REVIEW ARTICLE

Review of the Effects of Dairy and Exercise on Body Composition in Lactating Women

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ABSTRACT

Obesity in the U.S. has risen to epidemic levels over the past 10 years and, for women, childbearing itself may be a contributing factor. Breastfeeding is, therefore, recommended for the first 6 months and has been shown to help reduce long-term maternal weight retention from pregnancy. Conversely, lactation represents a period of increased bone loss, specifically of the lumbar spine and hip. Lactation alters bone mineral density due to the increased demand for calcium in breast milk, and up to 400 mg/day of calcium loss from the maternal skeleton can occur as a result. Dairy intake and weight-bearing exercise have been shown to provide bone protection in premenopausal women. The purpose to best reflect the review of the literature on the effects of dairy and exercise on body composition during lactation.

Key words: Body composition, bone mineral density, exercise, lactation, yogurt

INTRODUCTION

Breastfeeding has recently gained popularity in the U.S., and a large percentage of women now initiates breastfeeding after delivery.[1] Breast milk is optimal for an infant's growth and development, especially during the first 6 months of life.[2] Fully breastfeeding (<4 oz given occasionally) also provides beneficial long-term health effects for the mother, such as reduced breast and ovarian cancer risk.[3]

However, the practice of breastfeeding can pose challenges to a women's physicality,[2] lifestyle, and diet. For example, during lactation, calcium and bone metabolism are adjusted by increasing calcium demands to support the infant's nutritional needs, which lead to a decrease in bone mineral density (BMD). BMD losses range between 3% and 10% in the first few months postpartum (PP). Despite the observed BMD loss, the bone loss is usually reversed on weaning and resumption of the menses.[4] However, women are becoming pregnant later in life and may not return to their pre-pregnancy BMD before menopause.[5]

Normal maternal intestinal calcium absorption fails to meet the needs of both the mother and the infant during lactation. The failure to meet the calcium need may be contributed to American women consuming insufficient dietary calcium. Research has shown that during the first 6 months, lactating women would have to consume an additional 800 mg/day of calcium to support the infant's needs. Normal healthy adults absorb about 25% of dietary calcium.[6] However, few studies have indicated fermented dairy intake as a source of dietary calcium, increase BMD during skeletal growth, and prevent bone loss during periods of high bone turnover, for example, lactation.[7]

Dairy products include bone protecting elements as a source of calcium, phosphorus, and many vitamins. A liter of milk

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also contains approximately 32–35 g of protein from casein and whey, which are found in milk and promote growth and repair of bones. In addition, research shows that a combination of weight-bearing and aerobic exercise may have a protective effect on bone and minimize BMD loss seen in lactating women, especially after weaning where a return to early PP BMD levels has been reported.[8,9]

Research has also demonstrated that women who fully breastfed for more than 6 months had the lowest body mass index (BMI) at 3 years PP and the least amount of pregnancy weight retention compared to women who never breastfed.[10] In addition, research has revealed that in premenopausal women, consumption of a high-quality dairy protein after resistance exercise can promote fat loss, increase lean body mass (LBM), and provide bone protection.[11,12] This review summarizes the current literature available regarding BMD and body composition changes in lactating women participating in exercise (weight-bearing, aerobic, or both), energy restrictions, dairy, and calcium supplementation.

DAIRY CONSUMPTION DURING LACTATION

Participating in exercise training may result in weight loss and other health benefits such as a decreased risk of developing type 2 diabetes, preventing heart disease, and improving mental health.[13] However, moderate weight reduction has also shown a concomitant loss of BMD and increased bone turnover in overweight-to-obese individuals. High-calcium intake (1.5–1.8 g/day) in overweight pre- and postmenopausal women has demonstrated preventive BMD loss associated with moderate weight loss as well as minimizing bone turnover and parathyroid hormone secretion.[14-17] Weight loss studies that included diets high in dairy, which thus have high amounts of protein, calcium, and Vitamin D, have shown suppression of bone turnover plus preservative effects on BMD.[7,11,12] These results are still controversial because some studies[14] have found no association between adequate dairy consumption and BMD in individuals participating in a weight loss program.

Recent research reports have indicated that calcium and Vitamin D supplementation may only increase non-vertebral BMD and reduce fracture risk.[18-20] However, a recent study of Swedish pre- and postmenopausal women revealed that hip fracture risks were the lowest in participants who had the highest intake of fermented milk (yogurt or soured milk), fruits, and vegetables.[21] In addition, dairy consumption was related to hip BMD, but not the spine. Yogurt was directly associated with the hip (trochanter) BMD only.[22] These findings would suggest that there may be potential benefits of adequate dietary calcium intake through yogurt consumption on bone turnover, BMD loss, and fracture risk reduction in lactating women, but this has not been investigated.

BODY COMPOSITION DURING LACTATION

Obesity remains one of the most significant public health concerns in the U.S., particularly in women as approximately two in three women are classified as overweight or obese.[23] Pregnancy may be a contributing factor to these alarming numbers due to excess weight gain during pregnancy and PP weight retention. The excess weight retained after pregnancy is defined as the difference between PP and pre-pregnancy weight, which, on average, ranges from 0.5 to 4.0 kg. However, about 20% of women retain more than 4.5 kg 1-year PP.[24-26] Women who are overweight and obese pre-pregnancy are at a higher risk for excess weight retention PP.[27,28] Moreover, healthy pregnancy weight gain and an inability to return to pre-pregnancy weight can increase a woman's risk of obesity.[26,29] The amount of weight needed to support a healthy pregnancy and delivery is based on body mass index (BMI = weight in kg divided by height in meters squared) before pregnancy. Weight gain guidelines for a singleton pregnancy are 0.5–1.0 Lb/week during the second and third trimesters or 11–40 pounds total based on pre-pregnancy weight classification.[30]

Body composition defined as the distribution of body mass between or among two, three, or four separate compartments: Fat and fat-free mass; fat, lean mass, and bone; or fat, protein, water, and bone. Two-compartment methods range in cost and technique. Examples of two-compartment methods to measure body composition include skin folds, bioelectrical impedance analysis, hydrostatic weighing, and plethysmography. The dual-energy X-ray absorptiometry (DXA) is an example of a three-compartment measurement tool allowing for ease of body composition measurement and bone density with one test. Waist-hip circumferences are used for fat distribution and to assess disease risk. Several studies have investigated the effects of aerobic and weight-bearing exercise on the different compartments of body composition in lactating women. However, fermented dairy or yogurt supplementation still needs to be investigated further in this population.

Body composition

Fat mass is a measurement of total body fat on the human body. Most lactating women should lose body weight and subcutaneous fat during the PP period.[31] However, this is highly variable as some women gain weight during lactation.[32] Fat-free mass, which differs from LBM, is the measurement of LBM or muscle mass and skeletal mass, specifically bone mineral content. Skeletal mass is included in the measurement of fat-free mass because of the presence of some essential fat in the marrow of the bones and internal organs. BMD is the measurement of the amount of minerals, mainly calcium and phosphorous, contained in a specific volume of bone. Fermented dairy intake along with weight-bearing and aerobic exercise is effective treatments to reduce fat mass, increase fat-free mass, and minimize bone loss in lactating women.

BMD

Osteoporosis is a bone disease that is characterized by increased bone resorption, decreased bone deposition, or both, thereby increasing the risk of fractures and broken bones.[33] Approximately 10 million Americans are affected by osteoporosis, 8 million of whom are women. Risk factors for osteoporosis in women include diet, lack of exercise, and smoking.[34] Moreover, women who initiate lactation after birth are at an increased risk for lactation-associated osteoporosis, a rare condition that is a result of changes in maternal calcium homeostasis. Optimal bone health can be achieved through sufficient calcium intake which is necessary to prevent age-related bone loss overtime.[35,36]

The maternal demand for calcium during the time of lactation is increased significantly due to the production of breast milk plus bone resorption,[37] resulting in calcium losses that can reach an average of 400 mg/day. In addition, losses can accelerate up to 1000 mg/day in women nursing twins.[4,38] Consequently, the recommended dietary allowance (RDA) for calcium is also significantly increased during lactation (RDA = 1000 mg for lactating women).[39,40] However, calcium concentration in breast milk is independent of maternal dietary calcium intake[41] including supplements. Therefore, even in women with low dietary calcium intake, calcium concentration will not be affected.[39,42,43] In addition, several studies have shown that calcium intake by the mother during pregnancy may affect calcium concentration in breast milk.[43]

Physiological changes in maternal physiology may mobilize calcium from the mother's skeleton occur to meet the increased calcium demand.[5] However, calcium mobilization from the mother's skeleton may lead to fractures later in life and, theoretically, a decrease in bone mineral status. The bone remodeling phase takes approximately 4–6 months to complete a full cycle. Therefore, clinical trials for BMD loss should measure between 2-time intervals within this time frame to be able to detect changes in BMD.

YOGURT AND BODY COMPOSITION (FM, FFM, AND BMD) DURING LACTATION

Dairy or fermented products such as yogurt may also facilitate weight loss in lactating women. Consumption of high-quality protein following resistance exercise may augment muscle protein synthesis and increase muscle mass induced from training.[12,44,45] In one study with premenopausal women participating in a resistance exercise program with dairy consumption after each session, the intervention group had a significant fat mass loss compared to the control group; similar outcomes in a study where women consumed three servings of yogurt per day.[12,46] Zemel *et al*.[47] also examined yogurt consumption effects on weight loss in obese adults and found that the yogurt group lost significantly more weight compared to the control group.

There is no literature available on the effects of dairy or yogurt consumption on body composition in lactating women, but studies have been conducted on premenopausal women. One study investigated the impact of high dairy calcium intake and resistance exercise on fat mass loss and BMD in 29 overweight premenopausal women for 16 weeks.[36] Both groups participated in resistance training 3 times/week and received dietary counseling to restrict energy intake by 250 kcal/day during the 16-week intervention. Participants were either randomized into a low-calcium diet group (≤500 mg) or a high-calcium diet group (≥1200 mg). The study found that high dairy intake did not enhance fat loss. Still, lumbar spine (LS) BMD did increase significantly in the high-calcium group compared to the low-calcium group (+0.8% vs. −1.5%, $P < 0.05$, respectively). These findings suggest that dairy or yogurt consumption may have a contributory, positive effect on BMD. However, weight loss may not be due to high dairy consumption.

EXERCISE AND BODY COMPOSITION (FM, FFM, AND BMD) DURING LACTATION

Milk supply and production are not affected by water loss as a result of exercising. Ample research has shown that breast milk is not compromised, and infant growth remains normal in exercising lactating women.[24,32] Of two types of exercise intensities, moderate and vigorous, moderate exercise intensity is described as doing an activity where talking can be achieved, but not singing, resulting in a loss of 3.5–7 kcal/min. Moderate exercise intense activities include brisk walking, weight training, and doubles tennis. Vigorous exercise intensity is described as doing an activity where only a few words can be communicated without pausing for a breath, resulting in a loss >7 kcal/min. Vigorous exercise activities would include running and step aerobics.[48] Excluding vigorous exercise, research shows that when moderately intense exercise is conducted, the breast milk composition of PP or postnatal women is not compromised.[24] Moreover, infant growth does not differ between active and sedentary mothers.[32] On the other hand, mothers classified as overweight and obese who do not breastfeed or stopped early on and who have lower levels of physical activity may not return to their pre-pregnancy weight during the first 6 months PP.[31]

A meta-analysis examining approaches to weight loss effects on BMD in both men and women were recently conducted. The study found that in those who were obese, BMD significantly decreased at the hip in calorie restriction, exercise, or both types of interventions longer than 4 months. In energy restriction interventions for weight loss that lasted longer than a year, significant decreases in the LS and hip were observed, whereas exercise interventions for weight loss did not adversely affect BMD.[49]

Site-specific exercises that direct force to the bone may induce bone growth.[37] The frequency, intensity, time, and type of exercise (FITT) principle for improvement of bone in women with a low estrogen status, seen in PP women, has yet to be determined. Still, high-intensity interval training (HIIT) has proven effective in the previous studies. FITT makes up the dimensions of physical activity which results in different health outcomes. This form of physical activity has a significant impact on bone.[50] For example, Targeted Bone Loading is one type of activity that stimulates a specific bone or bone region through a force that is not accomplished through daily activities.[51] In premenopausal PP women, the focus is more on maintaining the BMD rather than increasing it. The high-intensity exercise aimed at targeted areas of bone has shown moderate increases in BMD. One study observed the effect of HIIT on BMD in premenopausal women and an exercise plan that resulted in an approximately 2% BMD increase in the LS and femoral neck (FN).[52] However, few studies have investigated the effects of HIIT on BMD in lactating women. Exercise training may not be beneficial once the stimulus for bone growth stops, detraining occurs, bone resorption increases, and bone formation decreases.[37]

To date, there is minimal research available on the effect of exercise on body composition during lactation. Several studies used DXA, skin folds, plethysmography, and hydrostatic weighing to investigate the impact of exercise, diet, or both on fat and fat-free mass in lactating women. Table 1 summarizes all of the available literature on the topic of body composition in lactating women.

The first longitudinal study examined seven skeletal sites in six female athletes before pregnancy, 6 weeks PP, and after 6 months of lactation and measured BMD over 2 years.[53] From 1 month to 6 months PP, they only observed a significant decrease in BMD at the FN of 3.1% and a non-significant 3.4% gain in LS BMD. However, the use of a small sample of highly active women, which is uncommon in this population, and no control were limitations in this study. The gain in LS BMD was unusual and represented a signal that exercise may provide a protective effect on bone during lactation.

In another study, 33 exclusively breastfeeding women were recruited at 6–8 weeks PP for an exercise weight loss intervention study.[54] The exercise group participated in an aerobic exercise program 5 days/week, 45 min/day for 12 weeks while the control group study engaged in resistance or aerobic exercise less than once per week. Body composition was measured by hydrostatic weighing. Weight significantly ($P < 0.05$) declined in both groups, but there was no significant difference between groups in the amount of weight loss or percentage of body fat.

An additional study examined the effects of lactation, weaning, and dietary intake on changes in body composition and BMD at four different time points (0.5, 3, 5, and 7 months) on 26 fully lactating Caucasian women.[9] Body composition was measured using an electronic digital balance scales (Sartorius Corp., Bohemia, NY). Dual-photon absorptiometry (DP3; Norland, Madison, WI) measured trabecular bone in the LS. Mid-way through the study, researchers switched to DXA technology (DPX; Lunar Corp., Madison, WI). Weight significantly declined throughout lactation (63.3 ± 9.2 kg and 61.0 ± 9.6 kg at 0.5 and 7 months, respectively), and LS BMD declined 4% between 2 weeks and 3 months. However, LS BMD returned to baseline values after weaning and resumption of menses, and only a weak correlation was found between LS BMD and maternal weight.

Another study examining exercise on BMD focused on 20 fully breastfeeding Caucasian women starting at 2 weeks PP for 3 months.[55] The intervention group included 11 women who met the American College of Sports Medicine (ACSM) guidelines for regular exercise (≥3 days/week, ≥20 min/day, ≥50% maximal oxygen consumption). Women assigned to the control group did not meet the ACSM guidelines for exercise during the PP period. Skinfold calipers were used to measure body composition using the five-skinfold technique. BMD was measured by a DXA using either a Lunar DPX (Lunar Radiation Corp., Madison, WI) or a Hologic QDR 2000 (Hologic Inc., Waltham, MA) bone densitometer. No significant difference was observed between groups for body fat percentage, although body weight and body fat percentage were less in the intervention group compared to the control. Weight significantly decreased in both groups over the PP period by 1.8 and 2.7 kg for the intervention and control, respectively.

A randomized study examined the effects of energy restriction due to diet alone versus diet plus exercise on lactation output of 67 exclusively breastfeeding women at 8–16 weeks PP.[56] Women were randomly assigned to one of the three groups: Diet-only, diet-plus-exercise, or the control group. The diet-only group was prescribed a diet with 35% energy deficit, the diet-plus-exercise group was prescribed a diet with 35% net energy deficit, including 40% additional exercise, and the control group was instructed to continue their usual diet

Table 1: Body composition in lactating women

Study	Infant feeding method	Subjects	Study design	Aerobic exercise intervention	Resistance exercise intervention	Body composition changes	Body composition measurement
Body composition and lactating women							
Drinkwater and Chesnut, 1991	EBF	EG=6 CG=25 (NP/NL)	2 years longitudinal study pre-preg., 1 months PP, 6 months PL BMI=20.8 kg^2	Pre-preg. activities: 1.3 h/days, 5.3 days/weeks, 32.8 miles/weeks running, cycling, swimming weights	None	L1-L4 BMD: 4.1% and −0.8% FN BMD: −2.9% and −5.9% (not compared to control)	DPA (Ohio Nuclear Series 84) (no report of PP activities)
Dewey *et al*., 1994	EBF	EG=18 CG=15	RCT	20–45 min walking, jogging or cycling (5 times/weeks) at 60–70% of HRmax	None	No difference between groups in %BF	Hydrostatic weighing measurements: 1. % BF
Little and Clapp, 1998	EBF	EG=11 CG=9 (NE)	Classified by physical activity 2 weeks–3 months PP BMI = 24.7 kg^2	Self-reported 3–6 days/weeks 25–70 min/session 55–75% pre-preg. VO2max walking, running, aerobics, step aerobics, stair machines, biking, swimming, resistance training	None	TB BMD: +0.4% (NS) L2-L4 BMD: −4.1% (NS) FN BMD: −2.8% (NS)	DXA (Lunar) 5-site skinfold (Jackson and Pollock)
McCrory *et al*., 1999	EBF	DG=22 DEG=22 CG=23	RCT DG=35% deficit DEG=35% deficit (60% diet, 40% exercise) BMI= 25 kg^2	10–12 days Any at 50–70% HRmax	None	Weight loss – DG and DEG=−1.9 kg versus −1.6 kg, respectively, $P<0.05$) FFM-DG and DEG=−0.9 kg versus 0 kg, respectively, $P<0.05$)	Hydrostatic weighing; skinfold thickness; plethysmography (BOD POD), Measurements: 1. FM 2. FFM 3. %BF
Lovelady *et al*., 2000	EBF	DEG=21 CG=19	RCT BMI=27–28 kg^2	10 weeks 45 min brisk walking, jogging or aerobic dancing (4 times/week), at predicted HRmax 65–80%	None	DG and DEG=−1.3 kg versus −1.6 kg, respectively, $P<0.05$) %BF lost DG and DEG=−0.9% versus −1.6%; $P<0.05$) DEG BF (−4.8 kg, $P<0.01$) and fat mass (−4.0±2.0 kg and −0.3±1.8 kg, respectively, $P<0.01$) DEG %BF (−3.3%±1.8 CG=−0.2±1.8) FFM (NS; −0.8 kg)	6-site skinfold; underwater weighing Measurements: 1. Body density 2. %BF

(*Contd*...)

Table 1: (*Continued*)

Study	Infant feeding method	Subjects	Study design	Aerobic exercise intervention	Resistance exercise intervention	Body composition changes	Body composition measurement
Lovelady *et al.*, 2009	EBF	EG=10 CG=10 (NE)	RCT 4 weeks–5 months PP BMI=24.8 kg^2 (CG), 26.1 kg^2 (EG), NS	45 min walking 3 days/weeks, predicted HRmax 65–85%	Split routine 3 days/weeks day 1: squats, bench press, standing military press, abdominal crunches, and wall sit day 2: stiff leg deadlifts, push-ups, high pulls, bent over dumbbell row, and abdominal plank	L1-L4 BMD: −4.8% (EG) versus −7% (CG), *P*<0.01 Hip BMD: −2.8% (EG) versus −2.2% (CG) (NS)	DXA (Hologic)
Colleran *et al.*, 2012		EG=16 CG=15 (NE)	RCT 3 weeks–5 months PP BMI=28.0 kg^2 (CG), 29.7 kg^2 (EG), NS	10,000 walking steps/day or 3000 aerobic steps per day 5 days/weeks	Strength training 3 days/weeks 1 RM squats, bench press, bent-over row, deadlifts, and military press	L1-L4 BMD: −3.4% (EG) versus −3.7% (CG), *P*<0.01 Hip BMD: −3.1% (EG) versus −3.1% (CG)	DXA (Lunar)
Bertz *et al.*, 2012	EBF and CF	DG=17 EG=18 DEG=16 CG=17	RCT 10 weeks–6 months PP BMI=30.2 kg^2 (CG), 30.0 kg^2 (DG), 30.4 kg^2 (EG), 29.9 (DEG)	45 min brisk walks (4 days/weeks) at 60–70% of HRmax	None	12 weeks and 1 year: ↓ in fat mass in DG and DEG (*P*<0.001) 1 year: ↓ in lean soft-tissue mass	DXA Measurements: 1. BMI 2. Fat mass 3. Lean soft tissue mass 4. Muscle mass
Colleran *et al.*, 2019	EBF	EG=18 CG=18 (NE)	1-year follow-up BMI=24.2 kg^2 (CG), 25.9 kg^2 (EG)	BEHIP 1 and BEHIP 2	BEHIP 1 and BEHIP 2	L1-L4 BMD: −1.05% (EG) versus −2.64 (CG), NS Hip BMD: 1.40% (EG) versus −3.00% (CG), NS	DXA (Lunar)

EBF: Exclusively breastfeeding; CF: Combined feeding, FBF: Fully breastfeeding, DG: Number of women in the diet group, EG: Number of women in the exercise group, DEG: Number of women in the diet-exercise group, CG: Number of women in the control group (non-exercise) , IG: Number of women in the intervention group, NP/NL: Non-pregnant/non-lactating, PP: Postpartum, PL: Post-lactation, RCT: Randomized control trial, BMI: Body mass index (weight in kg divided by height in meters squared) , HRmax: Heart rate maximum, 1RM: 1-repetition maximum, TB: Total body, L1-L4: Lumbar spine, FN: Femoral neck, DXA: Dual-energy X-ray absorptiometry, DPA: Dual-photon absorptiometry, NS: Non-significant result compared to the control group, if significant *P* value present and activity. Body composition was measured by hydrostatic weighing and air-displacement plethysmography (BOD POD; Life Measurement Instruments, Concord, CA). Skinfold thickness and waist-hip circumference were also measured. The exercise was self-supervised and consisted of aerobic workouts. The study found an average 1 kg/week fat mass loss difference in the two energy-restricted groups which was significantly greater than the control group. However, since the study's duration was only 11 days, it was difficult to derive any firm conclusions.

A similar energy restriction and exercise study observed 40 overweight (BMI between 25 and 30 kg/m^2) exclusively breastfeeding women.[32] Women randomized to the exercise-plus-diet group were instructed to restrict their energy intake by 500 kcal and participate in aerobic exercise 4 days/week for 45 min each day. The control group continued their usual dietary intake and exercised <1 time/week for 10 weeks. In this study, body composition was measured by underwater weighing and six-site skinfold thickness. The study's intervention was successful by observing significant ($P < 0.01$) decreases in fat mass and body fat percentage in the exercise-plus-diet group compared to the control (−4.0 ± 2.0 vs. −0.3 ± 1.8 and −3.3 ± 1.8 vs. −0.2 ± 1.8, $P < 0.01$, respectively). A significant loss in weight was also observed in the diet-and-exercise group compared to the control (−4.8 ± 1.7 vs. −0.8 ± 2.3 kg, $P < 0.001$, respectively).

The same laboratory group compared 20 women, 10 of which were in an intervention group that participated in 45 min of weight-bearing aerobic exercise 3 days/week for 16 weeks.[57] Body composition and BMD were measured using DXA (Delphi A Version 12.3; Hologic, Bedford, MA). A significant difference was observed in less LBM loss in the intervention group compared to the control (−0.7 ± 0.3 vs. −1.6 ± 0.3, respectively, $P < 0.05$). The intervention group lost significantly less LS BMD than the control group (−4.8 ± 0.3 vs. −7.02 ± 0.6, respectively, $P < 0.01$). There was no significance in total body and hip-BMD between groups. This study thus demonstrated that exercise paired with breastfeeding may not only result in weight loss but could also attenuate BMD loss.

The same laboratory group went on to determine the effects of energy restriction and exercise on bone density in overweight to obese women.[37] Thirty-one fully breastfeeding women were randomly assigned to a diet and exercise intervention group or minimal care, control group at 4 weeks PP. The intervention group consisted of a 16-week diet (−170 kcal deficit) and home exercise program (1–3 days/week), as well as 10,000 walking steps or 3000 aerobic steps per day at least 5 days a week. The minimal care group continued their usual diet and activity patterns during the 16-week duration. Body composition and BMD were measured in this study by DXA (Lunar Prodigy Adv.; Lunar Radiation Corp., Madison, WI; QDR encore software version 11.20.068). Both groups had significant decreases in percent body fat and fat mass, but no difference between groups. The intervention group lost significantly less BMD compared to the control group in the LS (−3.4 ± 2.5 vs. −3.7 ± 3.3, $P < 0.001$, respectively) and hip (−3.1 ± 1.7 vs. −3.1 ± 1.8, $P < 0.001$, respectively). These results suggest that a combination of aerobic and resistance exercise minimizes or reduces lactation-induced bone loss in the LS and hip.

The most recent energy restriction and exercise weight loss study observed 68 exclusively breastfeeding and combined feeding overweight and obese women at 8–14 weeks PP for 12 weeks to determine the effects of both dietary restriction and exercise on weight and body composition during lactation.[27] Women were randomized to one of four groups: Diet-only (−500 kcal energy restriction), exercise-only (brisk walking 4 days/weeks 45 min/days), diet-and-exercise or combination (−500 kcal energy restriction and brisk walking 4 day/weeks 45 min/day), and a control group. Body composition and BMD were measured by DXA (Lunar Prodigy; GE Lunar Corp). This study found a significant decrease in fat mass in the diet-only group and combination group, but not the exercise-only group or the control after the 12-week treatment (−6.9 ± 3.4 and −6.2 ± 3.1 vs. −1.8 ± 3.0 and −0.7 ± 3.1 kg, respectively, $P < 0.001$). A significant decrease in fat mass was observed again at 1-year PP, specifically in the diet-only group, but also in the combination group compared to the exercise-only group and the control (−9.2 ± 5.6 and −6.0 ± 7.0 vs. −2.5 ± 5.9 and −1.8 ± 6.2 kg, respectively, $P = 0.002$, respectively). In addition, a small but significant ($P < 0.05$) decrease in muscle mass and lean soft-tissue mass was seen in the diet-only and combination group, but not in the other groups.

Several studies in lactating PP women have examined bone metabolism and have shown losses ranging from 1% to 10% at trabecular rich sites,[8,37,55,57-60] specifically decreases in the FN and LS BMD in the first 5 months of lactation. The outcome of a study conducted by Little and Clapp revealed significant ($P < 0.05$) losses of BMD in both the control and exercise groups LS (−5.4% vs. −4.1%, respectively) and FN (−2.7% vs. −2.8%, respectively).[55] In another study, malnourished lactating Indian women consuming 445 mg of calcium had shown 4% lactation-induced BMD loss at the FN and 2% loss in the LS during the first 6 months PP.[61] This significant loss of BMD may be reduced by dairy consumption along with a prescription combination of diet and weight-bearing exercise[8] that has demonstrated a protective effect on bone.

As suggested by the previous studies, BMD loss associated with lactation is temporary and is usually reversed with weaning along with the return of the menses.[8,9,37] Krebs *et al*.[9] longitudinally measured lactating women BMD starting at 2 weeks up until 7 months PP. Fifteen women returned for post-weaning measurements around 15 months PP. BMD at the LS was not significantly different between the 2-week measurement and post-weaning measurement.[9] In addition, in a 1-year follow-up of a combination of two studies,[57] results showed significant changes in total hip BMD overtime ($P < 0.05$).[8] Specifically, the intervention group began to regain the lost total hip BMD from endpoint to 1 year PP. In contrast, the control group continued to lose BMD (1.40 ± 3.14 vs. −3.00 ± 3.11, respectively), although the difference was not significant. LS BMD was also significantly higher in the intervention group compared to the control (1.159 ± 0.128 vs. 1.102 ± 0.149, respectively). LS BMD seemed to be returning to baseline values at 1-year PP in the intervention group (intervention −1.05% vs. control −2.64%) but was not statistically different between groups. Only a small number of women returned to their pre-pregnancy LS and/or hip BMD potentially from a large percentage of women (55.6%) still breastfeeding at 1-year PP in both groups ($n = 3$ returned for 1-year follow-up). However, women that returned to pre-pregnancy BMD values had higher compliance to the exercise protocol as part of an intervention group, suggesting that exercise had a significant effect on BMD.[8] BMD may not return to pre-pregnancy levels in all women, such as those with short intervals between pregnancies, women who have given birth close to menopause, and adolescent mothers, thereby increasing the risk of postmenopausal osteoporosis.[5]

However, one study found that bone size and geometry are higher in women who breastfed for longer durations (>6 months).[62] A DXA (Prodigy; GE Lunar Corp., Madison, WI, USA) was used to assess the geometrical and material properties of the hip and left tibia in women 16–20 years after their last pregnancy. The study found that those who had breastfed longer than 10 months had larger bone size. Conversely, other research shows a negative correlation between the duration of breastfeeding and BMD in the LS.[63] Consequently, further research needs to be done to determine the long-term effects of breastfeeding duration on BMD, area, and geometry.

CONCLUSIONS

These findings suggest that fermented dairy consumption and a combination of aerobic and strength training exercise interventions may be effective in reducing PP weight retention and improving body composition in lactating women. For example, yogurt is beneficial in helping to increase fat mass loss and LBM following a resistance exercise session. However, this result must still be examined in lactating women. Exercise alone is unlikely to produce the necessary energy deficit to facilitate fat mass loss in PP overweight-to-obese lactating women unless performed at high intensity for a prolonged period.[64] Due to a greater loss of LBM in a dietary restriction intervention alone, a combination of energy restriction and exercise is advocated as a safer option for breastfeeding women. In overweight lactating women, energy restriction of 500 kcal/day and aerobic exercise 4 days/week are considered to be safe for the promotion of 0.5 kg/week weight loss.[24]

Yogurt has been shown to increase BMD at the hip, specifically the trochanter. Weight-bearing exercise also increases bone density in PP women. The few studies that included lactating PP women found that a combination of aerobic exercise and resistance training reduced lactation-induced bone loss in the LS. However, additional research in this area is warranted in overweight-to-obese women. Several studies noted significant decreases in BMD at the LS and hip. However, the effects of lactation on BMD are reversible and may be minimized with a combination of yogurt or fermented dairy consumption and exercise. Research on adequate calcium intake remains controversial with regard to the effects on BMD. Additional research thus needs to be conducted on yogurt and dairy consumption and the effects of exercise on the body composition of lactating women.

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AUTHORS' CONTRIBUTIONS

Conceptualization, H.C., T.F., R.S., and S.I.; writing – original draft preparation, A.S..; writing – review and editing, H.C., L.SD., T.F., R.S., and S.I..; supervision, H.C. and S.I.; project administration, L.SD.; and funding acquisition, H.C., T.F., and S.I. All authors have read and agreed to the published version of the manuscript.

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