Effects of a Dairy Supplement and Resistance Training on Lean Mass and Insulin-Like Growth Factor in Women

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Abstract:

Purpose:

To examine the effect of yogurt supplementation pre- and postexercise on changes in body composition in overweight women engaged in a resistance-training program.

Methods:

Participants (age = 36.8 ± 4.8 yr) with a body-mass index of 29.1±2.1 kg/m^2 were randomized to yogurt supplement (YOG; *n* = 15) or isoenergetic sucrose beverage (CONT; *n* = 14) consumed before and after exercise for 16 wk. Participants were also instructed to reduce energy intake daily (–1,046 kJ) during the study. Body composition was assessed by dual-energy X-ray absorptiometry, waist circumference, and sagittal diameter. Strength was measured with 1-repetition maximum. Dietary recalls were obtained by a multipass approach using Nutrition Data System software. Insulin-like growth factor-1 and insulin-like growth-factor-binding protein-3 were measured with ELISA.

Results:

Significant weight losses of 2.6 ± 4.5 kg (YOG) and 1.2 ± 2.5 kg (CONT) were observed. Total lean weight increased significantly over time in both YOG (0.8 ± 1.2 kg) and CONT (1.1 ± 0.9 kg). Significant reductions in total fat (YOG = 3.4 ± 4.1 kg vs. CONT = 2.3 ± 2.4 kg) were observed over time. Waist circumference, sagittal diameter, and trunk fat decreased significantly over time without group differences. Both groups significantly decreased energy intake while maintaining protein intake. Strength significantly increased over time in both groups. No changes over time or between groups were observed in hormone levels.

Conclusions:

These data suggest that yogurt supplementation offered no added benefit for increasing lean mass when combined with resistance training and modest energy restriction.

Keywords: yogurt | exercise | body composition | hormones

Article:

The timing of protein ingestion is a key factor for increasing muscle synthesis, decreasing muscle degradation, and enhancing muscle function (Tipton & Wolfe, 2003). Acute trials examining preexercise and postexercise supplementation with protein and carbohydrate support these benefits (Bird, Tarpenning, & Marino, 2006; Borsheim, Aarsland, & Wolfe, 2004; Elliot, Cree, Sanford, Wolfe, & Tipton, 2006; Miller, Tipton, Chinkes, Wolf, & Wolfe, 2003; Tipton, Elliott, Cree, Wolf, Sanford, & Wolfe, 2004; Tipton et al., 2001). In addition, the timing of protein ingestion has been implicated in modulating hormonal response (Ballard, Clapper, Specker, & Binkley, 2005), which in turn may contribute to muscle and strength accretion. However, studies examining nutrient supplementation's effects on insulin-like growth factor (IGF) are limited in number and report inconsistent results (Ballard, et al. 2005; Borst et al., 2001).

Further investigation to observe how hormones such as IGF-1 and IGF-binding protein-3 (IGFBP-3) respond to dietary manipulations may better define the resistance exercise- induced anabolic response that promotes body composition change. Currently, little research has been done to explain the effect of food protein supplementation on the IGF-1 and IGFBP-3 response in females. Ballard et al. (2005) reported that IGF-1 concentrations changed with a commercial postexercise protein supplementation (42 g); however, the energy density of the supplement may not appeal to women who want to lose weight. Moreover, chronic changes in IGF-1 and IGF-BP3 have not been thoroughly examined in overweight, untrained, premenopausal women enrolled in a resistance-training trial of >12 weeks. Investigating changes in these hormonal signals during a trial long enough to also observe appreciable changes in lean body mass adds to the limited literature on women.

Dairy-based supplements have been shown to be effective at promoting muscle-mass gain when provided after resistance exercise (Cribb & Hayes, 2006; Hartman et al., 2007; Josse, Tang, Tarnopolsky, & Phillips, 2010). After a 12-week resistance-training program, Josse et al. observed a significant increase in lean mass with a concomitant decrease in fat mass when supplementing 1 L of skim milk within 1 hr of resistance exercise. Although skim milk promoted favorable body-composition changes compared with isoenergetic carbohydrate in a sample of young healthy women, consuming 1 L of fluid milk after exercise may not be desirable for most women.

To date, no study has examined the effect of an easily consumed dairy product pre- and postexercise in untrained, overweight, premenopausal women who want to lose weight. Other trials examining the topic of postexercise supplementation in promoting healthful body-composition changes in women were short in duration (White, Bauer, Hartz, & Baldridge, 2009), did not match the energy density of the control and experimental supplements (Holm et al., 2008), and did not restrict energy intake (Holm et al., 2008; White et al., 2009).

Therefore, the primary purpose of this study was to examine the role of yogurt supplementation in relation to a resistance-exercise program as an effective means to augment increases in lean body mass and strength while reducing body fat in overweight women after an energy-restricted diet. We hypothesized that participants consuming yogurt 20 min before and immediately after each resistance-exercise bout would have greater muscle strength and lean body mass and lose more fat than participants receiving an isoenergetic, carbohydrate-only placebo. A secondary objective was to determine the influence of yogurt supplementation on the IGF-1 and IGFBP-3 responses to resistance training. We hypothesized that participants given yogurt before and after resistance training would experience larger increases in fasting levels of IGF-1 and IGFBP-3 than those consuming a placebo before and after exercise.

Methods

Participants

Participants were recruited using advertisements distributed across the university campus and nearby community. Potential participants with a self-reported height and weight meeting the body-mass-index (BMI) criterion of 25–30 kg/m2 underwent an in-depth phone interview covering current health status (ADA, 2003), exercise, and medical history to determine eligibility. Other inclusion criteria were being 29–45 years of age and having undergone no resistance training in the previous 3 months. The premise for selecting this age group and BMI range was twofold: Women of this age group are at a high risk for weight gain, and an intervention designed to improve body composition in overweight women of this age may reduce the chances of obesity-related comorbidities later in life.

Exclusion criteria included any medical condition that could compromise the safety of participation or confound study results. This included pregnancy or lactation, reported aversion to dairy products, previous history of orthopedic injury, gastrointestinal disease, and endocrine disorders. Volunteers taking the following medications were excluded: steroidal drugs, diuretics, calcium-channel blockers, insulin or antidiabetic agents, synthetic thyroid hormones, and over-the-counter weight-loss supplements. Oral-contraceptive use (n = 3 YOG, n = 6 CONT) was not considered a criterion for study exclusion, and all participants were measured at the same menstrual-cycle stage at each measurement time point.

Sample size was calculated on the basis of changes in lean body mass reported by Holm et al. (2008). Calculations estimated that a final sample size of 32 (16 per group), with an alpha level of .05 and an intraclass correlation of .30 for repeated measures, would provide .80 power to detect a small to medium (delta = .57) change in lean body mass. After we projected a moderate attrition rate (10%), we recruited 35 participants to ensure that the final sample-size requirement would be met. This study was approved by the university institutional review board, and all eligible volunteers gave written informed consent before participating.

Overall Design

After baseline measurements of diet, muscle strength, weight, and body composition, participants were randomly assigned to one of two supplement groups: yogurt 20 min before exercise and immediately postexercise (YOG) or isoenergetic placebo given 20 min before exercise and immediately postexercise (CONT). The primary goals of this study were to promote muscle-mass accretion through pre- and postexercise supplementation while enhancing hormone levels and to support the transition to a healthy body composition. Therefore, a modest weight loss of approximately 0.25 kg/week was our goal, and a prescribed daily energy deficit of 1,046 kJ was used to promote fat loss.

All volunteers participated in 3-days/week whole-body resistance training for 16 weeks and were instructed to follow a nutritious diet. They were reminded weekly to refrain from participating in additional exercise programs, changing their normal physical activity pattern, or using dietary supplements. Participant weight was documented weekly and used as a tool to assess diet compliance. In addition to monitoring body-weight changes, we had participants meet with the study's registered dietitian (RD) three times per week before the exercise sessions to discuss dietary barriers and address diet-related questions.

Anthropometric and Body-Composition Measurements

Height was measured at baseline with the participants shoeless on a stadiometer (Accustat, San Francisco, CA). Weekly body weight was measured on a stationary balance-beam scale in exercise clothing without shoes. Changes in total and regional body composition (fat and total lean mass) from study baseline to endpoint were assessed by dual-energy X-ray absorptiometry (DXA, Lunar-Prodigy Advance Plus). In addition to DXA analysis, waist circumference (Gulick II tape measure) and sagittal diameter (Rosscraft Campbell Caliper 20, Surrey, BC, Canada) were measured to assess changes in central adiposity. Waist circumference was measured at the narrowest part of the waist at all three study time points (ACSM, 2006).

Strength Assessment

Strength was assessed with one-repetition-maximum (1-RM) testing at baseline, at midpoint, and at the end of 16 weeks. Participants began with a warm-up of 5–10 repetitions at 40–60% of their perceived capacity for one lift. After a 2-min rest, they completed 3–5 repetitions at 60–80% of their perceived capacity for the same lift. Finally, successive 1-RM attempts were performed until failure, with the goal of determining the true 1-RM within 3–5 trials (Kraemer & Fry, 1995). Loads were increased by 2–5 kg for each trial, and participants were allowed to rest 3–5 min between attempts. Verbal encouragement was given on each attempt to maximize performance.

Dietary-Intake Assessment

Diet was assessed using the Nutrition Data System for Research (NDSR version 2008, Minneapolis, MN). NDSR is a nutrition software system designed to collect and assess 24-hr dietary-recall information over the phone. The system uses the multiple-pass recall method to help improve the validity of dietary data (Blanton, Moshfegh, Baer, & Kretsch, 2006; Moshfegh et al., 2008). Two random dietary recalls within the same week occurred before randomization, at midpoint, and at study endpoint.

Hormone Assessment

Within 10 days after the start of menstruation (early follicular phase), morning fasting (12 hr overnight) levels of IGF-1 and IGFBP-3 were assessed at study baseline, at midpoint, and immediately after the 16-week intervention. This phase of the menstrual cycle was chosen to control for estrogen-induced changes in the IGF system. Approximately 15 ml of blood was collected by standard antecubital venipuncture. All blood samples were processed, and serum was frozen at –80 °C until ready for analysis. Duplicate samples were assayed for IGF-1 (IDS, Fountain Hills, AZ) and IGFBP-3 (IDS) using enzymelinked immunosorbent assays (ELISA).

Intervention

Participants received individualized counseling from the RD and were instructed on the use of an exchangesystem diet to guide prescriptions for energy intake. The prescribed diet was based on the American Dietetic Association and American Diabetes Association's (ADA) exchange system (ADA, 2003) and was constructed to control for daily protein consumption (~15% of total energy intake from protein, 55–60% from carbohydrate, and 25–30% from fat). Exchange diets were designed by the study RD during initial counseling sessions to promote a modest energy reduction (–1,046 kJ) from weight-maintenance needs.

Energy needs for weight maintenance were calculated using the Food and Nutrition Board (2005) equation for determining energy needs in overweight and obese adult women. Adjustment of total energy expenditure (TEE) for physical activity level (PAL) was accomplished by multiplying the TEE by the appropriate PAL coefficient (sedentary = 1.0 or low active = 1.16). Initial energy-need estimates were determined by averaging initial energy calculations (TEE × PAL coefficient) with the baseline dietary-recall information. The initial intervention energy prescription was determined by subtracting 1,046 kJ to support 0.25-kg/week weight loss.

Participants in both groups received complimentary vitamin D (400 IU) and folic acid (400 μg) supplements to prevent insufficient dietary intake. Compliance with diet was monitored and maintained by assessing weekly weights, midpoint dietary-recall assessment, and weekly question-and-answer sessions with the RD.

Whole-body resistance training took place three times per week for 16 weeks. The exercises included dumbbell chops, dumbbell squats, dumbbell bench press, dumbbell rows, and dumbbell dead lift. Participants completed all training sessions in the human-performance laboratory under the close supervision of trained research personnel. The primary goal of the exercise design was to implement a protocol that could easily be repeated at home in less than 30 min and without the need for a gym membership.

All participants began the training program by completing a 2-week familiarization period followed by 14 weeks of progressive training. During the familiarization period participants completed all exercises with two sets of 10 repetitions at 60–70% of their initial 1-RM. To ensure proper technique for the squat exercise, participants performed the exercise (Weeks 1–2) using only their body weight and an exercise ball placed against the wall. Training for all exercises advanced to three sets per exercise at Week 3, with a goal repetition range of 8–12. Rest periods between sets were timed and enforced at 60 s. Participant progression followed the classic linear model of periodization as strength improved between 1-RM measuring points

(ACSM, 2006). Participants gradually progressed to training at 80–100% of their baseline 1-RM while maintaining a goal repetition range of 8–12. Training-load estimates, based on percent 1-RM, were readjusted at protocol midpoint (Week 8), when strength was reassessed with an absolute 1-RM. To help maintain intensity and progression between 1-RM assessments, load adjustments were based on participants' ability to complete 8–12 repetitions.

Participants in the YOG group consumed a 6-oz serving of fat-free yogurt (Yoplait Light Thick and Creamy) containing 418 kJ, 20 g of carbohydrate, 0 g of fat, and 5 g of protein 20 min before and immediately after each exercise session. Participants in the CONT group were asked to consume a 6-oz serving of an isoenergetic placebo beverage containing 25 g of carbohydrate, 0 g of fat, and 0 g of protein during the same time frame as the YOG group. The CONT supplement was a sucrose-sweetened beverage with the same energy density as the yogurt. Supplementation was blinded to all research personnel except the study RD. Each participant received her supplement in a private room with only the RD present and was not permitted to discuss supplementation with staff or other participants during training sessions. In addition to the supplement protocol, participants in each group were permitted to drink only water immediately before and after scheduled exercise times.

Statistical Analysis

Data were analyzed with SPSS (version 17.0). Baseline characteristics were compared between groups with Student's *t* test or chi-square analysis. Differences in body composition, weight, anthropometrics, strength, diet, and hormones over time and between groups were determined by repeated-measures analyses. Significance was determined at $p \leq .05$.

Results

After randomization, 6 participants withdrew from the study before completing the 16-week protocol because of pregnancy (n = 1, YOG) or personal reasons (n = 2, YOG; n = 3, CONT). A total of 29 participants completed the 16-week intervention.

The women were racially diverse, with no significant differences in race distribution among supplement groups when race was dichotomized to either Black (n = 10 YOG, n = 8 CONT) or other (White, Asian, or Latina; n = 5 YOG, n = 6 CONT). There was no significant difference in age between the YOG (37.1 ± 5.0 years) and CONT (36.4 ± 4.8 years) groups.

Table 1. Body Composition at Baseline and Endpoint, M (SD)

	Yogurt, n = 15		Control, n = 14		p		
	Baseline	Endpoint	Baseline	Endpoint	Group	Time	Group × Time
Height (cm)	163.3 (6.4)	-	162.1 (5.4)	-	-	-	-
Body-mass index (kg/m2)*	29.4 (2.0)	28.4 (1.8)	28.7 (2.2)	28.1 (2.3)	.489	.003	.584

Body weight (kg)*	78.3 (7.9)	75.7 (7.3)	75.3 (5.7)	74.1 (6.3)	.402	.007	.391
Total lean mass (kg)*	44.7 (4.8)	45.5 (4.9)	42.4 (2.5)	43.5 (2.8)	.158	.0001	.520
% Body lean mass*	57.2 (3.7)	60.3 (4.9)	56.5 (3.8)	59.0 (4.7)	.534	.0001	.551
Fat mass (kg)*	33.6 (5.2)	30.1 (5.3)	32.8 (5.0)	30. 5 (5.6)	.931	.0001	.370
Body fat %*	42.8 (3.7)	39.7 (4.9)	43.6 (4.1)	41.0 (4.6)	.507	.0001	.610
Trunk fat (kg)*	17.0 (3.1)	15.0 (3.1)	16.6 (3.2)	15.1 (3.3)	.887	.0001	.491
Waist circumference (cm)*	85.3 (6.5)	82.5 (6.8)	86.8 (6.0)	83.4 (5.6)	.594	.0001	.914
Sagittal diameter (cm)*	26.1 (2.0)	25.0 (2.2)	26.1 (2.5)	24.8 (2.3)	.815	.0001	.808

*Significant change over time, $p < .01$.

Body-Composition Changes

There were no significant differences in baseline weight, height, BMI, or lean and fat mass between groups (Table 1). Total lean mass increased over time in both YOG (0.8 ± 1.2 kg) and CONT (1.1 ± 0.9 kg). Participants gained 5.4% (YOG) and 4.4% (CONT) of their weight in lean body mass as a result of the intervention. This accretion of lean tissue occurred despite total mean weight losses of 2.6 ± 4.5 kg (YOG) and 1.2 ± 2.5 kg (CONT). Significant reductions in total fat (YOG = 3.4 ± 4.1 kg and CONT = 2.3 ± 2.4 kg), waist circumference, sagittal diameter, and trunk fat were observed over time, but the differences were not significant by supplement group.

Strength Changes

All measures of strength (1-RM) were similar between groups at baseline (Table 2). Exercise compliance was 92.1% in YOG and 92.6% in CONT. Total workload (Load × Repetitions) significantly increased over time in both groups without group differences. Strength increases in both groups were significant in the bench press, squat, dead lift, and dumbbell row, with no group differences.

Dietary Changes

Energy and protein intake per kilogram body weight (Table 3) were not significantly different between supplement groups at baseline. Significant reductions in total energy intake and energy intake per kilogram body weight were observed ($p \leq .001$). The mean reductions from baseline between groups were 1,134 kJ (YOG) and 1,393 kJ (CONT). Percent energy from protein significantly increased by time but not by protein grams. Average protein intakes at all three time points were 74.8 g (YOG) versus 69.5 g (CONT) and not significantly different between groups.

Furthermore, average protein intakes per kilogram body weight at three time points were 1.0 g/kg (YOG) versus 0.94 g/kg (CONT).

Table 2. Strength Measurements at Baseline, Midpoint, and Endpoint, M (SD)

	Yogurt, n = 15				Control, n = 14			
	Baseline	Midpoint	Endpoint	Increase	Baseline	Midpoint	Endpoint	Increase
Bench press (kg)*	25.3 (7.6)	32.0 (7.8)	36.0 (7.5)	48%	21.3 (4.3)	30.0 (5.0)	33.3 (4.8)	60%
Squat (kg)*	28.3 (9.7)	46.7 (13.2)	55.5 (13.2)	105%	25.9 (5.7)	41.1 (6.0)	54.7 (9.2)	117%
Dead lift (kg)*	28.6 (10.4)	46.2 (13.0)	59.9 (14.4)	124%	24.1 (6.5)	42.3 (7.9)	59.8 (7.4)	161%
Rows (kg)*	19.4 (5.0)	28.5 (4.5)	34.5 (6.3)	84%	19.0 (4.1)	28.6 (2.9)	32.5 (3.8)	81%

*Significant change over time, $p < .01$.

Table 3. Dietary Intake at Baseline, Midpoint, and Endpoint, M (SD)

	Yogurt, n = 15			Control, n = 14		
	Baseline	Midpoint	Endpoint	Baseline	Midpoint	Endpoint
Energy (kJ)*	7,632 (1,916)	6,464 (2,046)	6,527 (1,498)	7,937 (954)	6,627 (1,063)	6,464 (778)
kJ/kg	99 (29)	85 (29)	87 (21)	106 (14)	89 (14)	88 (14)
Protein (g)	72 (23)	70 (20)	80 (16)	69 (15)	67 (14)	72 (9)
Protein (%)*	15.8 (3.8)	20.4 (5.8)	21.9 (5.9)	14.6 (3.3)	17.0 (3.0)	18.8 (2.8)
Protein per kg	0.93 (0.35)	0.92 (0.29)	1.07 (0.26)	0.92 (0.23)	0.91 (0.22)	0.97 (0.13)
Fat (g)*	74 (28)	44 (19)	46 (20)	72 (14)	48 (17)	51 (13.3)
Total carbohydrate (g)	224 (60)	202 (42)	212 (56)	243 (48)	228 (35)	205 (41)
Calcium (mg)*	543 (154)	901 (452)	931 (493)	556 (127)	884 (537)	790 (484)

*Significant change over time, $p < .01$.

Hormone Changes

No change in IGF-1 concentration by time or by group was observed ($N = 28$). One participant was excluded from the analysis because of excessive turbidity of her samples. Percent concentration change from baseline was 14% for YOG (from 137.8 ± 25.9 to 157.4 ± 50.4 ng/ml) and –5% for CONT (139.7 ± 42.8 to 133.0 ± 40.0 ng/ml; $p = .24$). No change in IGFBP-3 concentration by time or by group was observed. Percent concentration increase from baseline was 4% for YOG (5,810 ± 1,908 to 6,062 ± 2,333 ng/ml) and 9% for CONT (4,849 ± 1,350 to 5,297 ± 1,622 ng/ml).

Discussion

In this study, protein and carbohydrate in the form of yogurt (418 kJ preexercise and postexercise) did not result in greater lean-tissue accretion than an isoenergetic sucrose control. Previous research has implicated dairy as an effective vehicle for increasing amino acid availability (Elliot et al., 2006; Hartman et al., 2007) and developing muscle mass with resistance training (Josse et al., 2010). Strength increases, total work output, and workout compliance were similar between groups. Therefore, it can be inferred that our protein supplement did not provide a large enough stimulus to augment strength increases associated with resistance exercise (Josse et al., 2010). Despite the absence of group differences, the overall increase in lean-tissue accretion from this trial was 0.95 kg. This was similar to the 0.8-kg increase observed in a recent study of postmenopausal women (Holm et al., 2008) and approximately half the increase observed by Josse et al. (2010).

It is conceivable that the carbohydrate from yogurt ingestion immediately after resistance exercise may work synergistically with the protein in yogurt to enhance muscle-mass and strength gains. However, carbohydrate ingestion in the CONT beverage immediately after resistance training may have masked group differences by increasing glycogen stores (Ivy, 2001), decreasing protein degradation, and ultimately promoting net protein synthesis (Roy, Tarnopolsky, MacDougall, Fowles, & Yarasheski, 1997). Furthermore, the CONT supplement was likely absorbed faster than the yogurt supplement. The yogurt used in this trial was primarily made up of casein (20% whey, 80% casein) and the disaccharide lactose, resulting in slower gastric-emptying rates and increased time to reach the bloodstream than the sucrose in the CONT beverage. Because of much slower digestion rates (i.e., 80% casein), yogurt in this trial may have limited effectiveness in providing an exogenous source of amino acids to ultimately promote muscle-protein synthesis.

The protein load of 10 g (preyogurt and postyogurt) was not maximal and may have been insufficient to promote significant muscle-protein synthesis despite the practical nature of pre- to postexercise delivery and quantity. Josse et al. (2010) observed that 2- to 500-ml servings of fat-free milk administered after resistance exercise for 12 weeks was adequate to promote a 1.9-kg gain in muscle compared with an isocaloric carbohydrate control ($p < .01$). The young women in the fat-free-milk group ($n = 10$) were also able to significantly reduce fat from baseline, by –1.6 kg compared with –0.3 kg in the control group.

Based on data from a young-male sample (Moore et al. 2009), the dose of protein that maximally stimulates muscle-protein synthesis to drive muscle accretion is approximately 20 g. Yogurt consumed in the current trial contained only 5 g of milk protein. Thus, the dose of protein consumed was not maximal and may have had a limited impact on muscle-protein synthesis. Although the dose of protein that is needed to promote muscle synthesis may be higher in some populations (Moore et al. 2009; Verdijk, Jonkers, Gleeson, & Beelen, 2009), to our knowledge the minimum-dose effect has not been thoroughly tested in women.

Our goal was to promote the reduction of body fat while promoting gains in lean body mass. Therefore, we decreased daily energy intake by 1,046 kJ. This deficit was designed to promote a maximum 3.6-kg fat loss over 16 weeks (1,046 kJ/day × 112 days = 117,152 kJ/32,239 kJ in 1 kg of fat). The YOG group almost achieved this loss, and the CON group did not (3.4 vs. 2.3 kg). In addition, the CON group reported a larger energy deficit than the YOG group (1,393 vs. 1,134 kJ/day). Other trials have not implemented an energy restriction while attempting to add lean body mass (Andersen et al., 2005; Esmarck et al., 2001; Holm et al., 2008; Josse et al., 2010; Verdijk et al., 2009; White et al., 2009). Finally, White et al. reported significant reductions in percent body fat by time but not by group in their yogurt group despite significantly higher energy intake during the intervention. Although our focus was to evaluate muscle changes by group, the trend in group fat-loss differences is an important observation.

The body-composition shift achieved in this study was very favorable from a metabolic standpoint. Although the difference was not statistically significant, participants in the YOG group lost greater amounts of fat. In addition, a large portion of the fat lost in the YOG group was trunk fat. Zemel (2005) highlights a potential mechanism involving cortisol to explain why dairy may help reduce total and trunk fat. These findings are consistent with literature supporting the role of increased dairy consumption and change in fat oxidation (Melanson, Donahoo, Dong, Ida, Zemel, 2005; Zemel et al., 2008).

In this study we did not control for total intake of dairy foods or calcium, and we realize that dairy intake in the CONT group may have confounded fat-loss findings. Despite the lack of power to detect significant group differences, both fat loss and calcium intake were greater in the yogurt group. However, it is still not known whether chronic dairy-food ingestion by overweight, sedentary, premenopausal women before and after resistance exercise significantly promotes fat loss. Future research with larger samples should examine whether dairy-intake timing is a significant factor in promoting fat loss as part of a resistance-exercise program.

Added protein has been shown to influence the IGF response to resistance training (Ballard et al., 2005), and added dairy has been associated with increases in IGF (Rich-Edwards et al., 2007). Based on significant changes in chronic IGF-1 levels observed by Ballard et al., we hypothesized that YOG participants would experience a greater chronic increase in IGF-1 than CONT participants in an older, more sedentary sample. The 14% increase in the YOG group's IGF-1 concentration with a 5% decrease in CONT concentration in this trial was similar to the pattern observed by Ballard et al. This is interesting considering that yogurt supplied much lower protein density than common commercial protein supplements. The acute trial by Josse et al. (2009) found similar IGF-1 response between groups despite administering sufficient protein amounts in the experimental group to promote an anabolic response. Nevertheless, the absence of significant group differences in chronic IGF-1 concentrations is likely explained in part by an insufficient amount of protein provided by the yogurt.

IGFBP-3 results were consistent with those of Ballard et al. (2005), who did not observe chronic changes in IGFBP-3 over the course of 26 weeks of training. Given the minimal IGFBP-3 response in the current trial, the equivocal results in trials that study both genders, and the positive effects of resistance training on IGFBP-3 concentrations seen in males, it is possible that women's IGFBP-3 response to resistance training and supplementation is minimal compared with that of men.

Strengths of this study include participant commitment, as evidenced by high study exercise compliance (≥90%), high total work output per unit of time, low study dropout rate, and the blinding of exercise trainers. In addition, participants were able to make significant body-composition changes by exercising 25–30 min three times per week and making small healthful dietary changes.

Limitations of this trial include possible underreporting of diet intake, as evidenced by reported energy intake compared with weight-loss rates during the trial; not controlling for calcium intake; and the absence of an energy-free placebo. It is also conceivable that the differences in lean body mass observed between groups may be so small that they cannot be identified by DXA.

Meal timing may have affected study outcomes by potentially masking any effects of supplement stimulus on lean body mass. Another limitation of this study is that we did not ask participants to refrain from food intake immediately before or after visiting the laboratory for exercise sessions. However, providing a sport beverage preworkout and scheduling standardized meals postworkout may coincide with participants' natural food-intake patterns and provide a more realistic model for testing the true benefit of pre- or postexercise supplementation in real-life situations (White et al., 2009).

Future research examining this topic is needed to further elucidate how timing of dairy intake before and after resistance exercise can maximize healthful body-composition change in overweight sedentary women. Research designs should provide larger sample sizes, explore dairy supplements with higher protein content, and pay special attention to maintaining consumer appeal. Finally, future research in this area should consider controlling for calcium intake.

In conclusion, protein supplementation in the form of yogurt did not enhance lean body mass, promote strength accretion, or alter IGF-1 and IGFBP-3 levels in overweight women more than an isoenergetic carbohydrate supplement when given before and after resistance exercise. The trend in greater fat loss observed with yogurt than with carbohydrate suggests a possible benefit and the need for more research. Overall, the prescribed diet and exercise program resulted in significant weight loss, reductions in trunk fat, and increases in lean mass. Relatively small dietary changes and resistance exercise lasting approximately 25 min three times per week significantly improved body composition over time. The convenient and time-efficient nature of this program may be relevant to improving the health of women at risk for further weight gain by preventing obesity.

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References

American College of Sports Medicine. (2006). *ACSM's guidelines for exercise testing and prescription* (366 pp.). Philadelphia, PA: Lippincott Williams and Wilkins.

American Dietetic Association & American Diabetes Association (2003). *Exchange lists for weight management*. Chicago, IL: American Dietetic Association

Andersen, L.L., Tufekovec, G., Zebis, M., Crameri, R.M., Verlaan, G., Kjaer, M., . . . Aagaard, P. (2005). The effect of resistance training combined with timed ingestion of protein on muscle fiber size and muscle strength. *Metabolism: Clinical and Experimental, 54,* 151–156.

Ballard, T.L., Clapper, J.A., Specker, B.L., & Binkley, T.L. (2005). Effect of protein supplementation during a 6-mo strength and conditioning program on insulin-like growth factor 1 and markers of bone turnover in young adults. *The American Journal of Clinical Nutrition, 81,* 1442–1448.

Bird, S.P., Tarpenning, K.M., & Marino, F.E. (2006). Liquid carbohydrate/essential amino acid ingestion during a short-term bout of resistance exercise suppresses myofibrillar protein degradation. *Metabolism: Clinical and Experimental, 55,* 570–577.

Blanton, C.A., Moshfegh, A.J., Baer, D.J., & Kretsch, M.J. (2006). The USDA automated multiple-pass method accurately estimates group total energy and nutrient intake. *The Journal of Nutrition, 136,* 2594–2599.

Borsheim, E., Aarsland, A., & Wolfe, R.R. (2004). Effect of an amino acid, protein, and carbohydrate mixture on net muscle protein balance after resistance exercise. *International Journal of Sport Nutrition and Exercise Metabolism, 14*(3), 255–271.

Borst, S.E., De Hoyos, D.V., Garzarella, L., Vincent, K., Pollock, B.H., Lowenthal, D.T., & Pollock, M.L. (2001). Effects of resistance training on insulin-like growth factor-I and IGF binding proteins. *Medicine and Science in Sports and Exercise, 33*(4), 648–653.

Cribb, P.J., & Hayes, A. (2006). Effects of supplement timing and resistance exercise on skeletal muscle hypertrophy. *Medicine and Science in Sports and Exercise, 38*(11), 1918–1925.

Elliot, T.A., Cree, M.G., Sanford, A.P., Wolfe, R.R., & Tipton, K.D. (2006). Milk ingestion stimulates net muscle protein synthesis following resistance exercise. *Medicine and Science in Sports and Exercise, 4,* 667–674.

Esmarck, B., Andersen, J.L., Olsen, S., Richter, E.A., Mizuno, M., & Kjaer, M. (2001). Timing of postexercise protein intake is important for muscle hypertrophy with resistance training in elderly humans. *The Journal of Physiology, 535,* 301–311.

Food and Nutrition Board. (2005). *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids (macronutrients).* Washington, DC: The National Academies Press. Retrieved May 4, 2010, from http://books.nap.edu/openbook.php?record_id=10490&page=202

Hartman, J.W., Tang, J.E., Wilkinson, S.B., Tarnopolsky, M.A., Lawrence, L.L., Fullerton, A.V., & Phillips, S.M. (2007). Consumption of fat-free fluid milk after resistance exercise promotes greater lean mass accretion than does consumption of soy or carbohydrate in young, novice, male weightlifters. *The American Journal of Clinical Nutrition, 86,* 373–381.

Holm, L., Olesen, J.L., Matsumoto, K., Doi, T., Mizuno, M., Alsted, T.J. . . . Kjær, M. (2008). Protein-containing nutrient supplementation following strength training enhances the effect on muscle mass, strength, and bone formation in postmenopausal women. *Journal of Applied Physiology (Bethesda, Md.), 105,* 274–281.

Ivy, J.L. (2001). Dietary strategies to promote glycogen synthesis after exercise. *Canadian Journal of Applied Physiology, 26*(Suppl.), S236.

Josse, A.R., Tang, J.E., Tarnopolsky, M.A., & Phillips, S.M. (2010). Body composition and strength changes in women with milk and resistance exercise. *Medicine and Science in Sports and Exercise, 42*(6), 1122–1130.

Kraemer, W.J., & Fry, A.C. (1995). In P.J. Maud & C. Foster (Eds.), *Strength testing: Development and evaluation of methodology* (pp. 115–138). Champaign, IL Human Kinetics.

Melanson, E.L., Donahoo, W.T., Dong, F., Ida, T., & Zemel, M.B. (2005). Effect of low- and high-calcium dairy-based diets on macronutrient oxidation in humans. *Obesity Research, 13*(12), 2102–2112.

Miller, S.L., Tipton, K.D., Chinkes, D.L., Wolf, S.E., & Wolfe, R.R. (2003). Independent and combined effects of amino acids and glucose after resistance exercise. *Medicine and Science in Sports and Exercise, 35*(3), 449–455.

Moore, D.R., Robinson, M.J., Fry, J.L., Tang, J.E., Glover, E.I., Wilkinson, S.B., . . . Phillips, S.M. (2009). Ingested protein dose response of muscle and albumin protein synthesis after resistance exercise in young men. *The American Journal of Clinical Nutrition, 89,* 161–168.

Moshfegh, A.J., Rhodes, D.G., Baer, D.J., Murrayi, T., Clemens, J.C., Rumpler, W.V., . . . Cleveland, L.E. (2008). The US department of agriculture automated multiple-pass method reduces bias in the collection of energy intakes. *The American Journal of Clinical Nutrition, 88,* 324–332.

Rich-Edwards, J.W., Ganmaa, D., Pollak, M.N., Nakamoto, E.K., Kleinman, K., Tserendolgor, U., . . . Frazier, A.L. (2007). Milk consumption and the prepubertal somatotropic axis. *The Journal of Nutrition, 6,* 28.

Roy, B.D., Tarnopolsky, M.A., MacDougall, J.D., Fowles, J., & Yarasheski, K.E. (1997). Effect of glucose supplement timing on protein metabolism after resistance training. *Journal of Applied Physiology (Bethesda, Md.), 82,* 1882.

Tipton, K.D., Elliott, T.A., Cree, M.G., Wolf, S.E., Sanford, A.P., & Wolfe, R.R. (2004). Ingestion of casein and whey proteins result in muscle anabolism after resistance exercise. *Medicine and Science in Sports and Exercise, 36,* 2073–2081.

Tipton, K.D., Rasmussen, B.B., Miller, S.L., Wolf, S.E., Owens-Stovall, S.K., Petrini, B.E., & Wolfe, R.R. (2001). Timing of amino acid-carbohydrate ingestion alters anabolic response of muscle to resistance exercise. *American Journal of Physiology. Endocrinology and Metabolism, 281,* E197–E206.

Tipton, K.D., & Wolfe, R.R. (2003). Protein and amino acids for athletes. *Journal of Sports Sciences*, *22*, 65–79.

Verdijk, L.B., Jonkers, R., Gleeson, B.G., & Beelen, M. (2009). Protein supplementation before and after exercise does not further augment skeletal muscle hypertrophy after resistance training in elderly men. *The American Journal of Clinical Nutrition, 89,* 608–616.

White, K.M., Bauer, S.J., Hartz, K.K., & Baldridge, M. (2009). Changes in body composition with yogurt consumption during resistance training in women. *International Journal of Sport Nutrition and Exercise Metabolism, 19,* 18–33.

Zemel, M.B. (2005). The role of dairy foods in weight management. *Journal of the American College of Nutrition, 24*(6), 537S–546S.

Zemel, M.B., Donnelly, J.E., Sullivan, D.K., Richards, J., Morgan-Hanusa, D., Mayo, M.S., . . . Washburn, R.A. (2008). Effects of dairy on weight maintenance. *Nutrition & Metabolism, 5,* 28.