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Effect of Two Different Weight-Loss Rates on Body Composition and Strength and Power-Related Performance in Elite Athletes

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When weight loss (WL) is necessary, athletes are advised to accomplish it gradually, at a rate of 0.5–1 kg/wk. However, it is possible that losing 0.5 kg/wk is better than 1 kg/wk in terms of preserving lean body mass (LBM) and performance. The aim of this study was to compare changes in body composition, strength, and power during a weekly body-weight (BW) loss of 0.7% slow reduction (SR) vs. 1.4% fast reduction (FR). We hypothesized that the faster WL regimen would result in more detrimental effects on both LBM and strength-related performance. Twenty-four athletes were randomized to SR (n = 13, 24 ± 3 yr, 71.9 ± 12.7 kg) or FR (n = 11, 22 ± 5 yr, 74.8 ± 11.7 kg). They followed energy-restricted diets promoting the predetermined weekly WL. All athletes included 4 resistance-training sessions/wk in their usual training regimen. The mean times spent in intervention for SR and FR were 8.5 ± 2.2 and 5.3 ± 0.9 wk, respectively ($p < .001$). BW, body composition (DEXA), 1-repetition-maximum (1RM) tests, 40-m sprint, and countermovement jump were measured before and after intervention. Energy intake was reduced by 19% ± 2% and 30% ± 4% in SR and FR, respectively ($p = .003$). BW and fat mass decreased in both SR and FR by 5.6% ± 0.8% and 5.5% ± 0.7% (0.7% ± 0.8% vs. 1.0% ± 0.4%/wk) and 31% ± 3% and 21 ± 4%, respectively. LBM increased in SR by 2.1% ± 0.4% ($p < .001$), whereas it was unchanged in FR (–0.2% ± 0.7%), with significant differences between groups ($p < .01$). In conclusion, data from this study suggest that athletes who want to gain LBM and increase 1RM strength during a WL period combined with strength training should aim for a weekly BW loss of 0.7%.

Keywords*:* energy restriction, strength training, hypertrophy

Weight loss in athletes is generally motivated by a desire to optimize performance by improving power-to-weight ratio, making weight to compete in a certain weight category, or for aesthetic reasons in leanness sports. Because of the negative effects of rapid weight loss and long periods of restricted energy intake (Hall & Lane, 2001; Koral & Dosseville, 2009; Umeda, Nakaji, Shimoyama,Yamamoto, & Sugawara, 2004), existing literature recommends a gradual weight loss through moderate energy restriction, promoting a weekly weight loss of 0.5–1 kg (Fogelholm, 1994; Rankin, 2002). To induce a weight loss of 0.5–1 kg/wk, an energy deficit corresponding to 500–1,000 kcal/day is needed. This can be achieved by reduced energy intake, increased energy expenditure, or a combination of the two.

However, a decrease in body mass resulting from energy restriction can lead to loss of lean body mass (LBM; Koral & Dosseville, 2009; Koutedakis et al., 1994) and thereby impair performance (Degoutte et al., 2006; Koral & Dosseville, 2009). Strength training in combination with mild energy restriction can preserve LBM during weight-loss periods in overweight sedentary subjects (Kraemer et al., 1999). Therefore, to make weight-loss interventions as effective as possible, we combined energy restriction with strength training to alleviate the expected negative consequences on LBM and performance.

Finally, when the weight-loss goal is fixed, most athletes choose to use the shortest amount of time to reach the goal to avoid extended periods of fatigue. There are probably different implications of reducing daily energy intake by 500 or 1,000 kcal, and a reduction of 1,000 kcal can compromise recovery and impair training adaptations in athletes, especially in those with an already low energy intake (American College of Sports Medicine [ACSM], 2009; Nattiv et al., 2007).

Consequently, the aim of this study was to compare two practical approaches to the recommended weight-loss regimen in the literature. We compared weekly BW losses of 0.7% and 1.4% (i.e., twice the relative weight), which corresponds to weekly weight losses of 0.5 and 1 kg, respectively, in a 70-kg athlete. We hypothesized that the faster weight-loss regimen would result in more detrimental effects on both LBM and strength- and power-related performance.

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Methods

Subjects

Thirty-six elite male and female athletes, age 18–35 years, were recruited, and 30 completed the study. The athletes were recruited by invitation from the Norwegian Olympic Sport Center when they contacted the center to get assistance with weight loss, or by invitation letters to sport federations. The following sports were represented in the study: football, volleyball, cross-country skiing, judo, jujitsu, tae kwon do, waterskiing, motocross, cycling, track and field, kickboxing, gymnastics, alpine skiing, ski jumping, freestyle sports dancing, skating, biathlon, and ice hockey. There were 43% versus 57% and 31% versus 69% men and women in the slow-reduction group (SR) and the fast-reduction group (FR), respectively. The physical and anthropometrical characteristics of the athletes are shown in Table 1.

Six female athletes with repeated weight fluctuations during the last season reported a low energy intake at baseline and therefore had to accomplish their weight goal with an intervention that included increased energy expenditure in addition to the reduced energy intake. They were included in the study because this is a daily practical challenge when working with athletes. However, because of the different intervention with additional energy expenditure included for this subgroup, the statistical analysis, results, and discussion are presented without this subgroup.

The athletes were informed about the purpose and experimental procedures before written consent was obtained. The study was conducted according to the Declaration of Helsinki and approved by the Data Inspectorate and the Regional Ethics Committee of Southern Norway. Permission to conduct the study was provided by the Norwegian Olympic Committee and the Norwegian Confederation of Sports.

Experimental Design

The athletes were screened and block-randomized to the SR and FR groups. All athletes followed a 4- to 12-week energy-restriction and strength-training period. The length of the intervention was determined by the rate of weight loss (SR or FR) and the desired weight loss (minimum 4% of BW). The final weight goal was set by a nutritionist and exercise physiologist based on results from the body-composition measurements that provided the information needed to calculate minimum percentage fat for each athlete and the athlete's desired weight loss. The length of the intervention period for each subject depended on the athlete's weight-loss goal and the weekly weight-loss rate. For example, a 70-kg athlete who wanted to reduce body weight by 5 kg (and the amount of weight loss was appropriate for the calculated minimum percentage fat) would have either a 5- (FR) or 10-week (SR) intervention depending on which intervention group he or she was randomly allocated to.

Preparticipation Screening

Screening included the Eating Disorder Inventory (EDI-2; Garner, 1991), followed by an interview and medical examination according to the standard for preseason health evaluation at the Norwegian Olympic Sports Center. The exclusion criteria were as follows: diseases and conditions known to affect metabolic functions in muscle, use of pharmaceuticals that might affect any of the measurements, and presence of one or more of the triad components—disordered eating/eating disorder, menstrual dysfunction, or low bone-mineral density (Nattiv et al., 2007). For possible diagnoses, *DSM-IV* criteria were used for anorexia nervosa, bulimia nervosa, and eating disorder not otherwise specified (American Psychiatric Association, 1994); clinically evident perimenopausal or postmenopausal condition; pregnancy; and fat mass corresponding to a predicted postintervention body-fat value of less than 5% for men and 12% for women (Fogelholm, 1994; Heyward & Wagner, 2004).

Intervention

Diet. Diet registrations were obtained by a 4-day (3 weekdays + 1 weekend day) weighed-food record that was analyzed by a national food database, "Mat Paa Data" (version 5.0, LKH, Mattilsynet, Norway). The athletes were instructed to make sure they were weight stable during the diet registration. The record served as

Table 1 Baseline Data, *M* ± *SD*

	Slow-Rate Weight Loss		Fast-Rate Weight Loss	
	Men (*n* = 6)	Women (*n* = 7)	Men (*n* = 5)	Women (*n* = 6)
Age (years)	24.9 ± 3.5	22.4 ± 3.1	20.9 ± 4.5	20.7 ± 6.4
Height (cm)	177 ± 11	169 ± 8	179 ± 4	167 ± 1
Body weight (kg)	78.5 ± 14.1	66.4 ± 8.8	81.9 ± 11.5	68.9 ± 6.7
Fat mass (kg)	13.3 ± 5.0	17.3 ± 4.4	13.3 ± 6.5	21.2 ± 5.2
Total body fat (%)	17 ± 5	27 ± 5	16 ± 3	30 ± 5
Lean body mass (kg)	62.3 ± 10.3	46.3 ± 5.5	65.5 ± 3.3	44.6 ± 3.6
Experience as athletes (years)	13 ± 6.4	10.7 ± 4.7	12.6 ± 4.5	13.1 ± 5.1
Training per week (hr)	15.6 ± 4.5	15.2 ± 3.1	15.2 ± 3.1	13.9 ± 5.3
Strength training last season (hr/week)	2.8 ± 1.6	2.7 ± 1.6	3.4 ± 1.1	2.1 ± 1.5

a basis for developing each athlete's individualized diet plan promoting weekly BW loss of 0.7% or 1.4%. This was calculated from the assumption that 1 g of mixed tissue gives 7 kcal. For example, a 60-kg athlete in SR had to reduce energy intake by ~420 kcal/day to achieve the weekly weight-loss goal of 0.4 kg (60,000 × 0.7%/7 days × 7 kcal). In the diet plans, the aim was to have a daily protein intake corresponding to 1.2–1.8 g/kg, a daily carbohydrate intake corresponding to 4–6 g/kg and ≥20% fat, with low-energy/high-nutrient foods that provided satiety, as well as food variety. There were 5–7 daily meals and snacks and no meal plan below 1,500 kcal/day. All athletes ingested a milk-protein-based recovery meal containing carbohydrates (20–40 g) and protein (6–20 g) within 30 min after training sessions and a balanced meal within 1–2 hr, in an attempt to optimize recovery. During implementation of the dietary plan, the athletes were encouraged to use a food scale to ensure correct portion sizes. They were encouraged to drink a minimum of 0.5 L/hr of water during training sessions and ~2 L of fluids during the day. If the athletes were unable to follow the dietary plan during the week, they were instructed to write down any deviations from it.

Supplementation. The athletes were not allowed to have used creatine supplementation during the 6 weeks before the intervention, and they did not take any supplements other than those given by the nutritionist during the intervention. A multivitamin–mineral supplement (Nycomed, Asker, Norway) and a cod liver oil supplement (Møller's tran, Oslo, Norway) were prescribed to ensure sufficient micronutrient intake and essential fat intake during the intervention. Furthermore, if blood samples indicated any other specific micronutrient needs (e.g., iron, vitamin B_{12}), these vitamins were provided to the athletes and blood levels were thereafter monitored.

Nutritional Counseling. The athletes received nutritional counseling once a week during intervention. The counseling included basic nutrition, sports physiology, and possible adjustments in the dietary plan or weight regimen, depending on progress.

Training. The intervention period started off-season for all athletes to be able to add additional training to their schedule and for practical reasons (e.g., traveling and competitions). All athletes continued their sport-specific training schedule (14.6 ± 3.5 hr/week, presented as a mean of the training during the previous year). They included four strength-training sessions per week to emphasize muscle strength and hypertrophy. The strength-training program was a two-split periodized program. Each muscle group was exercised twice a week with two exercises in each session, one main exercise attacking multiple muscle groups (e.g., squat) and one working on a specific muscle group (e.g., knee extension). Main exercises for leg muscles were clean (whole body), squat, hack squat, and dead lift, and main exercises for upper body muscles were bench press, bench pull, rowing, chins, shoulder press, and core exercises. In the first 4 weeks the athletes trained with a 3 × 8–12 repetition-maximum (RM) regimen, the next period with 4 × 6–12RM, and the last 4 weeks with 5 × 6–10RM. For the athletes who participated for less than 12 weeks, the program was adjusted with shorter periods. The rest period between sets was 1–3 min long. Once a week, athletes were supervised during training at the Olympic Sports Center to ensure correct training technique and adequate progress. A computerized exercise diary was recorded during the entire intervention period.

Experimental Assessments

All tests were conducted by the same test team before and after the intervention, and the test day was standardized. Athletes were not allowed to perform heavy training 48 hr before testing.

BW. BW was measured in a fasted state with a balance scale (Seca Model 708, Seca Ltd., Birmingham, UK) to the nearest 100 g on the test day in the morning between 8 and 9 a.m. During the intervention period, athletes used their own scales to monitor BW because their weekly meetings with the nutritionist were at different times during the day, and their weight would fluctuate depending on food and liquid intake. They were instructed to weigh themselves without clothes and with an empty bladder immediately after awaking and before breakfast.

Body Composition. Fat mass, percent body fat, and LBM were measured with dual-energy X-ray absorptiometry (DEXA; GE Medical Systems, Lunar Prodigy, WI) by a trained technician. The DEXA system was calibrated every day before testing, and the test was conducted with the participant in a fasted state between 8:30 and 10:00 a.m. For DEXA reproducibility, 10 athletes did two repeated measurements within 24 hr, and the coefficient of variation in the DEXA Lunar Prodigy total-body scan for repeated measurements was 3% for fat mass and 0.7% for LBM.

Performance. Performance was measured by 40-m sprint, countermovement jump (CMJ), and 1RM of bench press, bench pull, and squat. Before the sprint, CMJ, and 1RM strength tests, the athletes performed a standardized warm-up consisting of 15 min of low-intensity running or cycling. After the general warm-up they performed a more sprint-specific warm-up, followed by three maximal 40-m sprints, and the best result was used in the data analysis. CMJ was performed on an AMTI force platform (SG 9, Advanced Mechanical Technology Inc., Newton, MA), and the best jump of three was used in the data analysis. In the 1RM tests the weight was progressively increased until the athlete could not move it through the full range of motion on at least two attempts.

EDI-2. The EDI-2 is a self-report measure with 91 items, a 6-point forced-choice inventory assessing several behavioral and psychological traits common in anorexia nervosa and bulimia (Garner, 1991). The EDI-2 consists of the following 11 subscales: drive for thinness, bulimia, body dissatisfaction, ineffectiveness, perfectionism,

interpersonal distrust, interceptive awareness, maturity fears, asceticism, impulse regulation, and social insecurity. The athletes filled out the EDI before and after testing to assess behavioral and psychological traits.

Statistical Analyses

Data are presented as *M* ± *SD* for pre- and post- measurements and *M* ± *SE* for changes within and between groups. The computer software programs Graphpad Prism 5.0 (CA, SA) and SPSS 15 (Chicago, IL) were used for statistical analysis. The pre- to post- changes within groups were analyzed with paired-samples two-tailed Student's *t* test or Wilcoxon's paired-rank test when appropriate. Between groups, independent two-tailed Student's *t* test and the Mann–Whitney test were used when appropriate. Pearson's *R* or Spearman's rho was performed when appropriate to study correlations between variables. Values of *p* below .05 were considered statistically significant.

Results

A history of dieting and weight cycling was reported by 53% of the athletes in SR and 45% of the athletes in FR. The mean lengths of time spent in intervention for SR and FR were 8.5 ± 2.2 and 5.3 ± 0.9 weeks, respectively. There were no significant differences between groups in any of the baseline measurements (Tables 1, 2 and 3).

Diet

Baseline energy intakes were 2,409 ± 622 and 2,514 ± 518 kcal/day for SR and FR, respectively. Energy intake was reduced more in FR (30% ± 4%) than in SR (19% ± 2%; $p = .003$; Table 2), with the aim of faster weight loss. Although intake of most of the macronutrients was significantly reduced, none of the variables differed between groups (Table 2).

Table 2 Energy and Nutrition Variables Presented as *M* ± *SD* for Diet Registration and Meal Plan and *M* ± *SE* for Change

	Slow-Rate Weight Loss (*n* = 13)			Fast-Rate Weight Loss (*n* = 11)		
	Diet registration	Meal plan	Change	Diet registration	Meal plan	Change
Energy intake (kcal)	2,409 ± 622	1,940 ± 482	–469 ± 61*	2,514 ± 518	1,723 ± 234	–791 ± 113*
Energy (kcal/LBM)	45.6 ± 9.6	36.5 ± 6.5	–9.1 ± 4.2*#	47.8 ± 11.3	33.0 ± 5.2	–15.0 ± 2.2*#
Protein (g/kg BW)	1.6 ± 0.4	1.6 ± 0.4	0.1 ± 0.1*	1.6 ± 0.5	1.4 ± 0.2	–0.2 ± 0.1
Protein (E%)	19.6 ± 6.3	25.2 ± 3.7	7.0 ± 1.3*	18.2 ± 2.9	24.2 ± 3.3	4,5 ± 1.6*
CHO (g/kg BW)	4.1 ± 0.9	3.6 ± 0.7	–0.5 ± 0.2*	4.1 ± 1.1	3.2 ± 0.6	–1.0 ± 0.2*
CHO (E%)	51.0 ± 6.5	54.0 ± 3.3	3.1 ± 1.6	49.3 ± 6.3	55.5 ± 4.4	6.2 ± 1.5*
Fat (E%)	30.0 ± 6.9	20.8 ± 1.1	–9.2 ± 2.1*	31.1 ± 4.0	20.6 ± 2.0	–10.5 ± 1.4*

Note. LBM = lean body mass; BW = body weight; CHO = carbohydrate; E% = percent of total energy intake.

*$p < .05$ significantly different from pre. #$p < .05$ significant difference between groups.

Table 3 Body Composition and Performance Variables Presented as *M* ± *SD* for Pre- and Post- and *M* ± *SE* for Change

	Slow-Rate Weight Loss (*n* = 13)			Fast-Rate Weight Loss (*n* = 11)		
	Pre-	Post-	Change	Pre-	Post-	Change
Body weight (kg)	71.9 ± 12.7	67.8 ± 11.4	–4.2 ± 0.6*	74.8 ± 11.7	70.6 ± 10.6	–4.2 ± 0.6*
Lean body mass (kg)	53.7 ± 11.3	54.7 ± 11.2	1.0 ± 0.2*	54.1 ± 12.1	53.8 ± 11.1	–0.3 ± 0.4#
Fat mass (kg)	15.5 ± 4.9	10.5 ± 3.6	–4.9 ± 0.7*	17.6 ± 6.9	14.4 ± 6.8	–3.2 ± 0.5#*
Countermovement jump (cm)	32.3 ± 6.4	34.3 ± 5.5	2.0 ± 0.7*	31.3 ± 7.6	31.6 ± 7.7	0.3 ± 0.8
40-m sprint (s)	5.76 ± 0.61	5.80 ± 0.65	0.04 ± 0.05	5.99 ± 0.49	5.99 ± 0.44	0.00 ± 0.04
1RM press (kg)	59.2 ± 21.2	66.7 ± 22.3	7.5 ± 0.5*	73.2 ± 33.3	75.5 ± 29.1	2.3 ± 1.7#
1RM pull (kg)	63.5 ± 16.5	69.2 ± 15.8	5.8 ± 1.5*	69.5 ± 19.8	71.4 ± 17.2	1.8 ± 1.7
1RM squat (kg)	97.5 ± 38.3	106.5 ± 34.7	9.0 ± 2.1*	90.0 ± 25.6	97.0 ± 23.9	7.0 ± 1.7*

Note. 1RM = one-repetition-maximum.

*$p < .05$ significantly different from pre. #$p < .05$ significant difference between groups.

Body Composition

BW was reduced by 5.6% ± 0.8% in SR ($p < .001$) and 5.5% ± 0.7% in FR ($p < .001$; Figure 1). The average weekly rates of weight loss for the SR and FR were 0.7% ± 0.4% and 1.0% ± 0.4%, respectively. In accordance with the aim of the study, the rate of weight loss in FR was significantly faster than in SR ($p = .02$). Fat mass decreased more in SR than in FR (31% ± 3% vs. 21% ± 0%, respectively, $p = .02$; Figure 1). Total LBM increased significantly in SR by 2.1% ± 0.4% ($p < .001$), whereas it was unchanged in FR (–0.2% ± 0.7%), with significant differences between groups ($p < .01$; Figure 1). The increase in total LBM in SR was mainly caused by a 3.1% ± 0.8% increase in upper body LBM. The weekly gains in LBM were 0.3% ± 0.0% and 0.0 ± 0.1% ($p = .02$) for SR and FR, respectively.

Body Composition and Gender

Women gained LBM during the intervention, whereas men did not (1.8% ± 0.4% vs. 0.0% ± 0.7%, respectively, $p < .01$). In men, LBM was gained during the intervention in SR (1.7% ± 0.4%, $p < .01$), whereas men in FR tended to reduce LBM (–2.0% ± 1.0%, $p = .1$), with a significant difference between groups ($p < .01$). There were no significant differences between women in SR and FR in any of the body-composition variables.

Performance

Performance in CMJ was improved by 7% ± 3% ($p < .01$) in SR, whereas no significant change was observed in FR (Figure 2). There was no change in 40-m-sprint performance in any of the groups. 1RM squat improved similarly by 11.9% ± 3.4% ($p < .01$) in SR and 8.9% ± 2.3% ($p < .01$) in FR (Figure 2). Bench-press performance increased more in SR than in FR (13.6% ± 1.1% vs. 6.4% ± 3.3%, respectively, $p = .01$; Figure 2). The performance

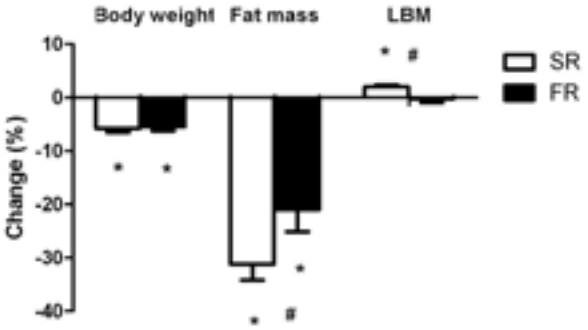

Figure 1 — Changes in body weight, fat mass, and lean body mass (LBM) in the slow-rate weight-loss group (SR) and the fast-rate weight-loss group (FR), $M \pm SE$. $*p < .05$ significantly different from pre. $\#p < .05$ significant difference between groups.

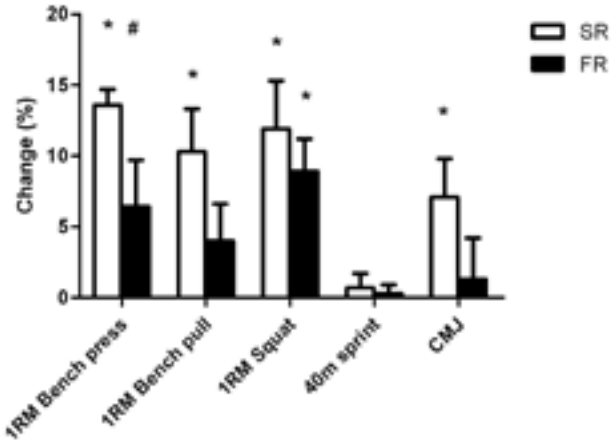

Figure 2 — Changes in one-repetition-maximum (1RM) bench press, bench pull, and squat; 40-m-sprint performance; and countermovement jump (CMJ) in the slow-rate weight-loss group (SR) and the fast-rate weight-loss group (FR), $M \pm SE$. $*p < .05$ significantly different from pre. $\#p < .05$ significant difference between groups.

in bench pull improved by 10.3% ± 3.0% ($p = .001$) in the SR and 4.0% ± 2.6% in the FR. Overall change in 1RM for the upper body exercises was higher in SR than in FR (11.4% ± 2.6% vs. 5.2% ± 2.4%, respectively, $p = .03$). The weekly gains in mean relative changes in all 1RM measurements were 1.4% ± 0.7% and 1.3% ± 0.5% for SR and FR, respectively. There were no significant correlations between changes in any of the performance variables, strength-training experience, weight-loss experience, or weekly weight-loss rate and changes in body composition.

Performance and Gender

The increase in 1RM squat was higher in women (16.2% ± 2.7%) than in men (4.7% ± 1.5%, $p = .002$). No other significant gender differences were observed for changes in performance tests.

EDI

There were no significant differences between groups at baseline in any of the EDI subscale scores, and there were no significant changes from pre- to posttest in either SR or FR (35.2% ± 16.5% to 26.2% ± 13.7% and 26.5% ± 11.5% to 27.6% ± 9.6%, respectively).

Compliers Versus Noncompliers

The defined weekly weight-loss goals for SR and FR were 0.7% and 1.4% of BW, respectively. All athletes are included in the current results according to the intention-to-treat principle. The mean weekly weight-loss rates and standard deviations were 0.7% ± 0.3% of

BW per week in SR and 1.0% ± 0.5% in FR. Three athletes in SR (cutoff values in weekly weight-loss rate: 0.5–0.9%) and 5 athletes in FR (cutoff values in weekly weight-loss rate: 1.0–1.6%) did not accomplish their weight-loss goals. When noncompliers were removed there were no significant changes in results, but differences between the SR and FR were generally more pronounced. No statistically significant differences in any of the variables were found between compliers and noncompliers.

Discussion

The aim of this study was to compare the effects of 5–6% BW loss at slow and fast rates on changes in body composition and strength- and power-related performance in elite athletes. We hypothesized that the faster weight loss would result in more detrimental effects on both LBM and performance. Surprisingly, LBM increased by 2.1% ± 0.4% in SR, accompanied with improved performance in CMJ and all the 1RM parameters, whereas there was no significant change in LBM or improvements in strength- and power-related performance, except 1RM squat, in FR. Total LBM increased more in SR than in FR, with weekly gains in LBM of 0.3% ± 0.0% and 0.0% ± 0.1% ($p = .02$) for SR and FR, respectively. Consequently, the slower weight-loss intervention had more positive effects on LBM and performance than the faster weight-loss intervention.

Diet

Compared with their high activity level the reported baseline energy intake was relatively low, and this may be a result of underreporting, undereating, or both, which is common in self-reported dietary intake (Magkos & Yannakoulia, 2003). We chose a 4-day weighed-food registration to minimize the burden, improve compliance, and avoid alteration of the subject's usual intake. The possible underreporting during the intervention was controlled for by weekly measurements of BW and sum of skinfolds. The calculated energy deficits for the SR and FR were 469 ± 61 and 845 ± 113 kcal/day, respectively. Because of daily training sessions, no meal plan was set below 1,500 kcal/day. The diet in both groups was a low-fat diet (~20% of total energy intake), and the mean carbohydrate intakes were 3.5 ± 0.7 g/kg (SR) and 3.2 ± 0.6 g/kg (FR), which is less than recommended (ACSM, 2009). The mean protein intakes were 1.6 ± 0.47 and 1.4 ± 0.27 g/kg in SR and FR, respectively, within the recommended protein intake for athletes (ACSM, 2009). Adequate protein intake was considered important to ensure sufficient amino acid supply to muscles and to enhance the anabolic response to strength training, in addition to thermogenic and satiety-inducing effects (ACSM, 2009; Karst, Steiniger, Noack, & Steglich, 1984). The meal plans were based on the dietary registrations and general guidelines for each nutrient, and the athletes took part in making the meal plans. This included choice of foods and drinks and timing of intake. We consider the individual planning crucial for compliance and motivation for the athletes.

Body Composition

LBM increased significantly in SR from pre- to postintervention and increased significantly more in SR than in FR. There were also highly significant differences for men between SR and FR in LBM, even though the sample size was somewhat low (6 vs. 5 athletes). There was no significant difference in weekly hours of strength training the season before entering the study between SR and FR or the men in SR and FR, which could have been a plausible explanation for different changes in LBM.

The first assumption for this difference in LBM changes is the fact that SR spent a significantly longer time in the intervention than FR. The mean amounts of time spent in intervention for SR and FR were 8.5 ± 2.2 and 5.3 ± 0.9 weeks, respectively ($p < .001$). Consequently, athletes in SR performed strength training for ~3 weeks longer than FR. This is likely the most important explanation for the differences in changes in LBM. However, although the athletes in SR had a longer period with energy deficit, they had a smaller restriction in energy intake, and this may also be a contributing factor to the larger increase in LBM. This is supported by the fact that the weekly gain in LBM was significantly higher in the SR group than in the FR group. Consequently, the rate of weight loss seems to be important in addition to the time spent in the intervention.

Note that increased upper body LBM was the major contributor to the increase in total LBM in the SR group. There may be several explanations for this finding, but it seems like upper body muscles generally respond better to strength-training stimuli than leg muscles (Wernbom, Augustsson, & Thomee, 2007). Furthermore, all athletes already had a heavy load on leg muscle in their sport-specific training, which may have reduced the training potential in these muscles. This is also supported by the performance results showing more gain in upper body strength in SR than FR. The increased LBM in SR and maintained LBM in FR during a 5–6% reduction in BW is a controversial result (Koutedakis et al., 1994; Smith et al., 2001; Umeda et al., 2004), because the subjects were normal-weight athletes with a history of high training volume, including strength training.

Studies on gradual weight loss in athletes are sparse, and the methodology is limited because of small sample sizes and different nutritional strategies and measurements of performance and body composition. However, it has been reported that loss of LBM accounts for 30–85% of total weight loss after reducing BW by 4–8% (Koutedakis et al., 1994; Slater, Rice, Jenkins, Gulbin, & Hahn, 2006; Umeda et al., 2004). Furthermore, a curvilinear relationship between initial body-fat content and the proportion of weight loss consisting of LBM is reported (Forbes, 2000). Consequently, weight loss in already lean people will normally compromise LBM even when

exercise is incorporated in the weight-loss intervention (Forbes, 2000). Although some studies support this, especially studies that include endurance exercise as the intervention (Kraemer et al., 1999), other studies report a different weight-loss composition in favor of preserving LBM when heavy strength training is added (Kraemer et al., 1999; Stiegler & Cunliffe, 2006). Although the composition of the weight loss varies between studies, most studies report loss of LBM during energy restriction even in obese subjects (Forbes, 2000; Stiegler & Cunliffe, 2006).

In contrast to the suggested curvilinear relationship between initial body-fat content and the proportion of weight loss consisting of LBM, we found no correlations between initial fat mass and changes in LBM. The reason for this may be that the heavy strength training during the intervention stimulated muscle growth and thereby overrode the catabolic effect of negative energy balance on LBM. In a study by Umeda et al. (2004), 38 athletes participated in a 20-day intense training regimen (21 hr/week exercise, including 2 hr/week of strength training) combined with energy restriction. The athletes reduced their BW by 2.8 kg, and loss of fat-free mass contributed to 61% of the total weight loss. Although the intervention was of shorter duration, the weekly weight-loss rate corresponded to 1.2% of BW and thus is comparable with the result in the current study. These results suggest that a certain amount of heavy strength training is critical to preserve or increase LBM during energy restriction in elite athletes.

The relative increase in LBM was significantly greater in women than men. There were no significant differences in total training hours or weekly hours of strength training between men and women the season before entering the study. The fact that women had a higher baseline percent body fat may have contributed to a greater potential for LBM increase in women, as well as other factors such as type of previous strength training.

Strength- and Power-Related Performance

The results of the performance tests support the fact that the duration of the intervention was important for changes in strength- and power-related performance. Study results are equivocal when it comes to performance. Some studies report unchanged or improved performance in certain tests after weight loss in athletes, despite loss of LBM (Smith et al., 2001), whereas other studies report impaired performance (Degoutte at al., 2006; Koral & Dosseville, 2009; Umeda et al., 2004). It is a challenge to measure sport-specific performance and interpret the results, especially if athletes from more than one sport are included. We included athletes from several sports in this study for several reasons. Adequate sample size is one of the limiting factors when elite athletes are included in more challenging intervention studies. Furthermore, it was important for us to include all the athletes that requested weight-loss assistance. Because of the heterogeneous group of athletes in this study, we included more general tests of strength- and power-related performance. Nevertheless, the more general impact on physical capacity measured in this study provides important information on how function is affected by the interventions.

EDI

Because dieting has been considered a risk factor for development of eating disorders (Nattiv et al., 2007; Sundgot-Borgen, 1994), it was expected that the athletes might increase their scores on the drive-for-thinness test (the higher the score, the more symptomatic). Neither SR nor FR increased any of the subscale scores during the intervention period. The lack of increased scores in EDI subscales can probably be explained by the fact that none of the athletes had symptoms of eating disorders at baseline. Furthermore, these athletes were all closely guided during the weight-loss period. It has been stated that in terms of developing eating disorders, it is not necessarily dieting, per se, that triggers an eating disorder but whether or not the athlete is guided during the weight-loss period (Sundgot-Borgen, 1994).

Compliance

Three athletes in SR and 5 in FR did not accomplish their weight-loss goals. Although every athlete was closely followed to reach their final weight goal, we did not put pressure on them in favor of study compliance for ethical reasons. One might also consider whether the noncompliers actually were nonresponders to the intervention because of counterregulatory mechanisms (i.e., reduced metabolism or other mechanisms increasing food efficiency; Brownell, Steen, & Wilmore, 1987).

Experimental Design

To be able to do a controlled weight-loss intervention in elite athletes' off-season, we had to accept some limiting factors in the study design and therefore interpret the results with caution. Studies and practical experience indicated that weight loss in normal-weight athletes would compromise LBM and thereby performance. Because many of the athletes were to participate in major competitions a short time after the intervention, we had to include strength training during the intervention to prevent decline in performance. A cleaner approach would be to look at weight-loss rate with standardized habitual training with no additional stimuli for muscle growth. Different amounts of weight lost during the intervention may also be a limiting factor. A cleaner approach would be to standardize amount of weight loss for all athletes (e.g., 5% of BW), but for ethical and health reasons this was not feasible.

Conclusion

The initial aim of twofold difference in weight-loss rate was not achieved in all the athletes in FR, resulting in a weekly weight-loss rate corresponding to 1.0% of

BW rather than 1.4%. However, total LBM increased significantly more in SR, accompanied by significantly improved performance in CMJ and all the 1RM tests, whereas there was no significant increase in LBM or improvements in performance except in 1RM squat in FR. Separating weekly gains in LBM and improvements in strength- and power-related performance, there was a significant difference between groups in favor of SR. This leads to a general suggestion that athletes who want to gain LBM and increase strength- and power-related performance during a weight-loss period combined with strength training should aim for a weekly weight loss of 0.7% of BW, whereas athletes who only want to keep LBM might increase their weekly weight-loss rate to 1.0–1.4% of BW.

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