche was no different between female judoists and

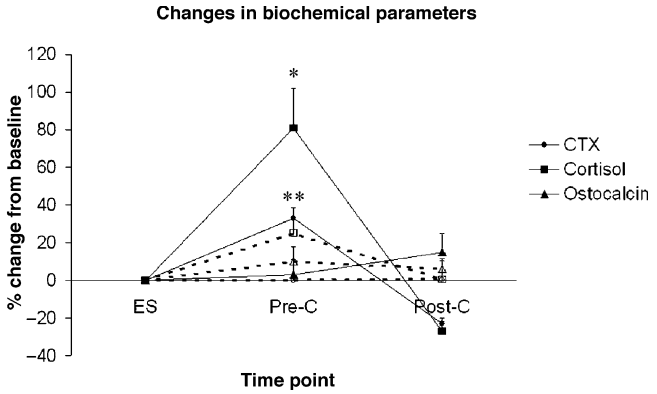

FIGURE 1—Changes in CTX, cortisol, and OC in WC (*continuous lines*) and NC (*dotted lines*) over the course of the study. WC: CTX and cortisol levels were significantly increased at Pre-C in response to weight loss. CTX and cortisol levels at Post-C were not significantly different from their respective ES values. OC levels were not significantly changed by weight cycling. NC: CTX, cortisol, and OC levels remained unchanged over the course of the study. * $P < 0.05$; ** $P < 0.0001$.

controls (12.7 ± 1.4 vs 12.2 ± 2.1 yr, respectively). Three women among the judoist population and none of the controls were amenorrheic. All other females had normal menses, including women taking oral contraception (judo, $N = 12$; controls, $N = 9$). Among the women menstruating regularly, none reported any history of menstrual cycle disturbances. With regard to the influence of menstrual status on bone metabolism, data were analyzed both with and without the three amenorrheic subjects included. Because results remained unchanged, these subjects were included in the final statistical analyses.

Effects of Weight Cycling

Anthropometry. Repeated-measures of ANOVA revealed that body composition was significantly altered in male and female WC, while remaining unchanged over the three point measures in NC. These results are presented in Table 3.

Bone markers and biological parameters. The percentage of changes (Δ) in bone markers and cortisol in response to Pre-C weight loss and Post-C weight gain did not reveal any significant differences between genders. Values in NC judoists remained unchanged over the three point measures.

A 4% body weight loss was accompanied by a 33% increase in CTX levels ($P < 0.0001$) and an increase in cortisol of 81% ($P < 0.05$). OC and total plasma protein concentrations remained unchanged from ES to Pre-C.

A 4% body weight regain was accompanied by a 23% decrease in CTX levels ($P < 0.0001$), a 27% decrease in cortisol ($P < 0.05$), and a nonsignificant 15% increase in OC. Total plasma protein concentrations remained unchanged from Pre-C to Post-C. Effects of weight cycling on cortisol, CTX, and OC levels (expressed as % Δ) are depicted in Figure 1.

Uncoupling index. Weight loss induced a sharp excursion of the UI into negative values, in favor of bone resorption. Regaining weight significantly reversed UI and restored positive values. No significant difference emerged between ES and Post-C values of the index.

The UI represented a convenient means to visualize effects of weight cycling on the balance between bone formation and resorption (Fig. 2).

DISCUSSION

The main findings of this study are as follows.

Pre-C weight loss negatively affected bone metabolic status, with an acute increase in CTX and a net increase in bone resorption relative to formation. This phenomenon was reversed with subsequent weight regain.

Bone status in male and female elite judoists during weight maintenance is characterized by a positive UI reflecting an imbalance in bone turnover strongly in favor of bone formation. This particular metabolic pattern may lend protection from increased resorption induced by weight loss.

The present study provides, for the first time, analysis of bone metabolic status combined with BMD in male and female judo athletes and the effects of weight cycling on the balance between bone formation and resorption. Effects of weight changes on bone metabolism had not yet been studied in healthy adults, but may represent an important future area of research. Moderate energy restriction may increase bone resorption in obese women (19), and weight loss has generally been associated with bone loss (5,12,18,22). Weight loss has been shown to induce acute as well as chronic increases in bone resorption (19,25), but the exact mechanisms by which bone resorption increases are not clarified yet.

Our findings in judoists are in line with these reports, as Pre-C weight loss resulted in a net increase in bone resorption. CTX are released into the circulation during bone resorption and thought to be the marker of bone resorption with the highest contribution from bone (23).

Interestingly, OC tended to increase 3 wk after the weight loss episode, although a wide range of responses

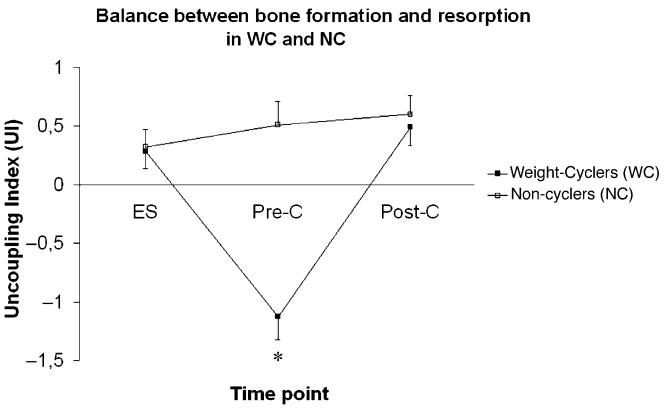

FIGURE 2—Changes in the UI in WC and NC over the course of the study. WC: UI was significantly decreased at Pre-C in response to weight loss, $P < 0.05$. UI at Post-C was not significantly different from ES value. NC: No significant changes in UI occurred over the course of the study. * $P < 0.05$.

TABLE 2. Baseline bone marker, cortisol, and total plasma protein values.

	Male		Female	
	Judoists (N = 22)	Controls (N = 8)	Judoists (N = 26)	Controls (N = 12)
Osteocalcin ($ng \cdot mL^{-1}$)	52.5 ± 5.5*	37.1 ± 3.6	45.3 ± 3.0*	26.3 ± 3.3
CTX ($ng \cdot mL^{-1}$)	0.857 ± 0.04	0.863 ± 0.03	0.728 ± 0.031*	0.582 ± 0.082
Cortisol ($ng \cdot mL^{-1}$)	118.0 ± 6.8	95.6 ± 7.0	160 ± 13.8*	92.9 ± 3.0
Total plasmaprotein ($\mu g \cdot mL^{-1}$)	367 ± 20	390 ± 17	336 ± 10	365 ± 11

Values are presented as mean ± SE.
* Significant difference judoist vs controls ($P < 0.05$).

did not permit reaching significance. To what extent this observation might have occurred in response to Pre-C weight loss remains to be ascertained. Bone turnover is always initiated by the activation of osteoclasts eroding a mineralized surface. The process of bone resorption is followed by the recruitment of osteoblasts to the outer edge of the erosion cavity. The latter secrete new bone matrix (osteoid) and gradually fill in the resorption cavity. Serum OC is a sensitive and specific marker of osteoblastic activity, and its serum levels are correlated with bone formation as determined by histomorphometry and reflect the rate of bone formation (23). In sum, an initial phase of bone resorption is followed by a more prolonged phase of bone formation mediated by osteoblasts. The absence of an acute response of OC to the relatively short weight reduction period (1 wk) is in accord with the fact that OC is involved in the late phase of the matrix mineralization. However, we do not rule out the possibility that the slight increase in OC occurring 3 wk after the weight loss episode might be the reflection of an overall increase in bone turnover triggered by weight loss. Indeed, increases in OC in response to weight loss within a comparable time span are documented in the literature (19,25).

The sharp excursion of the UI into negative values resulting from Pre-C weight loss indicated that rates of bone resorption exceeded rates of bone formation, thus establishing a bone resorptive state. Weight regain, by decreasing bone resorption, restored a positive balance in favor of bone formation. Calculation of the UI enabled a qualitative appreciation of the changes in bone metabolic balance with weight cycling. Bone formation and bone resorption were coupled in recreationally active students. Accordingly, such equilibrium ensures bone mass maintenance (10). In contrast, in euweighted judoists, bone turnover was unbalanced in favor of bone formation, as indicated by the positive UI at ES. This persistent elevated rate of bone formation, as confirmed over the three point measures, allowed WC to offset transitory increases in bone resorption. Whereas 3% body weight loss has been associated with bone loss in sedentary subjects (18), no consensus has emerged on the potential protective role of exercise on bone during weight loss.

The findings of the present study suggest that a powerful osteogenic mechanical environment may lend relative protection from adverse skeletal effects. Although further investigations are needed to substantiate this hypothesis, there is some evidence to support the notion that high-impact loading activities have the potential to override certain adverse environmental influences on bone (28). Reports in oligo- and amenorrheic gymnasts concluded that high-impact loading in gymnastic participation had a greater osteogenic effect than the increased resorption induced by amenorrhea (20). In contrast, these benefits are not seen in activities involving lower strain magnitudes (3). Although the effects of mechanical loading on bone have long been acknowledged, its cellular control mechanisms are not yet completely defined. Mechanical loading has been shown to stimulate proliferation, differentiation, and maturation of precursor cells in the osteoblast lineage and ultimately increase the number of mature osteoblasts in bone (4). Cell metabolism and proliferation are increased proportional to the load (13,26). Judo combines in one sport the biochemical strains thought to have the greatest effect on bone formation (9), namely, weight-bearing, high-magnitude, high-impact, high-velocity, and highly varied physical loading characteristics. This peculiar combination may ultimately magnify osteogenic stimulus, as suggested by the high rates of bone formation of the judoists.

Whereas many sporting activities lead to restricted, site-specific bone gains, judo in contrast produces strains distributed throughout the entire skeleton: high-magnitude forces transmitted via intense muscle pulling on the bone, ground reaction forces intensified by the absence of footwear to attenuate impact shocks, high-impact loading of the skeleton by repeated falls on the mat, and constantly changing strain distribution.

The present study may represent a rationale for previous DEXA findings reporting higher BMD in athletes practicing judo compared with other weight-bearing sports (1,15). No study had yet characterized metabolic bone status in judoists. To our knowledge, only one study investigated bone markers in judoists, as part of a comparative study including also swimmers and runners (15). However, bone markers measured in that study were not very specific to bone (i.e., urinary pyridinoline and deoxypyridinoline encompass turnover from cartilage and connective

TABLE 3. Effects of weight cycling on body composition in male and female judoists.

	% FM		LBM (kg)	
	Noncyclers	Weight Cyclers	Noncyclers	Weight Cyclers
Males				
ES	11.6 ± 1.0	11.6 ± 1.3	59.3 ± 1.4	64.9 ± 1.8
Pre-C	11.9 ± 0.9	10.9 ± 1.1	59.4 ± 1.3	62.7 ± 1.9
Post-C	12 ± 0.9	11.1 ± 1.1	59.8 ± 1.3	65.2 ± 1.8
ANOVA P	NS	<0.05	NS	<0.0001
Females				
ES	23.1 ± 1.1	22.8 ± 1.1	43.3 ± 1.4	44.6 ± 1.4
Pre-C	22.7 ± 0.9	22.1 ± 1.1	43.5 ± 1.4	43.4 ± 1.4
Post-C	22.7 ± 1.0	21.4 ± 1.1	43.7 ± 1.4	45.0 ± 1.4
ANOVA P	NS	<0.05	NS	<0.0001

Values are presented as mean ± SE.
LBM and %FM were significantly altered by weight cycling in male and female WC, whereas values remained unchanged over the course of the study in NC.
NS, not significant.

tissue). Unfortunately, no results on the state of bone formation were given, thus impeding comparisons with our findings.

The increase in cortisolemia with weight reduction may reflect increased gluconeogenesis. While it is well accepted that increased levels of circulating glucocorticoids lead to impairment of bone formation and ultimately to bone mass loss (7), the absence of a relationship with the concomitant increase in CTX suggests that cortisol is not a major contributing factor in increased bone resorption. Likewise, estimated daily calcium consumption was within the National Institutes of Health recommended daily intake (16), and the absence of an association with bone markers or bone mass suggests that calcium intake does not play a major role in increasing the bone formation rate.

Unfortunately, owing to the athletes' busy schedule, we were not able to assess nutritional deficits during weight loss. Understandingly, investigations were required to present as little interference with competitive preparation as possible. However, previous reports on weight loss found no relationship between increases in bone resorption and reductions in nutrient intake (25), or calcium and vitamin D intake (19,22), concluding that increased bone resorption was the result of weight loss rather than reduced nutrient intake.

It must be acknowledged that concomitant dehydration must have affected one of our male subjects who lost as much as 5.5 kg. However, overall plasma total proteins remained unchanged throughout the study in all groups, indicating that no significant fluid loss affected the subjects (11). Questionnaire data corroborated this finding, as food restriction over the week leading up to the contest was used to achieve weight goals.

In conclusion, elevated bone formation pertaining to judo athletes lent protection from alterations in bone metabolic balance with weight cycling. This observation suggests that high osteogenic stimuli provided by judo's unique biomechanical environment may help prevent bone loss associated with weight loss interventions. This preliminary evidence yields promising perspectives and calls for further research to shed more light on the mechanical loading conditions allowing such a beneficial exercise effect to occur.

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