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Impact of Milk Consumption and Resistance Training on Body Composition of Female Athletes

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Abstract

Resistance exercise (RE) preceding the provision of high-quality dairy protein supports muscle anabolism. Milk contains bioactive components, including two high-quality protein fractions, calcium and vitamin D, each of which has been shown modulate body composition (increasing lean mass and decreasing fat mass) under energy balance and hypoenergetic conditions. These dairy nutrients are also essential for skeletal health. Acutely, no study of RE and milk/whey consumption has been undertaken exclusively in female athletes, let alone women, nevertheless, studies with both men and women show increased lean mass accretion following milk/whey compared to soy/placebo. Currently, no longer-term RE studies with milk supplementation have been done in female athletes. However, trials in young recreationally active women demonstrated augmented increases in lean mass and decreases in fat mass with RE and milk or whey protein consumption. The amount of protein consumed post-exercise is also important; two trials using yogurt (5 g protein/6 oz) failed to demonstrate a positive change in body composition compared to placebo. For bone health, RE plus dairy improved bone mineral density at clinically important sites and reduced bone resorption. With energy restriction, in one study, higher dairy plus higher protein resulted in greater fat loss, lean mass gain and improved bone health in overweight women. In another study, milk and calcium supplementation showed no greater benefit. Neither trial exclusively utilized RE. Overall, RE and milk/dairy consumption positively impact body composition in women by promoting losses in fat, gains or maintenance of lean mass and preservation of bone. Future studies in female athletes and under energy restriction with RE alone are warranted.

It is well known that resistance exercise and the provision of high-quality protein are potent stimuli for the synthesis of skeletal muscle tissue [1, 2]. When combined, resistance exercise and protein nutrition are synergistic in their ability to stimulate muscle protein synthesis to a greater extent than either modality alone [3, 4]. The synergy between resistance exercise and protein in modifying body composition has been of interest not only for bodybuilders and active men [5], but also for recreationally active

women [6], for those wanting to lose weight [7] and for the elderly [8, 9]. Maintaining or increasing muscle mass and reducing fat mass is an important priority for athletes and those conscious of body image, but also from a health standpoint, it is also of pivotal importance for preventing and treating obesity and other chronic cardiometabolic and musculoskeletal diseases including diabetes, heart disease and osteoporosis [10–13].

Milk contains a variety of bioactive components, including protein, calcium, and vitamin D, that may act independently or synergistically to improve body composition during periods of energy balance [6] or energy restriction [7, 14, 15]. In addition, milk consumption following resistance exercise has been shown to increase muscle protein synthesis and lean mass to a greater extent than other similar protein sources (i.e. soy) [5, 16]. Thus, given the composition of milk/dairy foods and its physiological effects, it would seem to be an excellent post-resistance exercise food to help augment positive body composition change not only in athletes, but also in recreationally active and newly active persons or those seeking to lose body weight as fat.

Resistance training is not as common an exercise modality for women as it is for men. Reasons for this may be that women generally choose to avoid exercise that they perceive might contribute to muscle 'bulk', potential weight gain or less weight loss [17]. Moreover, milk and other dairy products are often avoided by women since they are cited as being fattening [18]. Thus, only a handful of studies have been carried out assessing the effect of resistance exercise and either milk, yogurt or other dairy products on body composition in women. In addition, no such studies have been undertaken in female athletes. Hence, this chapter highlights results from clinical studies carried out in women undergoing acute resistance exercise or chronic resistance training with the consumption of dairy, and explores the effect of this combined paradigm on body composition, namely fat, lean (muscle) and bone mass.

Milk and Body Composition – Mechanism of Action

Milk contains calcium (300 mg/cup), vitamin D (90 IU/cup) and protein (9 g/cup), each of which has been shown to modulate body composition [2, 3, 19, 20]. Calcium and vitamin D affect adipose tissue metabolism (stimulating lipolysis and inhibiting fat storage) [20, 21], improve bone health (inhibiting osteoclast resorption of bone) [10, 22], and decrease intestinal fat absorption by binding to fatty acids and forming insoluble soaps and by destabilizing the formation of micelles in the gastrointestinal tract [23].

Insofar as protein is concerned, a large part of dairy's bioactivity is in the whey protein fraction which is rich in branched chain amino acids (BCAA) [24]. In fact, BCAAs make up about 25% of total dairy proteins [25]. Leucine, a BCAA found in relatively high abundance in whey protein, has been shown to affect both fat and muscle metabolism [26, 27]. In vitro, leucine inhibits triglyceride synthesis

(lipogenesis), promotes fat cell breakdown (lipolysis), and increases fat oxidation in muscle cells [27]. In addition, and perhaps as its better known role, leucine stimulates the translation-initiation machinery for muscle protein synthesis [26]. The particulars of this mechanism will not be discussed here, but the effect of leucine on muscle protein synthesis may be one of the key ways in which milk and dairy foods augment muscle mass accretion following resistance exercise [1–3, 26], and promote the sparing of muscle during weight loss [7, 15].

Milk, Whey Protein and Resistance Exercise – Acute Response

Two recent acute studies assessed the effect of milk or dairy-derived proteins on muscle protein synthesis in women [28, 29]. Both of these studies employed a resistance exercise bout, *vastus lateralis* muscle biopsies and stable isotope tracer methodologies, however, neither were carried out exclusively in women. The first study assessed the acute ingestion of either fat-free milk or whole milk 60 min after resistance exercise. Both types of milk stimulated greater net uptake of amino acids representing increased rates of muscle protein synthesis following resistance exercise and milk consumption [28]. However, whole milk stimulated significantly greater threonine uptake suggesting that high-fat milk may have increased utilization of available amino acids for muscle accretion. This is an interesting observation given that the only relevant difference between whole milk and fat-free milk that could impact protein metabolism is the fat content. To our knowledge, there are no data in humans to suggest that added fat improves muscle protein synthesis. Added fat adds more energy to the 'system', which has been shown to minimally impact the protein synthetic response [30]. Nevertheless, since the difference between milk types is minimal, recommendations to consume whole fat milk over fat-free milk for improved muscle mass accretion are without good basis and require replication before they can be made.

The second study by West et al. [29] was designed to uncover sex-based differences in muscle protein synthesis following resistance exercise and ingestion of 25 g of whey protein. No differences in rates of muscle protein synthesis were observed between the sexes. Therefore, both studies suggest that the combination of milk or its whey protein component and resistance exercise can acutely increase the rate of muscle protein accretion in women. However, neither study compared milk or whey to a post-exercise control beverage devoid of protein or to a different protein source; this is clearly an area for future study.

Dairy and Resistance Training – Chronic Studies

Given that milk and whey robustly increase muscle protein synthesis in the acute setting, it is important to investigate whether this effect translates into longer-term

phenotypic changes, i.e. greater lean (muscle) mass gains. Five studies, four carried out in women only and one in a mixed sample, under conditions of weight maintenance or mild energy deficit (–250 kcal/day [31]), combined resistance exercise with milk, yogurt, whey protein, or a milk-like supplement for durations ranging from 6 to 24 weeks [6, 31–34].

As previously mentioned, whey protein provides all of the essential amino acids that are required for muscle protein synthesis [3, 26]. Soy protein is also considered a high-quality protein (i.e. Protein Digestibility Corrected Amino Acid Score (PDCAAS) = 1.0), however several studies [5, 16] have shown milk/whey to be superior, or at least equivalent [32, 35], to soy for skeletal muscle mass accretion. The duration of the training study may also be of importance. Studies shorter than 8 weeks in duration (training ~3×/week), usually considered the minimal amount of time to detect hypertrophy, may not be enough to observe significant differences in lean mass between treatments with different protein sources. Nonetheless, after just 6 weeks, trends were apparent in a study by Candow et al. [32] (two thirds were female participants), with lean mass gains of 2.5 and 1.7 kg in the whey vs. soy groups, respectively, and both protein groups showed significantly greater lean mass gains versus placebo (0.3 kg).

Yogurt contains most of the necessary bioactive components (except vitamin D unless fortified) to promote positive body composition change with resistance exercise. Due to its generally pleasant taste, and ease of consumption and digestion, it is an attractive way to provide the body with high-quality dairy post-resistance exercise. Despite this, only two studies of 8 [34] and 16 [31] weeks' duration have utilized yogurt (6 oz) as a post-exercise supplement, and both failed to demonstrate greater increases in lean mass compared to an isoenergetic carbohydrate-containing control. However, the yogurt supplements in both studies contained only 5 g of dairy protein, which is an amount that is substantially less than what is thought to be required (i.e. 20 g) to maximally stimulate muscle protein synthesis post-resistance exercise [36]. Thus, the lack of adequate amino acids during the critical post-exercise anabolic window [1] was probably responsible for a substandard anabolic stimulus for muscle protein synthesis and the lack of a superior gain in muscle protein mass. Nonetheless, we propose that yogurt would be an appropriate post-exercise dairy food if the right amount of protein is consumed. Future studies using yogurts with a higher per-serving protein content (i.e. some 'Greek-style' yogurts contain 16 g protein per 6 oz) may provide greater benefit from a body composition standpoint.

Only one resistance training study assessed body composition in young women after comparing an isoenergetic carbohydrate beverage to fat-free milk [6]. After 12 weeks, results showed that consuming 1 litre of milk post-resistance exercise (500 ml immediately after and an additional 500 ml 1 h after performing resistance exercise) resulted in greater lean mass gains, but also promoted a significantly greater loss of fat mass. The findings of this study are particularly relevant in terms of the beneficial change in body composition that occurred, i.e. concomitant fat mass loss and lean

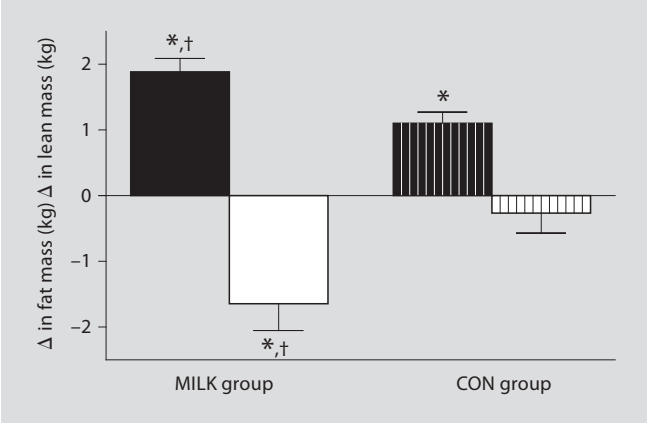

Fig. 1. Change from baseline (mean ± SE) in lean mass (positive y-axis of graph) and fat mass (negative y-axis of graph) after young normal weight women underwent 12 weeks of resistance training with either milk or carbohydrate drink consumption post-exercise in Josse et al. [6].
* Significantly different from baseline, $p < 0.05$.
† Significantly different from CON in same tissue, $p < 0.05$.

mass gain, in the face of very little (non-significant) change in body weight (fig. 1). On the other hand, the women consuming the isoenergetic carbohydrate beverage also showed lean mass gains, albeit significantly less than the milk group, and no loss of fat mass. The additional milk consumption-induced fat mass loss observed may be the cumulative result of the previously mentioned lipolytic mechanisms relating to other bioactive components in milk such as leucine, calcium and vitamin D. One other 24-week resistance training study carried out in early post-menopausal women utilized a daily supplement that resembled milk versus a placebo supplement [33]. The milk-like supplement contained whey protein (10 g), calcium (250 mg), vitamin D (200 IU), fat (1 g) and carbohydrate (31 g). They observed a more marked improvement in lean mass and strength in the milk-like group compared to the placebo [33].

Dairy, Resistance Training and Bone Health – Chronic Studies

Calcium and protein, two major components of milk, are essential for bone health [19]. They affect the structural integrity and strength of bone by influencing bone mineralization and collagen formation, respectively [10, 37]. Moreover, higher intakes of dietary calcium and vitamin D reduce circulating parathyroid hormone concentrations, which results in a positive effect on bone mineral density (BMD) and reduced rates of bone turnover [10]. Three studies have examined the effect of resistance exercise and dairy on bone health outcomes in women [6, 33, 38]; one study was carried out under slight energy restriction [38]. Compared to placebo treatments, lumbar spine BMD improved with resistance exercise and a high dairy-based calcium diet after 16 weeks in young women [38], and femoral neck BMD (adjusted for covariates) improved after consumption of a milk-like supplement for 24 weeks in early post-menopausal women [33]. In the third study, resistance training and milk

consumption tended to increase bone formation (osteocalcin) and decrease resorption (C-telopeptide (CTx)), although differences between groups were not significant [6].

Milk/Dairy, Resistance Training and Weight Loss

Although no studies have directly examined the effect of exclusive resistance training and dairy during energy restriction (–500 kcal/day) on body composition, two clinical trials implementing a structured resistance training program along with aerobic exercise have. These studies were carried out in overweight or obese young women [7, 39, 40]. In the first study, after 12 weeks of energy restriction and exercise, no differences were observed between the four treatment groups (calcium lactate (1,500 mg/day), calcium phosphate (1,500 mg/day), milk/dairy (3 servings/day), placebo (baseline diet containing 750 mg of calcium)) for weight loss, fat loss or bone formation. In fact, the milk/dairy group lost the least amount of body fat compared to the placebo group [40]. While total energy intakes were not significantly different between the groups, the milk/dairy group consistently consumed >100 kcal/day more than the placebo group and no information was presented on macronutrient intakes. Therefore, it is possible that those in the milk/dairy group did not completely compensate for the added milk/dairy calories, and in fact, had an increased total energy intake. In addition, a less sensitive method (bioelectric impedance analysis) was used to assess fat mass, and this may also explain, at least in part, the lack of greater fat mass loss in this group [40].

In contrast to the findings seen in the other study [40], a combination of lifestyle (diet and exercise) factors and good support for weight loss, including increased intakes of dairy (milk, cheese and yogurt) and dietary protein resulted in a highly favourable body composition change characterized by greater total and visceral fat loss, increased lean mass and improved bone health versus diets lower in protein and low in dairy [7, 39]. The *Improving Diet, Exercise and Lifestyle (IDEAL) for Women* study was a 16-week clinical trial that employed a 2×/week structured resistance training program (split upper and lower body routine), in addition to required daily aerobic exercise. Based on previous weight loss research highlighting the effectiveness of dairy [14, 15], calcium [41], higher protein diets [42], and exercise [42, 43] in promoting positive body composition change in young women, we combined all of these factors, for the first time, on the background of energy restriction. A major aim of the *IDEAL for Women* study was to have subjects achieve weight loss of the highest possible 'quality', i.e. preferential loss of fat mass and preservation of lean mass and bone health. Figure 2 displays the fat and lean mass results from the *IDEAL for Women* study. Although total body weight loss was the same across all three groups, the composition of this loss was markedly different [7]. It is clear that the manipulations undergone by the high-protein-high-dairy (HPHD: 30% kcal/day protein,

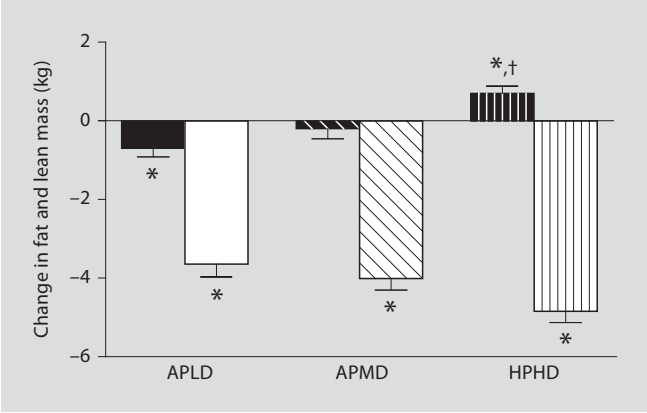

Fig. 2. Change from baseline (mean ± SE) in lean mass (black and textured bars) and fat mass (white and textured bars) after overweight and obese women underwent 16 weeks of diet and exercise-induced weight loss in the *IDEAL for Women* study [7]. APLD = Adequate-protein-low-dairy; APMD = adequate-protein-medium-dairy; HPHD = high-protein-high-dairy. * Significantly different from baseline, $p < 0.05$. † Significantly different from APLD, $p < 0.05$ (lean mass).

15% (i.e. half of the total dietary protein) as dairy protein, ~1,800 mg/day calcium) group succeeded in achieving high-quality weight loss. Furthermore, even in the face of energy restriction, which is a fundamentally catabolic process [44], these women continued to build lean tissue. The adequate-protein-medium-dairy (APMD: 15% kcal/day protein, 8% as dairy protein, ~1,200 mg/day calcium) group maintained lean mass with almost all of their weight loss as body fat, and this too represents a positive body composition change. Insofar as bone health is concerned, the two groups consuming dairy foods (HPHD and APMD) showed net increases in bone collagen formation (procollagen 1 amino-terminal propeptide [P1NP]/CTx ratio) and decreases in serum parathyroid hormone [39], whereas the opposite was observed for the adequate-protein-low-dairy (APLD: 15% kcal/day protein, 0% as dairy protein, ~300 mg/day calcium) group.

Conclusion

Milk and other dairy foods contain bioactive components (protein (leucine), calcium, vitamin D) that, in combination with resistance exercise [6, 7, 33, 38, 39], have been shown to consistently improve body composition in women under both iso- and hypoenergetic conditions. Acute studies demonstrate that resistance exercise with milk of different kinds [28] or whey [29] stimulate muscle protein synthesis in women, and that the myofibrillar synthetic response is no different from that observed in men [29]. Chronic resistance training studies confirm that acute muscle

tissue accrual indeed translates into longer-term lean mass gains in women, but only when dairy protein is consumed at a sufficient quantity (≥15 g protein post-exercise [36]). In addition, concomitant reductions in fat mass were apparent under isoenergetic conditions [6], and bone health following resistance training with increased dairy/calcium intakes was improved [6, 33, 38]. With weight loss, the *IDEAL for Women* study highlighted the considerable benefit of consuming hypoenergetic diets higher in dairy (and calcium) and dietary protein with aerobic and resistance exercise on body composition (fat, lean and bone mass) in otherwise healthy overweight and obese young women [7, 39].

Overall, resistance exercise and milk/dairy consumption positively impacts body composition in women by promoting favourable changes in all three body compartments: fat, lean (muscle) and bone. Future research is required to assess the effect of milk and dairy with resistance training on body composition in female athletes. This, along with previously published work, will not only help to further promote milk and dairy for exercise recovery, but also help increase its consumption adding high-quality protein, calcium and vitamin D to the diets of young women.

Disclosure Statement

The authors have no conflicts of interest to disclose.

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