Long-Term Effect of Weight Loss on Body Composition and Performance in Elite Athletes

Ina Garthe, Truls Raastad, and Jorunn Sundgot-Borgen

Context: When weight loss (WL) is needed, it is recommended that athletes do it gradually by 0.5–1 kg/wk through moderate energy restriction. However, the effect of WL rate on long-term changes in body composition (BC) and performance has not been investigated in elite athletes. Purpose: To compare changes in body mass (BM), fat mass (FM), lean body mass (LBM), and performance 6 and 12 mo after 2 different WL interventions promoting loss of 0.7% vs. 1.4% of body weight per wk in elite athletes. Methods: Twenty-three athletes completed 6- and 12-mo postintervention testing (slow rate [SR] n = 14, 23.5 ± 3.3 yr, 72.2 ± 12.2 kg; fast rate [FR] n = 9, 21.4 ± 4.0 yr, 71.6 ± 12.0 kg). The athletes had individualized diet plans promoting the predetermined weekly WL during intervention, and 4 strength-training sessions per wk were included. BM, BC, and strength (1-repetition maximum) were tested at baseline, postintervention, and 6 and 12 mo after the intervention. Results: BM decreased by ~6% in both groups during the intervention but was not different from baseline values after 12 mo. FM decreased in SR and FR during the intervention by 31% ± 3% vs. 23% ± 4%, respectively, but was not different from baseline after 12 mo. LBM and upper body strength increased more in SR than in FR (2.0% ± 1.3% vs. 0.8% ± 1.1% and 12% ± 2% vs. 6% ± 2%) during the intervention, but after 12 mo there were no significant differences between groups in BC or performance. Conclusion: There were no significant differences between groups after 12 mo, suggesting that WL rate is not the most important factor in maintaining BC and performance after WL in elite athletes.

Keywords: energy restriction, resistance training, hypertrophy, energy intake

Weight loss in elite 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 sports that emphasize leanness. Because of the negative effects of rapid weight loss (e.g., dehydration, fasting) and longer periods of restricted energy intake (Degoutte et al., 2006; Fogelholm, 1994; Hall & Lane, 2001; Koral & Dosseville, 2009; Nattiv et al., 2007; Umeda et al. 2004; Webster, Rutt, & Weltman, 1990), the extant literature recommends a gradual weight loss through moderate energy restriction promoting a weekly weight loss of 0.5–1 kg (O’Connor & Caterson, 2010; Walberg-Rankin, 2002). Whereas weight variations during the season are normal for most athletes, weight cycling and intentional weight loss are considered negative for both performance and body composition, as well as long-term health (Saarni, Rissanen, Sarna, Koskenvuo, & Kaprio, 2006). Thus, it is recommended that athletes reduce weight off-season and keep close to competition weight during the season (O’Connor & Caterson, 2010). However, practical experience indicates that some athletes have to use great effort to maintain a low body mass (BM) during the season and therefore engage in repeated weight-loss periods before competition. To our knowledge there are no studies on the long-term effect of different weight-loss interventions in athletes, but studies in overweight subjects show that only 20% are able to maintain changes in body composition after 1 year (Wing & Phelan, 2005).

The aim of this study was to compare the long-term effect of two weight-loss regimens recommended in the literature (O’Connor & Caterson, 2010; Walberg-Rankin, 2002). Thus, we compared the changes in body composition and performance 6 and 12 months after a weekly BM loss of 0.7% versus 1.4%, which corresponded to a weekly BM loss of 0.5 versus 1.0 kg in a 70-kg athlete. We hypothesized that athletes in the slower weight-loss regimen would maintain their body composition and physical predictors of performance better than athletes in the faster weight-loss regimen.

Methods

Participants

Thirty-six elite athletes, age 18–35 years, were recruited: 30 completed the intervention and 23 completed the 6- and 12-month postintervention tests (see Figure 1). The given reasons for dropout were as follows: The project was too time-consuming (n = 2), the strength-training
program interfered with sport-specific training techniques \((n = 1)\), injury \((n = 5)\), unable to meet for testing because of travel or training out of country \((n = 3)\), and retiring from sport \((n = 1)\). In addition, 1 athlete was removed from the study during the intervention because of early signs of disordered eating behavior. The athlete was cared for by the eating-disorder team in the project. 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, rifle shooting, freestyle sports dancing, skating, biathlon, and ice hockey. In slow reduction \((SR)\), 43% were men \((n = 6)\) and 57% were women \((n = 8)\), and in fast reduction \((FR)\), 33% were men \((n = 3)\) and 67% were women \((n = 6)\). The physical and anthropometrical characteristics of the athletes are shown in Table 1.

The athletes were fully informed about the purpose of the study and the experimental procedures before providing written consent. The study was conducted according to the Declaration of Helsinki and approved by the Data Inspectorate and the Regional Ethics Committee.

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Figure 1 — Flow chart from baseline to 12 months postintervention.

Table 1  Baseline Data, \(M \pm SD\)

<table>
<thead>
<tr>
<th></th>
<th>Slow-Rate Reduction</th>
<th>Fast-Rate Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men ((n = 6))</td>
<td>Women ((n = 8))</td>
</tr>
<tr>
<td>Age (years)</td>
<td>24.9 (\pm) 3.5</td>
<td>22.5 (\pm) 3.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177 (\pm) 11</td>
<td>170 (\pm) 7</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>78.5 (\pm) 14.1</td>
<td>69.6 (\pm) 7.0</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>13.3 (\pm) 5.0</td>
<td>18.8 (\pm) 5.9</td>
</tr>
<tr>
<td>Total body fat (%)</td>
<td>17 (\pm) 5</td>
<td>29 (\pm) 7</td>
</tr>
<tr>
<td>Lean body mass (kg)</td>
<td>62.3 (\pm) 10.3</td>
<td>45.9 (\pm) 5.2</td>
</tr>
<tr>
<td>Experience as athlete (years)</td>
<td>13 (\pm) 6.4</td>
<td>10.6 (\pm) 4.6</td>
</tr>
<tr>
<td>Training per week (hr)</td>
<td>15.6 (\pm) 4.5</td>
<td>12.0 (\pm) 2.3</td>
</tr>
<tr>
<td>Strength training last season (hr/week)</td>
<td>2.8 (\pm) 1.6</td>
<td>2.4 (\pm) 1.7</td>
</tr>
</tbody>
</table>
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 when they contacted the Olympic Sports Center. All athletes followed a 4- to 12-week weight-loss intervention with a combination of energy restriction and strength training. The length of the intervention was determined by the rate of weight loss (SR or FR) and the desired weight loss (minimum 4% of BM) for each athlete. The final weight goal was set by the team (nutritionist and exercise physiologist) based on results from body-composition measurements that provided the information needed to calculate minimum fat percentage for each athlete and the athlete’s desired weight loss. For example, a 70-kg athlete set to reduce BM by 5 kg would have either a 5-week (1.4%/week, FR) or 10-week (0.7%/week, SR) intervention depending on the intervention group to which the athlete was randomly allocated. The athletes received nutritional counseling once a week during intervention. The counseling included basic nutrition, sport physiology, and possible adjustments in the dietary plan or weight regimen, depending on progress. After the intervention, the athletes received one nutrition counseling session within 4 weeks and exercise counseling to stabilize the new BM and body composition. The athletes were called in 6 and 12 months after the intervention to investigate the long-term effects of the different interventions on body composition and performance.

**Preparticipation Screening**

The screening included the Eating Disorder Inventory (EDI-2; Cooper & Fairburn, 1987; 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; presence of one or more components of the female athlete triad—disordered eating or eating disorder, menstrual dysfunction, and/or low bone-mineral density; clinically evident perimenopausal condition; pregnancy; and fat mass (FM) corresponding to a predicted postintervention body-fat value of less than 5% for men and 12% for women (Fogelholm, 1994; Heyward & Wagner, 2004). For possible diagnoses, DSM-IV criteria were used for anorexia nervosa, bulimia nervosa, and eating disorders not otherwise specified (American Psychiatric Association, 1994).

**Diet**

A 4-day diet record was obtained before the intervention, and 24-hr recall 6 and 12 months postintervention, all of which were analyzed with a national food database, Mat På Data (version 5.0, LKH, Mattilsynet, Norway). The record served as a basis for developing each athlete’s individualized diet plan promoting weekly BM loss of 0.7% or 1.4%. The athletes were weight-stable during the 4 days they recorded their diets. 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-density foods that provided satiety, as well as food variety. All diet plans included 5–7 daily meals and snacks, and no meal plan was below 1,500 kcal/day (4 athletes followed a diet plan at exactly 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 of each training session and a balanced meal within 1–2 hr in an attempt to optimize recovery. During implementation of the dietary plan, the athletes used a food scale to ensure correct portion sizes during the first 2–3 weeks. After the third week, they were encouraged to use the food scale if they were uncertain about portion sizes. If they 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 use creatine supplementation during the 6 weeks before the intervention, and they did not take any supplements other than those given them 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 B₁₂), these vitamins were provided to the athletes and blood levels were thereafter monitored.

**Training**

The intervention period started off-season so that the athletes would 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) and 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 for multiple muscle groups (e.g., squat) and one more isolated on a specific muscle group (e.g., knee extension). The main exercises for leg muscles were clean (whole body), squat, hack squat, and dead lift, and the main exercises for upper body muscles were bench-press, bench-pull (horizontal rowing), rowing, chins, shoulder press, and core exercises. In the first 4 weeks the athletes trained 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 less than 12 weeks, the program was adjusted with shorter periods. The rest period between sets was 1–3 min. Once a week, athletes were supervised during training at the Olympic Sports Center to ensure correct training technique and adequate progress.

Experimental Assessments

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

BM
BM was measured in the fasted state with a calibrated 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 BM 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 waking up and before breakfast.

Body Composition

FM and lean body mass (LBM) were measured with dual-energy X-ray absorptiometry (DEXA; GE Medical Systems, Lunar Prodigy, Wisconsin, USA) by a trained technician. The DEXA system was calibrated every day before testing, and the test was conducted in a fasted state between 8:30 and 10 a.m. For DEXA reproducibility, 10 athletes did two repeated measurements within 24 hr, and the coefficient of variation in DEXA Lunar Prodigy total body scan for repeated measurements was 3% for FM and 0.7% for LBM. The athletes wore minimal clothing during the DEXA scan (underwear and sports top for women).

Indicators of Performance

Performance was measured by 40-m sprint, countermovement jump, and 1RM in bench-press, bench-pull, and squat. Before these 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. Countermovement jump was performed on an AMTI force platform (SG 9, Advanced Mechanical Technology Inc., Newton, MA), and the best jump out of three was used in the data analysis. For 1RM 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 patterns common in anorexia nervosa and bulimia nervosa (Garner, 1991). The EDI-2 consists of the following 11 subscale scores: drive for thinness, bulimia, body dissatisfaction, ineffectiveness, perfectionism, interpersonal distrust, interpersonal awareness, maturity fears, asceticism, impulse regulation, and social insecurity. It is frequently used in both clinical and nonclinical populations to predict risk of developing eating disorder. Hence, the athletes filled out the EDI before and after the intervention and 6 and 12 months afterward to assess behaviors and psychological attributes associated with eating disorder.

Statistical Analysis

With an expected net difference in change of FM of 6% from baseline to postintervention Test 1, the minimum sample size for two equally sized groups had to be 29, assuming a standard deviation of FM change equal to 7% and a significance level of 5%, \( n = 2 \times (1.96 + 1.28)2 \times (7/6)2, n = 29 \). However, we managed to include only 36 athletes, because the athletic population at this level is limited. Although we found significant differences from baseline to postintervention Test 1 (Garthe, Raastad, Refsnes, Koivisto & Sundgot-Borgen, 2011), dropouts and multiple \( t \) test (corrected with Bonferroni’s post hoc test) made the sample sizes too small for some of the 6- and 12-month follow-up tests.

Data are presented as \( M \pm SD \) for baseline and postintervention measurements and \( M \pm SE \) for changes within and between groups. The software programs Graphpad Prism 5.0 (California) and SPSS 15 (IBM, USA) were used for statistical analyses. Changes from baseline to postintervention and 6- and 12-month follow-up were analyzed with repeated-measures ANOVAs within groups and two-way repeated-measures ANOVAs between groups. Significant interactions were corrected with Bonferroni’s post hoc test. Values of \( p \) below .05 were considered statistically significant.

Results

A history of dieting and weight cycling was reported by 57% of the athletes in SR and 67% of the athletes in FR. The mean times spent in the intervention for SR and FR were 8.7 ± 2.3 and 5.9 ± 1.1 weeks, respectively. There were no significant differences between groups in any of the baseline measurements (Table 1 and 2).

Diet

Energy intake was reduced by 31% ± 5% in FR and 19% ± 5% in SR (Table 2) during the intervention. Although intake of most of the macronutrients was significantly reduced from baseline to postintervention, none of the variables differed between groups (Table 2). Maintenance
diet plans were reportedly followed for 6 months by athletes from both groups (2 and 5 athletes from SR and FR, respectively). Other athletes (8 and 4, respectively) reported partially following a diet plan. Four athletes in SR and none in FR reported following no diet plan. At 12 months, 2 and 4 athletes from SR and FR, respectively, reported having followed a maintenance diet plan for the last 6 months, 7 and 4 reported partly following, and 5 and 1 reported not following any diet plan.

**Body Composition**

BM was reduced by 5.8% ± 0.7% in SR (p < .001) and 5.7% ± 0.9% in FR (p < .001) during the intervention (Figure 2). 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 higher than in SR (p = .02). Six months after the intervention, SR had regained 77% of the lost BM, whereas FR had regained 14% from postintervention (p < .05). Twelve months after the intervention, both groups had returned to their original weight (Figure 2). Whereas FM tended to decrease more in SR than in FR during the intervention (31% ± 3% vs. 23% ± 3%, respectively, p = .06), SR regained 90% of the FM after 6 months and had significantly more than FR (p < .05; Figure 3). Twelve months after the intervention, both groups had regained their original FM. Total LBM increased by 2.0% ± 0.4% in SR (p < .001) during intervention but had returned to baseline after 6 and 12 months. LBM did not change significantly in FR during the intervention (0.8% ± 1.1%) or after 6 (1.3% ± 0.8%) or 12 months (0.3% ± 0.8%; Figure 4). There was no significant difference in total LBM between groups at any time.

**Performance**

Because of small sample sizes as a result of injuries, the analysis of jumping performance (countermovement jump; n = 8) and 40-m sprint (n = 5) were excluded.

### Table 2 Energy and Nutrition Variables, M ± SD

<table>
<thead>
<tr>
<th>Variable</th>
<th>4-day weighed-food record</th>
<th>Meal plan during intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake (kcal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>2,317 ± 689</td>
<td>1,909 ± 477*</td>
</tr>
<tr>
<td>FR</td>
<td>2,222 ± 682</td>
<td>1,688 ± 229*</td>
</tr>
<tr>
<td>Protein (g/kg BW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>1.4 ± 0.5</td>
<td>1.6 ± 0.4</td>
</tr>
<tr>
<td>FR</td>
<td>1.5 ± 0.6</td>
<td>1.4 ± 0.2</td>
</tr>
<tr>
<td>Protein (E%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>18.0 ± 3.0</td>
<td>25.0 ± 3.7*</td>
</tr>
<tr>
<td>FR</td>
<td>20.0 ± 7.0</td>
<td>24.3 ± 3.5</td>
</tr>
<tr>
<td>CHO (g/kg BW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>4.0 ± 1.1</td>
<td>3.5 ± 0.7*</td>
</tr>
<tr>
<td>FR</td>
<td>3.8 ± 1.3</td>
<td>3.2 ± 0.7</td>
</tr>
<tr>
<td>CHO (E%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>51.3 ± 6.3</td>
<td>54.0 ± 3.4*</td>
</tr>
<tr>
<td>FR</td>
<td>49.0 ± 6.7</td>
<td>56.0 ± 5.0</td>
</tr>
<tr>
<td>Fat (E%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>30.1 ± 6.6</td>
<td>20.7 ± 1.1*</td>
</tr>
<tr>
<td>FR</td>
<td>31.0 ± 3.5</td>
<td>20.3 ± 2.7*</td>
</tr>
</tbody>
</table>

**Note.** SR = slow-rate reduction; FR = fast-rate reduction; BW = body weight; E% = percentage of total energy intake; CHO = carbohydrate. SR n = 14, FR n = 9. *p < .05, significantly different from preintervention.

**Figure 2** — Changes in body mass (BM) in slow reduction (SR) and fast reduction (FR) from baseline to 12 months postintervention (n = 14, SR; n = 9, FR), M ± SE. *p < .05, significantly different from preintervention. #p < .05, significant difference between groups.

**Figure 3** — Changes in fat mass (FM) in slow reduction (SR) and fast reduction (FR) from baseline to 12 months postintervention (n = 14, SR; n = 9, FR), M ± SE. *p < .05, significantly different from preintervention. #p < .05, significant difference between groups.
There were no statistically significant changes in performance in any of the variables in FR at any time. 1RM squat improved by 15.6% ± 7.5% (p = .07) in SR but was back to baseline 6 and 12 months after the intervention (Figure 5[c]). Bench-press performance increased by 17.0% ± 2.6% (p < .01) in SR during the intervention and was still higher than baseline 12 months later (17.7% ± 6.0%, p = .01; Figure 5[b]). There was no significant change in bench-pull performance, and there were no significant differences between groups at any time point (Figure 5[a]).

**Training**

The athletes reported 7.5 ± 0.2 hr/week of strength training during the intervention. Athletes in SR reported training 15.0 ± 6.0 hr/week after 6 months, of which 4.7 ± 2.3 hr were strength training. FR reported training 14.9 ± 3.1 hr/week after 6 months, of which 3.9 ± 1.6 hr were strength training. After 12 months, SR reported training 11.9 ± 5.2 hr/week, of which 3.0 ± 1.7 hr were strength training, and FR reported training 13.3 ± 5.1 hr/week, of which 3.8 ± 2.0 hr were strength training.

**Gender**

Gender-specific analyses for SR and FR were not done because of the small sample size. However, when SR and FR were merged, the women tended to gain LBM (2.0 ± 1.8, p = .06), whereas men’s LBM was unchanged during the intervention (~2.0 ± 1.0), with a significant difference between genders (p = .03). Furthermore, women had significant improvements in all 1RM parameters, whereas performance parameters were unchanged for men. No other significant gender differences were observed for changes in performance tests, body composition, or subjective feedback during the weekly consultations.

**Discussion**

The aim of this study was to compare the long-term effect of 5–6% BM loss at a slow or fast rate on changes in body composition and indicators of physical performance in elite athletes. We hypothesized that the faster weight loss would result in a faster regain of BM and FM 6 and 12 months after the intervention. We actually found that SR resulted in a regain of BM and FM faster than FR after 6 months, but there were no significant differences between groups after 12 months. We also hypothesized that the SR group would maintain performance to a greater extent after 6 and 12 months. We found that they tended to maintain 1RM strength better than FR after 6 and 12 months, but there were no significant differences between groups at any time point.

**Diet**

We chose a 4-day (3 weekdays + 1 weekend day) weighed-food record before the intervention as a base for the meal plan to minimize the burden, increase compliance, and decrease alteration of the subjects’ usual intake. For their high activity level, the reported energy intake was relatively low, and this may be a result of underreporting, undereating, or both, which are common errors in self-reported dietary intake (Magkos & Yannakoulia, 2003). Thus, the effect of the meal plan was assessed by weekly measurements of BM and skinfold thickness during the intervention. We chose 24-hr recall at the follow-up 6 and 12 months after intervention to minimize the burden and increase compliance. However, these data are not presented in this article because they were clearly a result of underreporting and could not be compared with baseline data. Although 17 athletes reported that they followed or partly followed meal plans with energy intakes close to their meal plan, they had regained their initial BM. Despite the fact that there may be adverse effects in BM regulatory hormones, as well as decreased resting energy expenditure from a lower BM (King et al., 2007; Vogels, Diepvens, & Westerterp-Plantenga, 2005), we find it unlikely that 13 of the athletes had an energy intake below 1,500 kcal/day after 6 months with no changes in training hours. This strongly implies that these data rate a low level of confidence, and we chose not to present them. The calculated energy deficits during the intervention for the SR and FR were 408 ± 84 and 533 ± 179 kcal/day, respectively. Because the athletes performed daily training sessions during the intervention, no meal plan was set below 1,500 kcal/day. This
practice resulted in a slightly different intervention for 3 of the athletes (1 from SR, 2 from FR). Because of their low baseline energy intake, they had to increase energy expenditure to be able to reach their weekly weight-loss goal. This necessity also may be one reason why there were no significant differences between energy intakes between the two interventions.

There were no significant differences between groups in intake of any of the macronutrients at any time (Table 2). Adequate carbohydrate and protein intakes are considered among the most important nutritional factors for athletes (American Dietetic Association [ADA] et al., 2009). Thus, the diet during the intervention in this study was a low-fat, moderate-protein (~20% of total energy intake) diet. The mean carbohydrate intakes were 3.5 ± 0.7 g/kg (SR) and 3.2 ± 0.6 g/kg (FR), which are less than recommended (ADA et al., 2009). The mean protein intakes were 1.6 ± 0.47 g/kg and 1.4 ± 0.27 g/kg in SR and FR, respectively, and were within the recommended protein intake for athletes (ADA et al., 2009; Tipton & Wolfe, 2004). Adequate protein intake during the intervention 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 (Karst, Steiniger, Noack, & Steglich, 1984; Tipton & Wolfe, 2004). 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.

Body Composition and Strength Performance

Both BM and FM showed similar patterns, with significantly reduced values from baseline to postintervention. BM and FM were maintained to a greater extent in FR

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**Figure 5** — Changes in one-repetition-maximum performance in slow reduction (SR) and fast reduction (FR) from baseline to 12 months postintervention (n = 14, SR; n = 9, FR), M ± SE. *p < .05, significantly different from preintervention. #p < .05, significant difference between groups.
after 6 months than in SR. This difference was supported by a tendency toward a more restrictive energy intake in FR (Table 2). One possible explanation for this may be that there were more weight-class athletes in FR than SR (21% vs. 44%). These athletes have an extra motivation for weight maintenance, because they have weigh-ins before competitive events, as opposed to athletes who are changing BM and composition for aesthetic or performance-related reasons. Thus, frequent competitions during the 6 months after the intervention might be the main reason these athletes kept a stable weight and body composition. In addition, there were 5 dropouts in FR after the intervention (Figure 1), as opposed to none in SR. This may also have influenced the reported weight gain after 6 and 12 months for FR. The main given reasons for dropout were injuries and traveling. However, we do not know if the dropouts regained BM quickly after the intervention or if increased BM was one of the factors for dropping out.

After 12 months, all parameters had returned to baseline, suggesting that maintaining new BM and body composition was difficult. Maintaining BM and composition seem to be a multifactorial issue, including mechanisms that regulate an individual’s energy expenditure, body composition, and eating behavior (Vogels et al., 2005). Although athletes in this study maintained or increased LBM during the weight-loss period, there may be adverse effects in BM regulatory hormones, as well as decreased resting energy expenditure from a lower BM (Leibel, Rosenbaum, & Hirsch, 1995). Unfortunately, we did not measure resting energy expenditure in all the athletes in this study.

For the sedentary, overweight population, specific approaches associated with long-term weight loss have been identified (Wing & Phelan, 2005). High levels of physical activity (1 hr/day); consumption of a low-calorie, low-fat diet and regular breakfast; self-monitoring of weight; and maintenance of a consistent eating pattern across weekdays and weekends seem to be important factors (Wing & Phelan, 2005). For elite athletes there may be different approaches because of high training loads, traveling, and busy schedules. Most of the athletes reported maintaining food choices, recovery meals, and meal frequency after the intervention. They also reported that they thought they had a higher total energy intake than during the intervention and that they did not monitor BM regularly. Thus, many slowly slipped back to their initial BM. The most commonly reported reasons for not being able to maintain changes in BM and body composition were lack of follow-up and periods of injury or traveling. It also became apparent that most of the athletes thought that “voluntarily” keeping such a strict diet with a heavy training load was a mental challenge.

There were no significant changes in LBM or performance at any time in FR. LBM increased significantly in SR from baseline to postintervention but was back to baseline after 6 and 12 months. Increased upper body LBM was the major contributor to the increase in total LBM in the SR group during the intervention, likely contributing to the superior gain in upper body strength in SR compared with FR. Whereas LBM returned to baseline after 6 and 12 months, upper body strength was maintained in SR, suggesting a complex relationship between training status, LBM, and maximal strength. 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 who requested weight-loss assistance. Because of the heterogeneous group of athletes in this study, we therefore 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.

Although reporting close to 8 hr/week of strength training during the intervention, athletes from SR and FR decreased their time spent in strength training to baseline values after 6 and 12 months (4.7 ± 2.3 vs. 3.9 ± 1.6 and 3.0 ± 1.7 vs. 3.9 ± 2.0 hr/week, respectively). Because strength training was a major contributor to the maintenance and gains in LBM during the intervention (Garthe et al., 2011), the reduced stimuli for muscle growth after 6 and 12 months is likely to be the most important factor for the decline in LBM. Because time spent in the intervention was ~3 weeks longer for SR, they had a significantly greater effect of strength training than FR. Thus, they also had a trend for greater decrease after the intervention.

**Gender**

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 fat percentage may have contributed to a greater potential for LBM increase in women, as well as other factors such as type of previous strength training.

**EDI**

It is difficult to explain the fact that only a few athletes in FR fulfilled the criteria for being evaluated on the EDI. The EDI questionnaire was voluntary, and it takes close to 45 min for some athletes to complete. Although all athletes completed baseline to postintervention tests and completed the questionnaire at 6 and 12 months postintervention, they may have paid less attention while answering or avoided some of the difficult questions. However, because there were no significant differences in total EDI score for SR at any time point and there were no significant differences in total EDI score for SR from pre- to postintervention (Garthe et al., 2011), we speculate...
that total EDI scores for FR after 6 and 12 months would have been unchanged.

**Conclusion**

Athletes in FR maintained body composition better than those in SR during the first 6 months, and SR tended to maintain 1RM performance better than FR. Distribution of athletes from different sports may have had the greatest influence on these differences. There were no significant differences between SR and FR after 12 months, suggesting that several factors other than weight-loss rate contribute to maintenance of body composition and performance after weight loss. Long-term follow-up after an intervention may be more important for an elite athlete to maintain changes over time in a busy schedule with competitions, traveling, and periods of injury. We would like to emphasize the fact that both FR and SR achieved the recommended weekly weight loss. Furthermore, the FR supported a gradual weight loss over several weeks and consequently can be classified as a slow weight-loss regimen compared with other unhealthy regimens practiced by some athletes (e.g., dehydration, fasting, vomiting, and use of laxatives).

**Practical Implications**

In practical terms, we recommend that athletes who want to lose 5–6% of BM combine moderate energy restriction with strength training to achieve gains in LBM and improvements in strength. Both interventions in the current study were within the recommended range of weekly weight loss. There are different weight-loss methods used for different athletes—losing weight for weigh-in or losing weight for long-distance running require different strategies. Fast weight loss through dehydration, fasting, vomiting, and use of laxatives should be avoided because of negative effects on health and performance (Degoutte et al., 2006; Hall & Lane, 2001; Nattiv et al., 2007; Webster et al., 1990). Before any weight-loss intervention is started, there should be a thorough screening including weight history and weight goal, menstrual history for females, an estimate of body composition and energy status, and questions regarding motivation, dietary habits, thoughts, and feelings about body image, BM, and food. We also recommend that the weight-loss period be off-season and that the athlete’s health and performance be monitored by health-care professionals during the period. Change in body composition should be monitored on a regular basis, together with follow-up from health-care professionals after the weight-loss goal has been reached to detect any weight fluctuations and prevent regain during the season. Normal-weight athletes under the age of 18 and athletes with a previous history of eating disorder should be discouraged from starting a weight-loss intervention. Future research in this area should focus on revealing mental and motivational factors in elite athletes during and after weight-loss intervention.

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**References**


