COLLERAN, HEATHER L., Ph.D. The Effects of Energy Restriction and Exercise on Body Composition and Bone Mineral Density in Overweight Lactating Women. (2010)
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Lactation is a time of rapid bone loss due to hyperprolactinemia, amenorrhea, and increased bone turnover, especially in the lumbar spine and hip. Childbearing may be one of the causes for the high prevalence (59%) of overweight and obesity among women. Exercise, combined with a modest restriction in energy intake, has been shown in non-lactating women to improve body composition and protect bone during periods of weight loss. However, there is a paucity of research on exercise and dietary interventions in lactating women aimed at promotion of bone health and weight loss. Therefore, the primary objectives of the two studies in this dissertation were: 1) to describe the changes in dietary intake, bone turnover markers, and hormones related to lactation and exercise, as well as predict changes in bone mineral density (BMD) during lactation in women whom had undertaken resistance exercise, and 2) to promote lifestyle changes through a home-based nutrition and exercise intervention targeting overweight lactating postpartum women.

The first study concluded exercise and a higher dietary calcium intake were inversely related to bone loss during lactation, when controlling for parity. Additionally, an increase in bone formation markers predicted an increase of lumbar spine BMD, whereas increased levels of estradiol and IGF-1 were positively related to total body BMD. The second study results suggest moderate

energy restriction and resistance training are safe methods for weight loss in overweight fully breastfeeding women with no adverse affects on BMD and infant growth. Additionally, the use of *MyPyramid Menu Planner* appeared to be a novel tool to aid in weekly individual dietary counseling and weight loss.

This dissertation research was the first to examine the effects of an exercise and weight loss intervention on attenuation of lactation-induced bone loss in overweight women. The results suggest moderate energy restriction, walking, and resistance training are safe methods for weight loss in overweight fully breastfeeding women with no adverse affects on BMD and infant growth.

THE EFFECTS OF ENERGY RESTRICTION AND EXERCISE ON BODY

COMPOSITION AND BONE MINERAL DENSITY

IN OVERWEIGHT LACTATING WOMEN

by

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION

Approximately 8 million American women suffer from osteoporosis, and one out of every two women over the age of 50 will have an osteoporotic-related fracture in their lifetime (1). Lactation is a time of rapid bone loss due to hyperprolactinemia, amenorrhea, and increased bone turnover especially in the lumbar spine and hip. Lactation-induced bone loss is usually reversed with weaning; however, not all women recover the bone loss, thus increasing the risk of osteoporosis later in life. While epidemiological studies suggest that pregnancy and lactation are not associated with risk of fractures later in life, these studies did not control for site-specific decrements in bone mineral density.

Another public health problem is the increasing prevalence of obesity, with 59.5% of American women being overweight or obese (2). Excess weight retention after pregnancy increases a woman's risk for developing a chronic disease later in life (3). Exercise combined with a modest restriction in energy intake has been shown in non-lactating women to improve body composition and protect bone during periods of weight loss. There is a paucity of research on exercise and dietary interventions in postpartum lactating women aimed at promotion of bone health and weight loss.

We previously reported that exercise training resulted in significant attenuation of lactation-induced bone loss in lumbar spine bone mineral density, compared to a sedentary lifestyle (4). The goal of the first study of this dissertation was to describe the changes in dietary intake, bone turnover markers, hormones related to lactation and exercise, and bone (density, content, and area) during lactation in normal and overweight women whom had undertaken resistance exercise as compared to sedentary controls. The second goal was to determine if exercise, dietary intake, bone turnover markers, and hormones significantly predict changes in bone mineral density. The specific aims of this study were to evaluate in normal and overweight lactating women at three to 20 weeks postpartum whether an exercise intervention, compared to a sedentary lifestyle, would:

1. affect bone turnover markers and anabolic hormones. We hypothesized that the exercise group would increase bone formation, decrease bone resorption and increase anabolic hormones compared to the sedentary controls at 20 weeks postpartum.
2. predict changes in bone mineral density. We hypothesized that exercise, higher dietary calcium intake, increase in bone formation, and an increase in anabolic hormones would slow the loss of bone mineral density during lactation.

Expanding on the findings from the first study, the primary goal of the second study of this dissertation was to promote lifestyle changes through a home-based nutrition and exercise intervention targeting overweight and obese lactating postpartum women. A second goal was to describe the acute and chronic response of growth hormone to resistance exercise. The final goal was to improve total diet or overall pattern of food eaten using *MyPyramid Menu Planner for Moms* (5). The specific aims of the second study were to evaluate in overweight and obese lactating women at three and 20 weeks postpartum whether an exercise and weight loss intervention, compared to a minimal care group, would:

1. improve body composition. We hypothesized that the intervention group would have less loss of lean body mass and bone mineral mass and more fat loss compared to the minimal care group at 20 weeks postpartum.
2. promote an increase in cardiovascular fitness and strength. We hypothesized that the intervention group would increase predicted maximal oxygen consumption and maximal strength compared to the minimal care group at 20 weeks postpartum.
3. affect bone-related hormones. We hypothesized that the intervention group would increase growth hormone compared to the minimal care group at 20 weeks postpartum. Additionally, we would see an acute increase in growth hormone after the 1-repetition maximum strength test in both groups.
4. improve total diet or overall pattern of food eaten. We hypothesized that, based on menu modeling with *MyPyramid* (6), the intervention group will improve the quality of their intake by consuming the recommended amounts

of food groups established by *MyPyramid* compared to the minimal care group at 20 weeks postpartum.

This research was the first to describe and compare changes in bone turnover markers, hormones, and bone mineral density in exercising and sedentary normal and overweight women during lactation. Additionally, it was the first to examine the effects of an exercise and weight loss intervention on attenuation of lactation-induced bone loss in overweight and obese women as well as anabolic hormones. To our knowledge, this was also the first study to use *MyPyramid Menu Planner for Moms* for dietary counseling using the total diet approach.

The dissertation that follows will review relevant literature to the above two studies followed by three chapters. The first chapter is titled "Changes in Markers of Bone Turnover and Hormones and Their Association with Changes in Bone Mineral Density in Exercising Breastfeeding Women." The second chapter is titles "The use of *MyPyramid Menu Planner* for Moms in a weight loss intervention during lactation". The final chapter is titles "The effects of energy restriction and exercise on body composition in overweight and obese lactating women". This dissertation will conclude with the epilogue, which will provide an overall conclusion to the research presented, problems and approaches to overcome, as well as future directions for this research.

References

1. National Osteoporosis Foundation 2008. *Fast facts on osteoporosis.* Available at: http://www.nof.org/osteoporosis/diseasefacts.htm.

2. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999-2008. *JAMA* 2010; 303(3):235-241.

3. Walker LO, Sterling BS, Timmerman GM. Retention of pregnancy-related weight in early postpartum: Implications for women's health services. *JOGNN* 2005; 34:418-427.

4. Lovelady C, Bopp MJ, Colleran HL, Mackie HK, Wideman L. Effect of exercise training on loss of bone mineral density during lactation. *Med Sci Sports Exerc* 2009; 41(10):1902-1907.

5. US Department of Agriculture. *MyPyramid for pregnancy and breastfeeding.* Available at: http://www.mypyramidtracker.gov/planner/launch.aspx.

6. Hornick BA, Krester AJ, Nicklas TA. Menu modeling with *MyPyramid* food patterns: Incremental dietary changes lead to dramatic improvements in diet quality of menus. *J Am Diet Assoc* 2008; 108(12):2077-2083.

CHAPTER II

REVIEW OF LITERATURE

Effects of Lactation and Calcium Intake on Bone Mineral Density

During peak lactation women transfer approximately 200 mg of calcium per day in breast milk (1-3). In order for the body to meet the extra demands for calcium during lactation, bone resorption increases, which increases calcium in the blood to be actively pumped into the breast milk for the infant (2-3). This loss of maternal calcium over a six-month period is equivalent to approximately a 4% loss in skeletal reserve with 1-10% bone density lost at trabecular rich sites (4).

Research on dietary and supplemental calcium intake of lactating and non-lactating postpartum women and their changes in lumbar spine and femoral neck bone mineral density (BMD) are summarized in Table 2.1. Calcium intakes in the literature ranged from 400 to 1600 mg per day, with lactating women having higher intakes of calcium and a greater loss of bone density at the lumbar spine and femoral neck compared to non-breastfeeding women. In a study with undernourished Indian women consuming 445 mg of calcium, a 4% lactation-induced BMD loss was seen in the hip, 4% loss in the femoral neck, and a 2% loss in the lumbar spine during the first 6 months of lactation (5).

Table 2.1. ***Calcium Intake and BMD during Lactation and Weaning***

Study	Subjects	Calcium intake (mg/d)	% change BMD lactation		% change BMD weaning		BMD measurements and weaning defined
Drinkwater and Chesnut 1991 (15)	6 L	diet+suppl. 1622	L1-L4 -4.1%	FN -2.9%	L1-L4 -0.8%	FN -5.9%	DPA (Ohio Nuclear Series 84) Weaning = following 6 mo. lactation (baseline = prepregnancy)
Sowers et al. 1993 (14)	20 L (<1mo.) 26 L (2-5 mo.) 64 L (>6mo.)	dietary 939 1158 1596	LS 0.2% 0.1% -5.1%	FN -1.4% 0.1% -4.8%	LS 1.6% 2.4% -0.8%	FN -1.3% 0.8% -2.7%	DXA (Lunar) Weaning = 12 mo. PP (baseline)
Cross et al. 1995 (17)	15 L	diet 1308	L2-L4 -4.9%	-	L2-L4 -3.4%	-	DXA (Hologic) Weaning = 2 mo. postwean (baseline)
Kalkwarf and Specker 1995 (97)	65 L 48 NL	dietary 828 728	L2-L4 -3.9% +1.5%	-	L2-L4 +5.5% +1.8%	-	DXA (Hologic) Weaning = less than 1 breastfeed per day for 2 mo. (recovery)
Affinito et al. 1996 (16)	18 L 18 NL	dietary 1782 1245	L2-L4 -7.5% NC	-	L2-L4 +3% NC	-	DPA (NovoDiagnositcs Systems) Weaning = 6 mo. postlacation (recovery, LS still below baseline values)
Lopez et al. 1996 (13)	30 L 26 NL	dietary 1479 536	L2-L4 -0.3% +0.4%	RFN -3.1% +0.2%	L2-L4 +5.7% -0.7%	RFN +5.3% +4.1%	DXA (Lunar) Weaning = 6 months post wean (baseline)
Krebs et al. 1997 (18)	26 L 8 NL	dietary 1161 823	L2-L4 -4% NC	-	L2-L4 NS baseline NC	-	DPA (DP3 Norland) & DXA (Lunar) Weaning = 6 mo. postwean (baseline)
Kolthoff et al. 1998 (12)	16 L (4.8 mo.) 26 L (8.8 mo.) 17L (12.2 mo.)	dietary 1624 1232 1299	L2-L4 -3.6% -5.5% -7.2%	RFN -4% -5% -7%	L2-L4 inc.> baseline inc.> baseline inc < baseline	RFN all groups inc. < baseline	DXA (Hologic) Weaning = 18mo. postdelivery
Ritchie et al. 1998 (20)	14 L	dietary 1087	L1-L2 -9.8%	-	L1-L2 +0.4%	-	DXA (Lunar) Weaning = after menses (baseline)
Laskey et al. 1998 (9)	47 L 11 NL	diet+suppl. 1256 668	L1-L4 -4% -1%	LFN / Hip -2.4% / -1.5% -0.4% / 0.4%	-	-	DXA (Hologic)
Little and Clapp 1998 (11)	20 L (3 mo.)	dietary 1100	L2-L4 -4.7%	FN -2.9%	-	-	DXA (Hologic)
Laskey and Prentice 1999 (23)	59 L 11 NL	diet+suppl. 1476 1108	-	-	L1-L4 2.7% 0.8%	LFN / Hip -2.1% / 0.4% -0.4% / 1.2%	DXA (Hologic) Weaning = 3 mo. postlactation (baseline)

Study	Subjects	Calcium intake (mg/d)	% change BMD lactation		% change BMD weaning		BMD measurements and weaning defined
Holmberg-Marttila et al. 1999 (8)	5 L	diet 894	L2-L4 ~ -5%	RFN ~ -5%	L2-L4 ~ -0.7%	RFN ~-3.5%	DXA (XR-26 Norland) Weaning = 1 yr after resumption of menses (baseline = prepregnancy)
More et al. 2001 (22)	7 L (0.7 mo.) 11 L (3.8 mo.) 20 L (9.1 mo.)	diet 1350 1250 1290	L2-L4 -0.5% -4.8% -7.4%	-	L2-L4 +1.9% -2.6% -9.9%	_	DXA (Lunar DPX-L) Weaning = 12 mo. postpartum (baseline)
Chan et al. 2005 (7)	 9 L 14 NL	diet 743 506	L2-L4 ~ -6% NC	FN ~ -2.5% NC	L2-L4 inc. < baseline NC	FN inc. < baseline NC	DXA (XR 26, Norland) Weaning = 12 mo. postpartum (avg. lactation duration 7.8 mo.) (baseline) FN (non-dominant leg)
Kulkarni et al. 2009 (5)	36L (6 mo.) 35 L (12 mo.) 33 L (18 mo.)	diet 449	L1-L4 -2% +3.75% +6.25%	FN/ Hip -4% / -4% -4% / -2.5% NC	-	-	DXA (Hologic) (baseline = 16 d PP)
Lovelady et al. 2009 (10)	10 L (5 mo.)	diet 1035	L1-L4 -7%	Hip -2.2%	-	-	DXA (Hologic) (baseline = 1 mo. PP)

L= lactation; NL= non-lactation/ formula feeding; BF = breastfeeding; suppl. = calcium supplement; FN = femoral neck; RFN = right femoral neck; LFN = left femoral neck; L1-L2, L1-L4, L2-L4, or LS = lumbar spine; PP = postpartum; DPA = dual-photon absorptiometry; DXA = dual energy x-ray absorptiometry; NC = no change

Two studies with calcium intakes less than the dietary reference intake (DRI) for lactation (1000 mg/d) (6), observed a 2.5 to 5% loss in femoral neck BMD, with a loss of 5 to 6% in the lumbar spine (7-8). In studies with well-nourished lactating women, consuming high dietary calcium intakes (1000 to 1800 mg per day), less loss of BMD was seen in the hip [-1.5%] (9-10), similar results in the femoral neck [-2.4 to -4.8%] (9,11-15) and the loss lumbar spine BMD had a greater variance from 0.3% to 9.8% loss (9,12-21).

Results of some studies indicate that dietary intake of calcium or supplementation does not appear to be protective of bone loss during lactation. Kolthoff et al. (12) found the magnitude and duration of bone loss at the trabecular rich sites was more likely attributable to the duration of lactation and postpartum amenorrhea versus calcium intake. The average dietary calcium intake in the study was well above the recommendation of 1000 mg/d (1232 mg/d to 1624 mg/d). Women who breastfed longer (12.2 months versus 4.8 months) had a longer duration of postpartum amenorrhea (11 months versus 2.3 months, respectively). This corresponded to a greater loss seen in lumbar spine and femoral neck BMD.

However, in one study by Krebs et al. (18), lumbar spine (L2-L4) BMD in 26 lactating women was positively associated with levels of estradiol ($p<0.001$) and calcium intake [dietary and total-including supplementation (1161 mg/d), $p=0.03$], and negatively associated with parity ($p=0.03$) and dietary protein (*p*=0.01). A positive association was also seen with the calcium to protein ratio (*p*=0.01).

Other studies, such as More et al. (22), found that women who breastfed longer than one month lost more bone mass at the lumbar spine compared to women who breastfed less than one month (-6.1% and -0.5%, respectively). The average calcium intake was 1270 mg/d for those who continued to breastfeed after the first month postpartum. In addition, the women who continued to breastfeed from six to twelve months postpartum lost an additional 2.7% BMD at the lumbar spine, where as those who only breastfed from two to six months postpartum gained 5.2% after weaning, in the following six to twelve months postpartum, despite adequate calcium intake. Conversely, Laskey and Prentice (23) found the duration of lactation and postpartum amenorrhea were significantly correlated ($r^2 = 0.70$, $p<0.001$), but the relationship was independent of lumbar spine and femoral neck BMD. In other words, there was no difference in the amount of bone loss three to six months after weaning between women who breastfed for less than three months and those who breastfed longer than three months. The average calcium intake was 1476 mg/d, well above the DRI.

Lost bone mass usually returns to pre-pregnancy levels with cessation of lactation and return of normal menses independent of calcium intake, making breastfeeding a safe feeding choice for the infant and the mother (2,24-25). However, not all women return to pre-pregnancy bone mass (20). There is a concern that lactation-induced bone loss may increase a women’s risk of osteoporosis during lactation or after menopause; particularly in women with low bone status prior to pregnancy or women who have their children later in life (9,20). Adequate calcium (> 1000 mg/d) intake may be protective of lactation-induced bone loss.

Effects of Exercise (Without Energy Restriction) on Body Composition (Bone Density, Lean Body Mass, Fat Mass)

Studies reviewed in this section are exercise interventions only without prescribed energy restriction [Table 2.2]. Weight bearing exercise in non-pregnant, non-lactating women with normal estrogen status has shown to increase bone mineral density (BMD) in the lumbar spine and femoral neck by increased mechanical stress on bones (21,26-28). Studies with postmenopausal women, not using hormone replacement therapy (HRT), have found exercise to be beneficial for preservation of bone and reversal of bone loss as a result of the low estrogen state (29-34). The types of exercise need to be site specific and direct force into the bone to induce bone growth (28,30,35-37).

Chilibeck et al. (38) reported no change in total body, femoral neck or lumbar spine BMD in premenopausal women who participated in two sessions per week of resistance training using Universal weight machine. Other studies in premenopausal women demonstrated improvement of BMD focused the exercise to stimulate bone through a combination of free-weight (dumbbell) resistance training and jumping (impact) (26-28).

Table 2.2. ***Effects of Exercise (Without Energy Restriction) on Body Composition (Bone Density, Lean Body Mass, Fat Mass)***

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Premenopausal Women						
Cullinen and Caldwell 1998 (43)	Ex =20 C = 10	RCT BMI = 27 to 30 kgm-2 Age = 26 yrs	None	12 wks (weight training) 2 supervised sessions/wk Session 1: 3 set 10 reps 30-60 min rest dumbbell bench press, seated dumbbell press, lat pull-down, dumbbell curl, leg extension, leg curl Session 2: 3 set 10 reps 30-60 min rest fly, upright row, lat pull-down, bicep curl, leg extension, leg curl	Wt NC FFM +2 kg %BF lost -2.6% significant changes from wk 0 to wk 12 (between groups not reported)	3- site skinfold (Wilmore and Behnke) Ca 2+ = 813 mg/d (average)
Bassey et al. (21)	Ex=30 C=25	RCT BMI = 23 kgm-2 Age = 37 yrs	None	20 wks (Jump/ stretching) 6d/wk, 10min/session Gentle movement, followed by 5 bouts of 10 vertical jumps (two legs) progressing to 50 jumps, finish with lower limb stretching	(Ex) FN BMD +1.1%, L2-L4 BMD 2.1%, p<0.05 NS between groups FN or L2-L4 BMD Wt +0.14 kg (Ex), +1.05 kg (C) ,p<0.02 FFM NC FM NC	DXA (Lunar DPX-L) Body Composition (bioimpedance meter, EZ Comp. 1500)
Chilibeck et al. 1996 (38)	Ex =20 C = 10	RCT BMI = 22 kgm-2 Age = 20 yrs	None	2- 10wk training periods 70-80% 1RM universal weight machines upper body: 5 sets 6-10 reps bench press, “lat” pulldown, arm “curl”, triceps extension lower body: 5 set 10-12 reps leg press, knee extension, knee flexion *n*=10 whole routine *n*=10 split routine	NC in TB, LS, FN BMD Wt loss no change FFM +1.5 kg (p<0.05) FM -3.7% (p=0.06) %BF -1.1% (p<0.05)	DXA (Hologic) Ca 2+ = 899 mg/d

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Park et al. 2003 (44)	Aerobic Ex = 10 Aerobic + RT = 10 C =10	RCT BMI = 25 kgm-2 Age = 43 yrs	24 wk 60 min/d, 6 d/wk (Aerobic Ex) and 3 d/wk (Aerobic+RT) 60-70% HRmax Aerobics progressing to jumps with aerobics	24 wk 60 min/d, 3d/wk 60-70% 1RM bench press, side raise, triceps push away, barbell curl, leg curl, leg extension, leg press, leg raise, abdominal crunch, lat pull down	Wt loss: Aerobic Ex -4.7 (p<0.05); Aerobic+RT -6.0 (p<0.05) FFM: Aerobic Ex +0.9 (NS); Aerobic+RT +5.6 (NS) FM: both groups reduced visceral and subcutaneous FM %BF Aerobic Ex -9.2% (p<0.01); Aerobic+RT -10.3% (p<0.01)	Inbody 3.0 (Biospace, Korea)
Vainionpaa et al. 2005 (27)	Ex = 39 C = 41	RCT BMI = 25.6 kgm-2 Age = 38 yrs	None	12 mos. 3x/wk 60 min (10 min warm-up/ cool-down) Impact training: Step patterns, stamping, jumping, running and walking + 10 min at home training daily	L1-L4 BMD +0.1% (NS) FN BMD +1.1% (p=0.03) Wt loss -1.1% (p=0.08)	DXA (Hologic) Ca 2+ = 1099 mg/d
Premenopausal Women						
Winters-Stone and Snow 2006 (28)	Lower Ex (LE) = 19 Upper + Lower Ex (ULE) = 16 C = 24	RCT BMI = 24 -24.9 kgm-2 Age = 38 to 41	None	12 mo. 3x/wk warm-up and jumping (100/session) lower body 9 sets 10-12 jumps (15-30sec rest); 9 sets 10-12 reps (2-3min rest): squats, lunges, calf raises), upper body 3 sets 8-12 reps (1-2min rest): upright row, one-arm row, lat. pull-down, chest press, chest fly, biceps curl, tricep extension	TB, Hip, FN BMD NC LS BMD ULE +1.3%, LE +0.3%, C -0.5%, p<0.05 Wt loss NC reported FFM ULE +0.8 kg, LE, +1.2 kg, C +0.5 kg, NS FM ULE -1.5 kg, LE -0.4 kg, C +0.8 kg, p<0.05 %BF	DXA (Hologic) Ca2+ = 791 - 1060mg/d

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Singh et al. 2009 (26)	Ex = 26 C = 28	RCT BMI 25 kgm-2 (Ex), 26.8 kgm-2 (C) Age 41 yrs	9 mo. 15 wk supervised/ 39 wk unsupervised 1-2 walks/wk	3 sets 8-10 RM Cybex (squats, leg press, leg extension, setaed leg curl, lat pulldowns); free wts (bench press, overhead press, biceps curls, tricep extension)	TB BMD 1.2% (Ex) vs. 0.9% (C), NS LS BMD +2.2% (Ex) vs. +0.3% (C), NS Hip BMD -0.1% (Ex) vs. -1.6% (C), NS Wt +0.3kg both groups FFM +1.2 kg (Ex) vs. 0.4 kg (C),p=0.03 FM -0.8 kg (Ex) vs. -0.1 kg (C), NS	DXA (Lunar Prodigy) Ca 2+ = 718 mg/d C, 950 mg/d Ex
Postmenopausal women (no HRT)						
Bassey et al. 1998 (21)	Ex = 45 C = 32	RCT (5-6 YSM) BMI = 25 kgm-2 Age = 55 yrs	None	12 mo. 50 jumps /d for 10 min no shoes 6x/wk	L2-L4 BMD -0.2% (NS) FN BMD -1.7% (NS)	DXA (Lunar) Bioimpedance meter (EZ Comp. 1500) Ca2+ = 1005 mg/d
Chien et al. 2000 (30)	Ex = 22 C = 21	Non-RCT, based on anticipated compliance (YSM 11-12) BMI = 22-23 kgm-2 Age = 57 yrs	3-50 min sessions/wk for 24 wk Graded TM walking and stepping ex 5 min warmup, 30 min 70-85% VO2 max, 5 min cool-down 10 min stepping 96 beats per min, 20 cm high bench, rest after 5 min.	None	non-HRT FN BMD +6.7% vs. C -1.1%, p<0.05 non-HRT LS BMD NS +1.5% vs. C -2.2%, p<0.05	DXA (Norland) Bioelectrical impedance (RJL Systems) Average Ca2+ = 1000mg
Brooke-Wavell et al. 2001 (39)	Walk/Sed = 15 Sed/Sed = 20 Walk/Walk = 16 Sed/Walk = 17	Follow-up 1 yr post RCT (YSM 5) BMI 25.7 kgm-2	From 1 yr study Brisk walking start 120min/ 2wks to 280min/ 2 wks after 3mo.-1yr. at least 20 min/ walk, min. 3x/wk.	None	L2-L4 BMD NS FN BMD NS Wt Change NS	DXA (Lunar, DPX-L) Hip = FN, trochanter, Ward's triangle) Ca 2+ = 887 mg/d (avg between groups)

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Hagberg et al. 2001 (33)	Active = 11 Athletes = 12 C = 11	Self-selected base on PA Cross Sectional (YSM 16) BMI Active = 25.8 kgm-2 BMI Athletes = 22 kgm-2 BMI C = 23.6 kg/m-2 Age 65 yrs	Active = low-to-mod intensity PH > 90mi/wk, > 3d/wk Athletes = distance runners training for competitive endurance events C = not participated in regular activity > 2yrs	None	Active/ Athlete TB BMD higher than C Active LS BMD higher than Athlete/C FN BMD NS Wt Athletes < C < Active %BF Athletes 28% (p<0.05) versus 37% C and 38% Active FFM NS	DXA (Lunar) Average Ca2+ 978 to 1557 mg/d (NS)
Cussler et al. 2003 (35)	Ex = 70 C = not reported	Block RCT (YSM 6) BMI 25.6 kgm-2 Age 56 yrs	None	1 year 3d/wk 60-75 min stretching, balance, warmup, weightlifting 2 sets of 6 to 8 reps (seated leg press, lat pull-down, weighted march, seated row, back extension, one-arm dumbbell press or military press, squats, rotary torso), and weight-bearing circuit (walk/jog, skipping, hopping) stair-climbing/ step boxes with weighted vests	baseline %BF 38.6% FFM 38.6 kg Changes in body composition or bone not reported Relationship found between BMD change and total/ ex specific weight lifted = positive association between type of ex and BMD	DXA (DPX-L Lunar) Calcium Citrate suppl. 800 mg/d
Douchi et al. 2003 (32)	Ex = 45 C = 89	Classified by physical activity (YSM 5) BMI = 23 kgm-2 Age = 55.5 yrs	2 years 2 h/ wk walking, jogging, volleyball, tennis, swimming, aerobics	None	L2-L4 BMD higher (p<0.001) Wt (NS) FFM higher (p<0.05) FM lower (p<0.05) %BF lower (p<0.05)	DXA (Hologic)
Postmenopausal women (no HRT)						
Chubak et al. 2006 (31)	Ex = 87 C = 86 (stretchers)	RCT (YSM not reported) BMI = 30.5 kgm-2 Age = 60.6 yr	12 mo. 45 min moderate-intensity 5d/wk treadmill walking, stationary bicycling	2 sets 10 reps 3 days/ wk leg extension, leg curls, leg press, chest press, seated dumbbell row (not required)	TB BMD +0.5% (NS) Wt loss -1.3kg (p=0.01) FFM +0.2kg (NS) FM -1.4 kg (p=0.001)	DXA (Hologic) Ca 2+ = 800 mg/d

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Engelke et al. 2006 (36) , Kemmler et al. 2005/ 2007 (34,40), and Stengel et al. 2005 (37)	Ex = 48 C = 30	RCT (YSM 5) BMI = 25.4 kgm-2 Age = 55.2 yrs	3-yr 2 group sessions/wk, 60-70 min each 1. Warm-up (walking and running, high impact aerobics) 2. Jumping sequence (4 set 15 mulitdirectional jumps) 3. Strength 2 sets 20 reps 50%-90% 1RM machines 13 exercise all main muscle groups Isometric ex. (elastic belts, dumbbells, weighted vests) 2 to 4 sets wide bench press, one arm dumbbell row, squats, deadlift 4. Flexibility training (stretching 1-2 sets and 30s passive all main muscle groups) 2 at home sessions/wk, 25 min each rope skipping, isometric and belt exercises, stretching		L1-L4 BMD +0.8% (NS from baseline) FN BMD -0.2% (NS from baseline) Wt loss -1.1% (NS) FFM -0.2% (NS) %BF -2.2% (NS)	DXA (Hologic) 21% and 29% dropout of Ex and C, respectively Attendance 77% for group and 61% for home sessions (avg 2.4 sessions/ week) 3-yr EFOPS (Erlangen Fitness Osteoporosis Prevention Study) Ca2+ = 1000 mg/d
Bocalini et al. 2009 (29)	Ex = 15 C =10	RCT (YSM not reported) BMI 28 kgm-2 (Ex), 27 kgm-2 (c) Age = 69 (Ex), 67 (C)	None	24 weeks 85% 1 RM for 10RM every other day. leg press, chest press, leg curl, lateral pulldown, elbow flexion & extension, leg extension, upper back row, military press, hip ab/adductor, abdominal curls	L1-L4 BMD NC (Ex), -1% (C), p<0.05 FN BMD NC (Ex), -1.5% (C), p<0.05 Wt loss -5kg (Ex), NC (C), p<0.05 %BF -4% (Ex), +1% (C), p<0.05 BMI -3kgm-2 (Ex), +1kgm-2 (C), p<0.05	DXA (DEA-DTX 200 osteometer)
Velthuis et al. 2009 (45)	Ex = 95 C = 88	RCT (YSM 9-10) BMI 26.6kgm-2 (Ex), 27.3kgm-2 (C) Age 58.9 (ex), 58.4(C)	1 yr moderate/ vigorous 30 min sessions/ wk + 30min at home, (walking/cycling) 10min warm-up, 20 min aerobic 60-80% HRmax, 25 min strength, 5 min cool-down	60% 1 RM, 20 to 25 reps general muscle strength (back, lower and upper extremities) 50% 1RM, 30 to 40 reps abdominal muscles	Wt loss 1% (Ex), 0.5% (C) (NS) FFM +0.7% (Ex), -0.5% (C) p<0.05 FM -3% (Ex), -0.5% (C) (NS) BF% -2.2 (Ex), 0% (C) (NS)	DXA (Lunar, Prodigy)

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Brooke-Wavell et al. 2001 (39)	Walk/Sed=15 Sed/Sed=20 Walk/Walk=16 Sed/Walk=17	Follow-up 1 yr post RCT (YSM 5) BMI 25.7 kgm-2	From 1 yr study Brisk walking start 120min/ 2wks to 280min/ 2 wks after 3mo.-1yr. at least 20 min/ walk, min. 3x/wk.	None	L2-L4 BMD NS FN BMD NS Wt Change NS	DXA (Lunar, DPX-L) Hip = FN, trochanter, Ward's triangle)
Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Exercise and Lactating Women						
Drinkwater and Chesnut 1991 (15)	Ex = 6 C = 25 (NP/ NL)	2 yr. longitudinal study prepreg., 1mo. PP, 6 mo. PL BMI = 20.8 kgm-2	Prepreg activities: 1.3 h/d, 5.3 d/wk, 32.8 miles/wk running, cycling, swimming, weights	None	L1-L4 BMD -4.1% & -0.8% FN BMD -2.9% -5.9% (not compared to control)	DPA (Ohio Nuclear Series 84) (no report of PP activities) Ca 2+ = 1622 mg/d
Lovelady et al. 1990 (46)	Ex=8 C=8	Cross-sectional classified by PA 3 to 4 mo. PP BMI = 30 kgm-2 (Ex), 273. Kgm-2 (C)	Self-reported average 88min/d >1yr vigorous ex, with decreased intensity during pregnancy	None	Wt NS %BF 21.7% (Ex) vs. 27.9% (C), p<0.01	Hydrostatic weighing 6-site skinfold (Jackson & Pollock)
Little and Clapp 1998 (11)	Ex = 11 C = 9	Classified by physical activity 2 wk to 3 mo. PP BMI = 24.7 kgm-2	Self-reported 3-6 d/wk 25-70 min/ session 55-75% prepreg. VO_2max 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) Wt lost -1.8kg (NS) %BF (2wksPP) 23.4%	DXA (Lunar) 5-site skinfold (Jackson & Pollock) Ca 2+ = 1292 mg/d
Lovelady et al. 2009 (10)	Ex = 10 C =10	RCT 4 wk to 5 mo. PP BMI = 24.8 kgm-2 (C), 26.1 kgm-2 (Ex), NS	45 min. walking 3 d/wk, predicted HRmax 65-85%	Split routine 3 d/wk d 1- squats, bench press, standing military press, abdominal crunches, and wall sit d 2- stiff-leg deadlifts, push-ups, high pulls, bent-over dumbbell row, and abdominal plank	L1-L4 BMD -4.8% (Ex) vs. -7% (C), p<0.01 Hip BMD. -2.8% (Ex) vs. -2.2% (C) (NS) Wt lost -3.6kg (Ex) vs. -3.5kg (C) (NS) FFM -0.7kg (Ex) vs. -1.6kg (C), p=0.05 FM -2.9kg (Ex) vs. -1.9kg (C) (NS) %BF -9.5% (Ex) vs. -4.3% (C) (NS)	DXA (Hologic) Ca 2+ = 944 mg/d C to 1209 mg/d Ex

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Dewey et al. 1994 (47)	Ex = 18 C = 15	RCT BMI = 28 kgm-2	12 wks (6-8 wks PP start) 45 min/d, 5 d/wk walking, jogging, or bicycling (60 to 70% HHR)	None	Wt lost -1.6 (NS) %BF lost -1.5% (NS)	Hydrostatic weighing

Ex = number of women in the exercise group; C = number of women in the control group (non-exercise); Sed = sedentary; 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); YSM = years since menopause; HHR = heart rate reserve; HRmax = heart rate maximum; reps = repetitions; 1 RM = maximum weight lifted one-time; TB = total body; L2-L4 = lumbar spine; FN = femoral neck; FFM = fat-free mass; FM = fat mass; %BF = percent body fat; DXA = dual energy x-ray absorptiometry; DPA = dual-photon absorptiometry; Ca2+ = calcium intake; NC = no change; (NS) = non-significant result compared to the control group, if significant *p* value present; HRT = hormone replacement therapy.

Bassey et al. (21) found 50 vertical jumps per day, six days per week for 20 weeks significantly improved BMD in the femoral neck and lumbar spine in premenopausal women compared to a control group.

In postmenopausal women (no HRT) twelve months of 50 vertical jumps per day for 10 minutes had no effect on femoral neck or lumbar spine BMD (21). Additionally, aerobic exercise (walking) appears to have no effect on femoral neck or lumbar spine BMD in postmenopausal women (39). Conversely, a comparison of physical active women who participated primarily in aerobic exercise (walking, running, tennis) for at least 2 hours per week for two years to sedentary counterparts had higher lumbar spine BMD (32-33). Chien et al. (30) combined aerobic exercise (50 minutes per session, 3 sessions per week graded treadmill walking) with 10 minutes of stepping 96 beats per minute significantly improved femoral neck and lumbar spine BMD in postmenopausal women (no HRT). Positive effects on BMD were seen in studies that incorporating free-weight resistance training (29), aerobic and resistance training (31), and aerobic, resistance training and jumping (34,36-37,40).

The optimal training strategy (intensity, frequency, duration, and volume) for improvement of bone in women with a low estrogen status has yet to be determined (37). However, once the stimulus for bone growth stops, detraining occurs, bone resorption increases, and bone formation decreases thus losing any gains from exercise training (41).

There is limited research into the benefits of exercise or physical activity on bone density in women during the postpartum period. To date, three published studies have directly addressed exercise during the postpartum period with respect to attenuation of lactation-induced bone loss (42). The first study by Drinkwater and Chesnut (15) measured bone mineral density at seven skeletal sites in six female athletes enrolled in a two-year longitudinal study who became pregnant. From one month postpartum to six months of lactation, the femoral neck was the only site with a significant decrease of 3.1%. Although not statistically significant, a gain of 3.4% in lumbar spine BMD was observed during the same time- period. The changes in femoral neck bone density observed in this active population during lactation were similar to femoral neck bone density changes reported in the literature for non-exercising lactating women (Table 2.1). Conversely, the changes in lumbar spine were not similar. However, the sample size was a relatively small sample to draw definitive conclusions regarding the effects of exercise on BMD during lactation and there was no control group of non-exercising women.

The second published study was with twenty fully breastfeeding women for the first three months postpartum (11). Exercise was defined as an aerobic session more than three days per week for longer than 20 minutes per session. There were no statistical differences between the control or exercise group in the loss of lumbar spine BMD (-5.4% and -4.1%, respectively) or femoral neck BMD (-2.7% and -2.8%, respectively). This bone loss was similar to other studies investigating the effects of lactation-induced bone loss (Table 2.1). There are three limitations to this study. The first was a lack of randomization into an exercise or control group. Group assignment was based on self-reported activity. Second, the self-selected and self-reported exercise mode (aerobic) might not have provided a sufficient stimulus for bone. Finally, the third limitation was the study duration, only three months in length. The short time span may not have been long enough to see an effect of exercise on bone remodeling.

The third study was a 16-week exercise aerobic and resistance exercise intervention with twenty fully breastfeeding women (10). Aerobic exercise was 45 min of walking three days per week at 65 to 85% of predicted heart rate maximum. Resistance exercise was a split routine three days per week focused on exercises that directed force through the axial skeleton. The exercise group lost significantly less lumbar spine BMD compared to the control group (-4.8% vs. -7%, respectively). Hip BMD loss was similar between the groups (-2.8% exercise vs. -2.2% control). The results suggest that exercise slows the loss of lactation-induced bone loss in the lumbar spine.

The use of resistance exercise for improvement of body composition (decrease in fat mass and increase in lean body mass) has been demonstrated in both pre- and postmenopausal (not using HRT) women (26,28,31,38,43-45) [Table 2.2]. However, Bassey et al. (21) found 50 jumps per day, six days per week for 20 weeks had no effect on body composition in premenopausal women. In postmenopausal women (no HRT), a one year walking intervention has no effect on weight (39). Conversely, postmenopausal women, who are aerobically active (> 2 hours per week for at least 2 years), have higher fat free mass (32), lower fat mass and percent body weight (32-33) regardless if actual weight was different from their non-active peers.

The Erlangen Fitness Osteoporosis Prevention Study (EFOPS) (34,36-37,40) was a 3 year aerobic and resistance training intervention with jumping in postmenopausal women (no HRT). Although, body composition changes were non-significant compared to the control group, the exercise group lost 1.1% body weight, 2.2% body fat, and 0.1% fat free mass. The women had a BMI of 25.4 kg/m2 and consumed 1000 mg/d of calcium. The loss of fat free mass may have been due to a low compliance (77% group and 61% at home).

Other exercise interventions with postmenopausal women (no HRT), found improvements in body composition. In a twelve month intervention, Chubak et al. (31) found forty-five minutes of moderate-intensity aerobic exercise five days per week coupled with three days a week of resistance exercise induced weight loss (-1.3 kg) primarily from fat mass (-1.4 kg) and fat free mass was preserved (+0.2 kg) compared to the control group. Velthuis et al. (45) found similar results in body composition (1% weight loss, -3% fat mass, -2.2% body fat, and +0.7% fat free mass) with a combination of aerobic and resistance exercise during a 1-year intervention. In postmenopausal women (no HRT) aerobic exercise combined with resistance training may improve body composition, however, frequency, intensity, duration, and mode of exercise may be important.

There are few studies to date investigating exercise on body composition during lactation. There are two studies to date that have investigated the effects of aerobic exercise on body composition and only one study investigated the effects of aerobic and resistance exercise on body composition in lactating women [Table 2.2]. In a cross-sectional study comparing fully breastfeeding women around three to four months postpartum, women who engaged in aerobic exercise on average 88 min/d for at least the prior 12 months had a lower body fat percentage compared to a less active cohort ($21.7 \pm 3.5\%$ versus $27.9 \pm 4.7\%$, $p < 0.01$, respectively) (46). The body weight between the two groups was similar. Additionally, there were no statistically significant differences between the groups for weight, infant's body weight, or breast milk volume or composition.

In a randomized control trial investigating the effects of a 12 week aerobic exercise intervention on body composition in fully breastfeeding women, no statistical differences between the exercise or control group for body fat percentage, lean body mass, weight, and breast milk volume or composition were seen (47). The exercise group engaged in walking, jogging, or cycling on average of 4.5 days per week at 60 to 70% heart rate reserve. Both groups lost 1.6 kg of body weight and 1.5% of percent body fat.

In another randomized control trial, resistance training during lactation was found to preserve lean body mass with no difference in weight or fat mass between women who exercised compared to the control (10). The weight loss between the exercise group and control group was similar (-3.6 kg versus -3.5 kg, respectively) during the 16-week intervention. However, the exercise group lost significantly less lean mass (-0.7 kg) compared to the control group (-1.6 kg), $p = 0.05$.

Aerobic and resistance exercise may improve body composition in lactating postpartum women, regardless of weight loss. Additionally, exercise during lactation had no adverse affects on infant's body weight, or breast milk volume or composition (48). However, there is a need for more research on the effects of resistance training on body composition (bone density, fat-free mass, fat mass) during the postpartum period.

To summarize the research, studies in premenopausal and postmenopausal (no HRT) women found exercise to increase bone density and improve body composition; however, frequency, intensity, duration, and mode of exercise are important. The few studies in lactating postpartum women found aerobic exercise improved body composition, and a combination of aerobic and resistance training attenuated lactation-induced bone loss in the lumbar spine; however, further research is needed.

Effect of Energy Restriction and Exercise on Body Composition (Bone Density, Lean Body Mass, Fat Mass)

Creating a negative energy balance to induce weight loss can be achieved either by increased energy expenditure through exercise or decreased energy intake through diet or both. Studies with premenopausal healthy women show preservation of bone density with a moderate reduction of energy intake or when combined with an increase in energy expenditure (49-52). In studies with postmenopausal women, energy restriction with exercise induced weight loss without changing or affecting bone mineral density at the hip and spine (53-55) [Table 2.3].

Redman et al. (56) created an energy deficiency of 25% either through energy restriction or energy restriction with aerobic exercise in premenopausal women. There were no significant differences between the amount of weight loss from energy restriction or from aerobic exercise combined with energy restriction. However, the energy restriction with exercise group lost more weight from fat mass compared to the group with just energy restriction.

In overweight/ obese postmenopausal women (not using HRT), a significant change in body weight and fat-free mass was seen over an 11-week study using a reduced energy diet with no exercise (57). Although 78% of the weight loss was from fat mass, the women lost a significant amount of fat-free mass, with no significant change to bone mineral content. A similar study, investigated the effect of a reduced energy diet (250-500 kcal per day reduction) plus a walking program (3 days per week) on weight loss over a six-month period (54,58-59).

Table 2.3. ***Effects of Energy Restriction (and Exercise) on Body Composition (Bone Density, Lean Body Mass, Fat Mass)***

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Premenopausal Women						
Hunter et al. 2008 (62)	Ex A (aerobic) =16 Ex R (RT) = 17 C =13	RCT BMI = 28.3 kgm-2 Age 35.7 yrs All groups consumed 800 k/d; 18-22% Pro	10 wks: 40 min walking/ jogging on treadmill 67% HRmax inc. to 80% HRmax 3d/wk	Warm-up 5min, stretching 5min 2 sets 10 reps @ 80% 1RM 3d/wk squats, leg extension, leg curl, elbow flexion/ extension, lateral pull-down, bench press, military press, lower back extension, and bent leg sit-ups	Wt loss 12.7kg (ExA), 12.5 (ExR), C 13.7kg (NS) %BF -8.8% (ExA), 10.7% (ExR), 9% (C) (NS) FFM -1.8kg (ExA), +0.1 (ExR), C -1.9kg (p<0.01) FM -10.9kg (ExA), -12.4 (ExR), C -11.8kg (NS)	BOD POD Controlled diet, prepared 800 kcal/d
Nakata et al. 2008 (52)	Diet (D) = 21 Diet + RT (DR) = 21	RCT BMI – 27.5 kgm-2 Age 40 to 42 yrs Dietary intake 1200 kcal/d 800 mg/d calcium	Pedometer (Lifecorder) at d7 and weeks 10 avg steps/d both groups 8000 to 9000	90 min RT 3d/wk alternate days. 14 wks Warm-up, free wts RT, cool-down. bench press, squats, leg curls and extensions, situps. progress 1 to 3 sets 12 to 15reps	Diet 1302 kcal (D), 1272kcal (DR), NS Protein 1.2 g/kg both groups Ca 1044mg (D), 969 mg (DR), p<0.05 TB BMD -0.8% (D), NC (DR), NS LS BMD NC both groups Wt loss 6.2kg(D), 8.6 (DR), NS FFM -1.7kg (D),-1.8kg (DR), NS FM -4.5kg (D), -6.9kg (DR), p<0.05	DXA (Lunar DPX-L) Prescribed diet, 3d food records
Riedt et al. 2007 (61)	High Ca Wt loss (HCaL)=14 Normal Ca Wt loss (NCaL)=17 Normal Ca Wt Maintance (NCaM)=13	RCT BMI 27.7 kgm-2 Age 38 yrs 8 mo. Wt loss/ wt. maintance Dietary intake 1200-1500 kcal/d	diet only (NS) HCaL 1376kcal, 1890mg/d Ca NCaL 1406kcal, 1162mg/d Ca NCaM 1624, 1202mg/d Ca	None	TB BMD +0.6% (HCaL) vs -0.2% (NCaL) vs -1.1% (NCaM), p=0.03 LS BMD , FN BMD and Hip BMD NS Wt loss -5.5kg (HCaL)(NCaL) vs. -0.1kg (NCaM), p<0.0001 FFM -0.8kg (HCaL) vs -1.8kg (NCaL) vs +0.2kg (NCaM), p=0.02 FM -5kg (HCaL) vs -3.2kg (NCaL) vs -0.2kg (NCaM), p<0.0001	DXA (Lunar Prodigy) Ca Citrate Supplementation + 600mg/d diet Ca = High Ca 1.8g/d Recommended Ca 1 g/d (normal) ADA exchange and behavior modification, 3d food records
Bowen et al. (98-99)	High dairy Protein/ High Ca (DP)=15 High mixed protein/moderate Ca (MP)=15	Matched RCT 12 wk Energy Resisted Age 46 yrs BMI 34.6 (DP), 31.9 (MP)	diet only DP 1390kcal, 2371mg/d Ca MP 1418kcal, 509mg/d Ca 1.3 g protein/kg (NS group) Ca p<0.001 groups	None	TB BMD NC Wt loss -9.4kg (DP) vs. -7.8kg (MP) NS FFM -0.9kg (DP) vs. -1.0kg (MP) NS FM -9.2kg (DP) vs -7.1kg (MP) NS	DXA (Norland XR36) Prescribed diet, 3d food records DP = 9 premenopausal women; MP = 8 premenopausal women

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Layman et al. 2005 (51) and Thorpe et al. 2008 (100)	Pro=12 Pro+Ex=12 CHO=12 CHO+Ex=12	RCT 4 mo diet + exerc, 8 mo. followup Age 45 to 48 yrs BMI (kgm-2): Pro=34.8 Pro+Ex=31.4 CHO=35.4 CHO+Ex=30.2	All groups= walking 5d/wk for 30min/d	Ex only = 2d/wk 30min RT 7 nautilus machines 1 set 12 reps	All groups 1300-1500kcal (NS) Pro 1.3g/kg (Pro, Pro+Ex) vs 0,7f/kg (CHO, CHO+Ex), p<0.001 diet TB BMD +1.6%, LS BMD +2.1%, Hip BMD +1.4% higher in Pro compared to CHO at 1yr (no effect of exercise was seen) Wt loss -9.3kg (Pro, Pro+Ex) vs. -7.3kg (CHO, CHO+Ex), p<0.05 FFM -2kg (Pro), -0.4kg (Pro+Ex), -2.7kg (CHO), -1kg (CHO+Ex), p<0.001 exercise FM -7.3kg (Pro, Pro+Ex), -5.3kg (CHO, CHO+Ex), p<0.05	DXA (Hologic) Prescribed diet, daily menus 24 recall + 3d weighed food records 1700kcal/d Pro Diet= 1.6g/kg/d Pro, low CHO (40%) CHO Diet= 0.8g/kg/d Pro, high CHO (55%)
Anderson et al. 1997 (50)	Diet =8 Diet + RT - 11	RCT 24 wks Age 38 to 41 yrs BMI 34 kgm-2	diet only 925 to 1500kcal/d	3d/wk supervised 24 wks 1-2 sets 8-12 RM 50 min; Nautilus and Cybex circuit exercises: bench press, lat pull-down, chest fly, shoulder press, leg extension, curl & press, hip extension, arm curls & extensions, sit-ups, back extension	NS decrease TB, LS, Hip BMD FN BMD 2.9% (diet), 3.9% (diet+ex), p<0.05 Wt loss -19.4kg (Diet) vs -16.6kg (Diet+Ex), NS FFM -2.8kg (Diet) vs -1.3kg (Diet+RT), NS FM -16.6kg (Diet) vs -15.3kg (Diet+RT), NS	DXA (Lunar DPX) Prescribed diet, controlled only wk 2 to 17 900 to 925kcal/d liquid meals + dinner 18 to 24wks add solid food
Postmenopausal women (no HRT)						
Campbell et al. 2009 (49)	Ex + diet =8 C =8	16 wk RCT (YSM not reported) BMI 29 kgm-2 Age = 68 Ca not reported 1g Protein/kg/d -500kcal/d	None	16 wk: 3d/wk, 2 sets 8 reps, 1 set 12RM. Leg extension, leg curl, leg press, chest press, arm pull extensions	Diet 2138kcal (C), 2212kcal NS FFM -1.6kg (C), -0.3kg (Ex) *p* = 0.05 Wt and FM both groups decreased (NS between groups)	BOD POD Harris Benedict x 0.7 times minus 500kcal/d Controlled diet, prepared

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Ryan et al. 1998 (54)	Diet = 15 Diet + Ex =15	6mo. Subject Preference for group (YSM not reported) BMI = 30.5 kgm-2 Age = 63 yrs	Walking/ jogged treadmills 3x/wk 6mo. 35 min with 10 min warm up/ cool down. >70% VO2max	None	Diet 1400-1500kcal both groups TB BMD -1.7% (Diet), -1.4% (Diet+Ex), NS LS BMD -1% (Diet), +1.4% (Diet+Ex), p=0.07 FN BMD -2.6% (Diet), +1.2% (Diet+Ex), p=0.01 Wt loss -7.4kg (Diet), -6.6kg (Diet+Ex), NS FFM -0.5kg (Diet), -0.7kg (Diet+Ex), NS FM -7kg (Diet), -5.8kg (Diet+Ex), NS	DXA (Lunar DPX-L) American Heart Association Step I diet 7d food records 250-250kcal/d deficit
Gallagher et al. 2000 (57)	Postmenopause (PM)=14 Ref=40 studies diet only weight loss Ballor and Poehlman 1994 (101)	16wk Prospective comparison to young obese (YSM not reported) women Age 63 yrs Ref age 37 yrs BMI 35.3 kgm-2 Ref BMI 33.8 kgm-2	diet only 1200 kcal/d 0.7g protein/kg/d	None	Diet 1200kcal/d TB BMD 0.02% (PM) Wt loss -9.6kg (PM) vs -10.6kg (Ref) FFM -2.1 kg (PM) vs -2.5kg (Ref) FM -7.4kg (PM) vs -6.8kg (Ref)	DXA (Lunar DPX) Prescribed diet, controlled
You et al. 2006 (102), Bopp et al. 2008 (60), Silverman et al. 2009 (55)	Diet Diet+High Intensity Ex (DHE) Diet+Low Intensity Ex (DLE)	20wk RCT (YSM not reported) Age 58 yrs BMI 33kgm-2	20wk: 3d/wk walking on treadmill Low intensity= 45-50% HHR 55min High intensity= 70-75% HHR 30min combined with diet 2800kcal/wk deficit (400kcal/d)	None	Diet 1288kcal/d NS groups Pro 0.62g/kg/g NS groups FN BMD +2.01%(DHE+DHL), NC (Diet), p=0.001 LS BMD NS groups Wt loss -10.8kg NS groups FFM -3.7kg NS groups FM -8kg NS groups	DXA (HOlogic Delphi QDR) Prescribed diet, controlled 350kcal/d deficit

Study	Subjects	Study Design	Aerobic Exercise Intervention	Resistance Exercise Intervention	Body Composition Changes	Body Composition Measurement
Exercise and Lactating Women						
McCrory et al. 1999 (74)	Diet = 22 Diet+Ex = 22 C = 23	RCT diet 35% deficit diet+Ex 35% deficit (60% diet, 40% Ex) BMI = 25kgm-2	10-12 –d 50-70% HRmax walking, jogging, low-impact aerobics, step-aerobics, bicycling, swimming, stair steppers, and stationary cycles	None	Wt loss Diet -1.9 kg (p<0.05 C) Diet+Ex -1.6 kg (p<0.05 C) FFM Diet -0.9 kg (p<0.05 C & Diet+Ex) Diet+Ex 0.0 kg (p<0.05 Diet) FM Diet -1.3 kg (p<0.05 C) Diet+Ex -1.6 kg (p<0.05 C) %BF lost Diet -0.9% (p<0.05 C & Diet+Ex) Diet+Ex -1.6% (p<0.05 C & Diet)	Hydrostatic weighing (*n* = 23) Bod Pod (*n* = 44)
Lovelady et al. 2000 (73)	Diet+Ex = 21 C =19	RCT BMI = 27-28 kgm-2	10 wks (4wks PP start) 45 min session 4x/wk (65-80% HRR) walking, jogging, aerobic dancing Diet 500 kcal/d deficit	None	Wt loss -4.8 kg (p<0.01) FFM -0.8 kg (NS) FM -4.0 kg (p<0.01) %BF lost -3.3% (p<0.01)	6-site skinfold (Lohman) Underwater weighing
O'Toole et al. 2003 (75)	Diet+Ex (DE)=21 Lifestyle (L) =19	RCT BMI=29.8 kgm-2 Age= 31 to 32 yrs 12 to 14 wks PP Mixed lactating and formula feeding women	12 wks to 1 year Specific individualized plan moderate intensity activity guided by HR	None	Diet 1918 (L) vs 1758 (DE), NS Wt loss –0.6kg (L) vs -5.6kg (DE), p<0.05 FM -1.7kg (L) vs. -5.9kg (DE), p<0.05	BodPod Harris Benedict * 1.3 activity factor + 500 lactation – 350kcal wt loss Goal 500kcal/d deficit DE= specific diet plan 3d food records

Ex = number of women in the exercise group; C = number of women in the control group (non-exercise); 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); YSM = years since menopause; HHR = heart rate reserve; HRmax = heart rate maximum; RT= resistance training; reps = repetitions; 1 RM = maximum weight lifted one-time; TB = total body; L2-L4 = lumbar spine; FN = femoral neck; FFM = fat-free mass; FM = fat mass; %BF = percent body fat; DXA = dual energy x-ray absorptiometry; DPA = dual-photon absorptiometry; NC = no change; (NS) = non-significant result compared to the control group, if significant *p* value present; HRT = hormone replacement therapy; Pro= protein; Ca=calcium; CHO=carbohydrate.

The intervention induced a significant amount of weight loss and decreased fat mass, without a significant change in fat free mass or lumbar spine bone mineral density. Similar results were seen with energy restriction and resistance training only intervention (49). Other studies have shown an increase in protein (>1g/kg body weight) and calcium (>1000mg/d) consumption to be protective of bone and fat-free mass during periods of weight loss (51,60-61), especially when coupled with resistance training exercise (49,52,62) [Table 2.3].

It is important to emphasize, the above studies investigated moderate reductions in energy intake with or without modest increases in energy expenditure. In studies that have investigated extremely low levels of energy intakes (405 to 1000 kcal/d) (63-65) or in studies with rapid weight loss (> 1 kg/week) during a short periods of time (less than three months) (66-67) have found significant reductions in bone density . One study reported a 15.6 kg weight loss over 10 weeks resulted in a total body BMD loss of 2.5% in women (63). Extreme weight loss methods (diet or gastric surgery) have also been shown to negatively impact BMD in men and women (65,68-72). A rapid weight reduction of 40 to 45 kg over the first year post-operatively, corresponded to BMD loss in the TB (3%), lumbar spine (3 to 7%), femoral neck (9 to 10%), and total hip (8 to 10%).

In fully breastfeeding overweight postpartum women, there are only two studies that have investigated the effects of weight loss on body composition, and no studies to date on the effects on BMD. Lovelady et al. (73) investigated the effects of a ten week, 500 calorie per day reduction in dietary intake plus aerobic exercise on body composition in overweight exclusively breastfeeding postpartum women. The diet plus exercise group lost more weight and fat mass compared to the control group. There were no statistical differences between changes in fat-free mass. McCrory et al. (74) compared the effects of a 35% diet deficit to a combined diet plus aerobic exercise deficit of 35% on body composition. Both groups lost weight, but the diet group lost more fat-free mass whereas the diet plus exercise group lost more fat mass. These two studies had no adverse affects on infant growth (weight or length) or on breast milk composition and volume (73-74) [Table 2.3].

Another study in postpartum women (breastfeeding and formula feeding) examined a structured diet and physical activity compared to a lifestyle intervention on weight retention (75). The study began around the 13th week postpartum and followed the women until one year postpartum. The structured diet group was prescribed a specific diet plan and individualized moderate exercise prescription. Both groups consumed around 1800 kcal/d, but the structured diet and physical activity group lost more body weight (-5.6 kg) and more weight from fat mass (-5.9 kg) compared to the lifestyle group [Table 2.3]. The study did not examine the effect of weight loss on BMD nor stratified the participants by infant feeding status. Additionally, the diet and exercise program was not defined.

In summary, moderate weight loss from a modest reduction of energy (500 kcal/d) leads to a reduction in fat mass while preserving fat-free mass and BMD. Additionally, an increase in protein and calcium may provide a protective effect on fat-free mass and bone. Extreme weight loss methods (severe energy restriction or surgical methods) decrease BMD regardless of exercise. Furthermore, moderate energy restriction in overweight lactating women is a safe method to promote weight loss without adverse effects on breastmilk or infant development. However, no studies have looked at the effect on BMD.

Hormonal Response during Lactation (Prolactin and Estradiol) and Effects on BMD

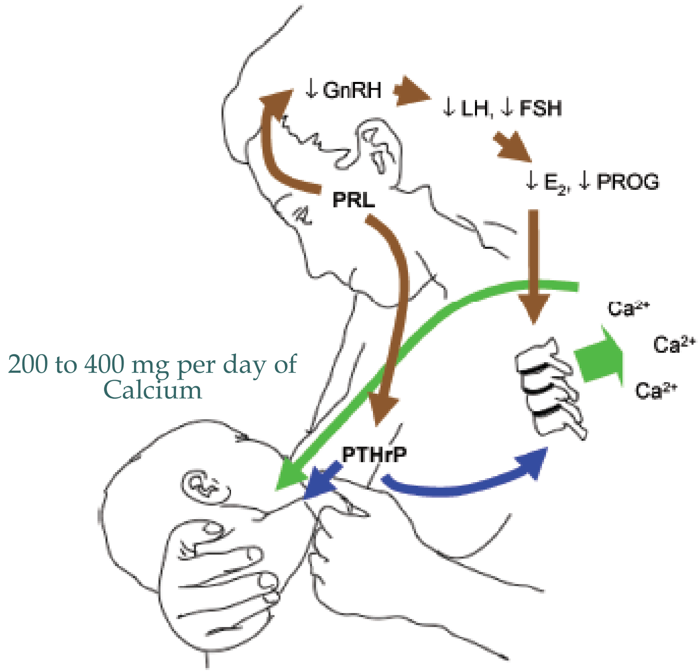
The primary functions of prolactin are to initiate breast development and maintain lactation. Prolactin levels rise 10 to 20 times above normal (<20 μg/L) during pregnancy, and in non-lactating women decline to normal levels by 3 to 4 weeks postpartum. Breastfeeding mothers maintain high levels of prolactin, which slowly decline over the course of lactation (Table 2.4). Suckling induces the release of prolactin from the anterior pituitary gland, which inhibits hypothalmic gonadotropin releasing hormone pulse center (Figure 2.1). The inhibition suppresses leutenizing hormone and follicle stimulating hormone leading to low estradiol (70-300 pmol/L) and progesterone levels (2). Additionally, prolactin and suckling stimulate the production and release of parathyroid hormone related protein (PTHrP) from the mammary glands.

Table 2.4. Estradiol and Prolactin Concentration during Lactation

Study	Subjects mean (SD)	Estradiol (pmol/L)	Prolactin (μg/L)	BMD during Lactation	Comments
Krebs et al, 1997 (18)	L = 26 NL = 8 (controls) Wean =15 Age 31 yrs Parity 1.7 (1) BMI 21.6 (2.0) kgm-2	2 wks 300 12 wks 150 20 wks 140 28 wks 150 Postwean. (15 mo.PP) 200	2 wks 140 12 wks 65 20 wks 50 28 wks 40 Postwean. (15 mo. PP) <20	**(L2-L4)BMD** 2 wks to 12 wks PP = -4% Postwean. return to baseline	E2 and Prolactin concentrations extrapolated from graphs (actually values were not reported). E2: RIA (Coat-A-Count) Prolacatin: IRMA-count BMD: DPA (DP3; Norland) *n*=10; DXA (DPX; Lunar) *n*=11; DPA and DXA *n*=14
Holmberg-Marttila et al, 2003 (8)	L = 32 Wean = 1 mo. resumption menses Age 31 yrs Mixed lactation (exclusive lactation avg. 3mo., duration 5.7(2.9) mo. *N*=11 at return of menses) Parity 1 to 4 Prev. lactation 10.6(6.3) mo.	12wks 100 Postmenses (5.7mo.) 130 1 yr post menses 110	Not measured	**(L2-L4) BMD** Delivery to menses: -1.8(4.3)%, p=0.02 1 yr F/U: 3.2(4.2)%, p<0.001 (full recv) **FN BMD** Delivery to menses: -3.1(4.2)%, p<0.001 1 yr F/U: -0.9(2.4)%, p=0.03 (partial recovery)	E2: RIA assay (Sorin Biomedica, Italy) BMD: DXA (XR-26, Norland)
Sowers et al, 1993, 1996, 1998 (14,25,76)	*N* = 100 stratified by lactation status and time (BF = providing 2/3rd of EER per kg of infant wt, partial BF and FF) Age 29.3 BMI 24.9	2 wks (*n*=88) 68 8 wks (*n*=75) 99 16 wks (*n*=70) 117 24 wks (*n*=64) 125 52 wks (*n*=2) 77 72 wks (*n*=0)	2 wks (*n*=88) 160 8 wks (*n*=75) 100 16 wks (*n*=70) 60 24 wks (*n*=64) 40 52 wks (*n*=2) 20 72 wks (*n*=0) 20	**LS** (BF ≥6mo.)-5.1% **FN** (BF≥6mo.) -4.8% Postwean. Return to baseline value	Prolactin concentrations extrapolated from graphs (actually values were not reported). E2: RIA (Pantex, Santa Monica, CA) Prolactin: two-site chemiluminometric immunoassay BMD: DXA (DPX-L; Lunar)
Ritchie et al, 1998 (20)	*N* = 14 (*N* =10 excl. BF, *N*=2 25% total milk vol; *N*=2 80% total milk vol.) Age 29.4(2.3); BMI 22.4(2.7) Duration of L 12(10) mo. Duration of PP amenorrhea 8(3) mo.	6-10wks 250 Postmenses [5(2)mo.] 440	Not measured	LS BMD: prepreg value to 6-10wks PP = -9% (p<0.001) Postwean. return to prepreg value	E2: RIA (Diagnostic Products Corp,LA) BMD: DXA (DPX; Lunar)

Study	Subjects mean (SD)	Estradiol (pmol/L)	Prolactin (μg/L)	BMD during Lactation	Comments
Little and Clapp, 1998 (11)	*N*=20 (C *n*=9, EX *n*=11.) Age: C 34(5)., EX 31(4), NS BMI C 26.1, EX 23.5, NS Parity= C 1(1). EX 2(1), NS EX = self-reported BF ≥ 3mo. PP.	EX 12wks 170.6 CG 12wks 158.4 (NS)	Not measured	**(L2-L4) BMD**: CG -5.4%, EX - 4.1%, NS **FN BMD**:CG -2.7%, EX - 2.8%, NS	E2: RIA (Diagnostic Products, LA) BMD: DXA (Lunar DPX) or (Hologic QDR 2000)

L = # of participants lactating; NL = # of participants not lactating; BMI = body mass index; BF = breastfeeding; EX = exercise; C = control; PP = postpartum; DPA = dual-photon absorptiometry; DXA = dual energy x-ray absorptiometry



GnRH, gonadatropin releasing hormone; LH, lutenizing hormone; FSH, follicle stimulating hormone; PROG, progesterone; PTHrP, parathyroid hormone related peptide; Ca^{2+}, calcium.

“ With kind permission from Springer Science+Business Media: Journal of Mammary Gland Biology and Neoplasia, Calcium and Bone metabolism during pregnancy and lactation, 2005, 113, Christopher S Kovacs, Figure 4: The role of the breast in controlling skeletal demineralization during lactation, (c) 2005.”

Figure 2.1. *Prolactin (PRL) and Estradiol (E2) Response during Lactation and the Effects on Bone* [adapted from Kovacs 2005 (2)]

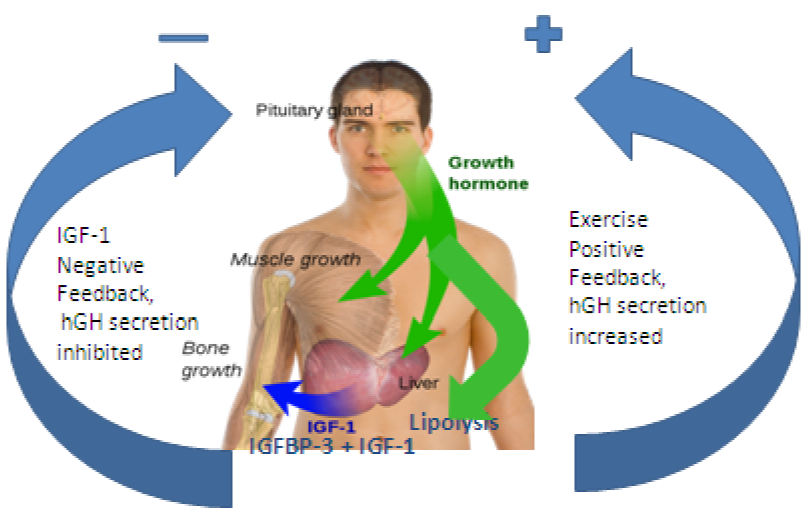
PTHrP, combined with systemically low levels of estradiol, up-regulate maternal bone resorption and increase renal conservation of calcium (2,9). The increased calcium in the blood stream is actively pumped into the breastmilk for the infant. This mechanism is different compared to postmenopausal women, who are also in an estrogen deficient state (0-100 pmol/L). The low levels of estradiol increase skeletal resorption and decrease parathyroid hormone which increases the renal conservation of calcium (2).

The peak rate of bone loss during lactation is 1-3% per month, whereas the rate of loss during menopause is 1-3% per year (1-2). The bone loss from six months of lactation is equivalent to 2 years of bone loss during menopause. Krebs et al. (18) followed 26 lactating women for 7 months, with 15 women returning at 15 months postpartum to examine changes in estradiol, prolactin and lumbar spine BMD. Levels of prolactin at 2 weeks postpartum were around 140 μg/L and gradually declined to less than 20 μg/L by 15 months postpartum. Estradiol levels at 2 weeks postpartum were still high from pregnancy (300 pmol/L), but declined and stabilized over the 7 months of lactation (150 pmol/L). By 15 months postpartum the women had resumed normal menses and levels of estradiol increased (200 pmol/L). During the first 3 months of lactation, a 4% loss was seen in lumbar spine BMD. Lumbar spine BMD levels returned to baseline values upon weaning and resumption of menses (15 months postpartum). Similar results were seen in other studies [Table 2.4] (8,11,20,76).

Lactation-induced bone loss is usually reversed with weaning (decrease in prolactin levels) and resumption of normal menses (increase in estradiol). The amount of lactation-induced bone loss may be related to milk volume (9), duration of lactation and postpartum amenorrhea (4). Additionally, not all women return to prepregnancy BMD levels after weaning and resumption of menses (8,15,17,20). Exercise in eumenorrheic women increase prolactin level, however the increase for prolactin during exercise is below the levels seen during lactation (77).

Hormonal Response from Chronic Exercise (GH, IGF-1, IGFBP-3) and Effects on BMD

The primary role of anabolic hormones, such as human growth hormone (hGH) and insulin-like growth factor-1 (IGF-1), are tissue growth and bone remodeling (Figure 2.2). hGH is released from the anterior pituitary gland into the bloodstream in a pulsatile manner under the regulatory control of hypothalamic somatostatin and hGH-releasing factor.



http://commons.wikimedia.org/wiki/File:Endocrine_growth_regulation.svg

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Figure 2.2. ***The Response of Human Growth Hormone (hGH), Insulin-like Growth Factor- 1(IGF-1), and Insulin-like Growth Factor Binding Protein-3 (IGFBP-3) During Exercise* [adapted with permission from (103)]**

Most anabolic actions are thought to be mediated through hGH-dependent production of insulin-like growth factors (IGF-1) and their associated binding proteins (IGFBP-3) (78-80). IGF-1 increases amino acid uptake by muscle tissues, increasing protein synthesis therefore increasing muscle mass (78). IGF-1 binds to receptors on osteoblasts to decrease bone resorption and promote bone remodeling through inhibition of the parathyroid and PTHrP receptors (81). IGF-1 is also involved in one of two negative feedback loops to inhibit further release of hGH from the anterior pituitary gland. Exercise counteracts the negative feedback to allow for continued secretion of hGH (79-80).

Acute bouts of aerobic and resistance exercise in eumenorrheic women have been shown to stimulate hGH production post exercise and may increase IGF-1 (82-83). However, the magnitude of hGH increase is related to duration and intensity of exercise (82-83) but continuous versus intermittent exercise was found to be equally effective (84). Kraemer et al. (85) found 6 sets of 10 repetition maximum (RM) squats increased the immunoreactive fraction (<30 kDa) of hGH but not the biological active fraction (30-60 kDa). In an earlier study, Kraemer et al. (83) found no significant increase in IGF-1 regardless of resistance protocol in nine eumenorrheic women. Additionally, there was no correlation between hGH and IGF-1.

Chronic aerobic exercise has shown to increase hGH in women depending on intensity of training (77,82,86). Circulation of IGF-1 levels may not increase with exercise training despite the increase in hGH secretion from the pituitary, but rather the increase may be localized to the muscle from an autocrine response (87). Weltman et al. (86) examined the effect of running 35 to 40 miles per week for one year on hGH levels in 21 untrained eumenorrheic women. The women who trained above lactate threshold increased hGH secretion and had an amplified pulsatile release of hGH at rest. Tworoger et al. (77) found no association between physical activity and IGF-1 and IGFBP-3 in premenopausal women. IGF-1 levels may increase in young women and may potentially be correlated to fat-free mass and maximal oxygen consumption, but more research is needed (82).

Chronic resistance training has little influence on resting levels of hGH in women regardless of age (82). Kraemer et al. (85) found a 24 week resistance program (6 sets 10 RM) had little effect on changing the immunoreactive fraction of hGH (<30kDa), but increased the circulating concentration of biologically active GH (30-60kDa). Additionally, resistance training has been found to increase IGFBP-3 levels, which helps protect IGF-1 from degradation, thus decreasing free IGF-1 (88).

There is a paucity of literature determining the effects of chronic aerobic and resistance training in women on anabolic hormones. The results are equivocal and may depend on a number of factors such as age, fat mass or fat-free mass, estradiol levels, and exercise stimulus (78-80,82-83). The role of diet may impact levels of serum IGF-1 and IGFBP-3 levels (89). In regards to postpartum women, there are no studies to date that have examined the effects of exercise on anabolic hormones. A chronic exercise program may increase hGH and IGF-1 and given the role in bone metabolism, may ultimately influence BMD in lactating women.

Use of *MyPyramid* for Dietary Counseling

The internet offers a valuable resource for promotion of healthy eating and web-based communication between the practitioner and client (90). The recent launch of *MyPyramid Menu Planner* (March 2008), *MyPyramid for Pregnancy and Breastfeeding for Moms* (August 2008), and recently in 2009 *MyPyramid Menu Planner for Moms* (a combination of the two previous sites) (91) offers a unique opportunity for internet based dietary counseling to help achieve a healthier diet.

MyPyramid Menu Planner for Moms interactively notes how well the diet meets the *MyPyramid* recommendations, both graphically and by text, through translation of foods into *MyPyramid* food groups (92). Based off menu modeling (93), *MyPyramid Menu Planner* provides suggestions on ways to meet recommended levels in areas where the diet falls short and tracks changes throughout a seven day period. It allows opportunity for a food and nutrition professional to determine whether a participant’s diet over a seven day period meets *MyPyramid* food group recommendations for their energy intake and food choices. Additionally, it allows for immediate tailoring of dietary counseling.

The American Dietetic Association recommends using a total diet approach for dietary counseling (94). Coupled with a focus on education of better choices within each of the *MyPyramid* food group versus overall servings (95), *MyPyramid Menu Planner for Moms* offers a unique approach to dietary counseling. To date there are no published studies that have used *MyPyramid Menu Planner* as a dietary counseling tool.

Summary of Literature Review

Lactation-induced bone loss is usually reversed with weaning and resumption of normal menses. However, BMD does not return to pre-pregnancy levels in all women. In addition, there is a concern that lactation-induced bone loss may increase a women's risk of osteoporosis during lactation or after menopause. The amount of bone loss may be related to milk volume, duration of lactation and postpartum amenorrhea making breastfeeding a safe feeding choice for the infant and the mother.

Weight bearing aerobic and resistance exercise may be protective of bone density and preserve lean body mass during periods of weight loss. However, further research is needed to investigate the effects of aerobic and resistance exercise in lactating postpartum women. Moderate energy restriction in overweight lactating women is a safe method to promote weight loss without adverse effects on breastmilk or infant development. Additionally, *MyPyramid Menu Planner for Moms* (96) offers a unique opportunity for internet based dietary counseling to help achieve a healthier diet.

Therefore the purpose of this research was twofold. The first study describes changes in markers of bone turnover and hormones and their association with changes in BMD in exercising breastfeeding women. The second study examines the effects of energy restriction and exercise on body composition (fat and lean mass, as well as BMD) in overweight lactating women, and the use of *MyPyramid Menu Planner for Moms* (96) for dietary counseling.

References

1. Kalkwarf H, Specker B. Bone mineral changes during pregnancy and lactation. *Endocrine* 2002; 17(1):49-53.

2. Kovacs CS. Calcium and bone metabolism during pregnancy and lactation. *J Mammary Gland Biol and Neo* 2005; 10(2):105-118.

3. Prentice A. Micronutrients and the bone mineral content of the mother, fetus and newborn. *J Nutr* 2003; 133(Suppl 2):1693S-1699S.

4. Kalkwarf HJ. Hormonal and dietary regulation of changes in bone density during lactation and after weaning in women. *J Mammary Gland Biol and Neo* 1999; 4(3):319-329.

5. Kulkarni B, Shatrugna V, Nagalla B, Kumar P, Rani K, Omkar A. Maternal weight and lean body mass may influence the lactation-related bone changes in young undernourished Indian women. *Br J Nutr* 2009; 101:1527-1533.

6. Food and Nutrition Board Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients)*, 2005. National Academy Press, Washington DC, pp. 107-264.

7. Chan SM, Nelson EAS, Leung S, Cheng J. Bone mineral density and calcium metabolism of Hong Kong Chinese postpartum women- A 1-y longitudinal study. *Eur J Clin Nutr* 2005; 59(7):868-876.

8. Holmberg-Marttila D, Sievanen H, Tuimala R. Changes in bone mineral density during pregnancy and postpartum: Prospective data on five women. *Osteo Int* 1999; 10:41-46.

9. Laskey M, Prentice A, Hanratty LA, Jarjou LM, Dibba B, Beavan SR, Cole TJ. Bone changes after 3 mo of lactation: Influence of calcium intake, breast-milk output, and vitamin D-receptor genotype. *Am J Clin Nutr* 1998; 67:685-692.

10. Lovelady C, Bopp MJ, Colleran HL, Mackie HK, Wideman L 2009 Effect of exercise training on loss of bone mineral density during lactation. *Med Sci Sports Exerc* 2009; 41(10):1902-1907.

11. Little K, Clapp J. Self-selected recreational exercise has no impact on early postpartum lactation-induced bone loss. *Med Sci Sports Exerc* 1998; 30(6):831-836.

12. Kolthoff N, Eiken P, Kristensen B, Nielsen SP. Bone mineral changes during pregnancy and lactation: A longitudinal cohort study. *Clin Sci* 1998; 94:405-412.

13. Lopez JM, Gonzalez G, reyes V, Campino C, Diaz S. Bone turnover and density in healthy women during breastfeeding and after weaning. *Osteo Int* 1996; 6:153-159.

14. Sowers M, Corton G, Shapiro B, Jannausch ML, Crutchfield M, Smith ML, Randolph JF, Hollis B. Changes in bone density with lactation. *JAMA* 1993; 269(24):3130-3135.

15. Drinkwater B, Chesnut C. Bone density changes during pregnancy and lactation in active women: A longitudinal study. *Bone and Miner* 1991; 14:153-160.

16. Affinito P, Tommaselli GA, Carlo CD, Guida F, Nappi C. Changes in bone mineral density and calcium metabolism in breastfeeding women: A one year follow-up study. *J Clin Endocrinol Metab* 1996; 81:2314-2318.

17. Cross N, Hillman L, Allen S, Krause G. Changes in bone mineral density and markers of bone remodeling during lactation and postweaning in women consuming high amounts of calcium. *J Bone Miner Res* 1995; 10(9):1312-1320.

18. Krebs NF, Reidinger CJ, Robertson AD, Brenner M. Bone mineral density changes during lactation: Maternal, dietary, and biochemical correlates. *Am J Clin Nutr* 1997; 65:1783-1746.

19. More C, Bhattoa HP, Bettembuk P, Balogh A. The effects of pregnancy and lactation on hormonal status and biochemical markers of bone turnover. *Eur J Obstet Gynecol Reprod Biol* 2003; 106:209-213.

20. Ritchie L, Fung E, Halloran B, Turnlund J, Van Loan M, Cann C, King J. A longitudinal study of calcium homeostasis during human pregnancy and lactation and after resumption of menses. *Am J Clin Nutr* 1998; 67:693-701.

21. Bassey E, Rothwell M, Littlewood J, Pye D. Pre- and Postmenopausal women have different bone mineral density responses to the same high-impact exercise. *J Bone Miner Res* 1998; 13(12):1805-1813.

22. More C, Bettembuk P, Bhattoa HP, Balogh A. The effects of pregnancy and lactation on bone mineral density. *Osteo Int* 2001; 12:732-737.

23. Laskey MA, Prentice A. Bone mineral changes during and after lactation. *Ostet Gynecol* 1999; 94:608-615.

24. Laskey M, Prentice A. Effects of pregnancy on recovery of lactational bone loss. *The Lancet* 1997; 349:1518-1519.

25. Sowers M, Hollis B, Shapiro B, Randolph J, Janney C, Zhang D, Schork A, Crutchfield M, Stanczyk F, Russell-Aulet M. Elevated parathyroid hormone-related peptide associated with lactation and bone density loss. *JAMA* 1996; 276(7):549-554.

26. Singh J, Schmitz K, Petit M. Effect of resistance exercise on bone mineral density in premenopausal women. *Joint Bone Spine* 2009; 76:273-280.

27. Vainionpaa A, Korpelainen R, Leppaluoto J, Jamsa T. Effects of high-impact exercise on bone mineral density: A randomized controlled trial in premenopausal women. *Osteo Int* 2005; 16:191-197.

28. Winters-Stone K, Snow C. Site-specific response of bone to exercise in premenopausal women. *Bone* 2006; 39:1203-1209.

29. Bocalini D, Serra A, dos Santos L, Murad N, Levy R. Strength training preserves the bone mineral density of postmenopausal women without hormone replacement therapy. *J Aging Health* 2009; 21(3):519-527.

30. Chien M, Wu Y, Hsu A, Yang R, Lai J. Efficacy of a 24-week aerobic exercise program for osteopenic postmenopausal women. *Calcif Tissue* 2000; 67:443-448.

31. Chubak J, Ulrich CM, Tworoger SS, Sorensen B, Yasui Y, Irwin ML, Stanczyk FZ, Potter JD, McTiernan A. Effect of exercise on bone mineral density and lean mass in postmenopausal women. *Med Sci Sports Exerc* 2006; 38(7):1236-1244.

32. Douchi T, Matsuo T, Uto H, Kuwahata T, Oki T, Nagata Y. Lean body mass and bone mineral density in physically exercising postmenopausal women. *Maturitas* 2003; 45:185-190.

33. Hagberg JM, Zmuda JM, McCole SD, Rodgers KS, Ferrell RE, Wilund KR, Moore GE. Moderate physical activity is associated with higher bone mineral density in postmenopausal women. *J Am Geriatr Soc* 2001; 49:1411-1417.

34. Kemmler W, Von Stengel S, Weineck J, Lauber D, Kalender W, Engelke K. Exercise effects on menopausal risk factors of early postmenopausal women: 3-year Erlangen fitness osteoporosis prevention study results. *Med Sci Sports Exerc* 2005; 37(2):194-203.

35. Cussler EC, Lohman TG, Going SB, Houtkooper LB, Metcalfe LL, Flint-Wagner HG, Harris RB, Teixeria PJ. Weight lifted in strength training predicts bone change in postmenopausal women. *Med Sci Sports Exerc* 2003; 35(1):10-17.

36. Engelke K, Kemmler W, DL, Beeskow C, Pintag R, Kalender W. Exercise maintains bone density at spine and hip EFOPS: A 3-year longitudinal study in early postmenopausal women. *Osteo Int* 2006; 17:133-142.

37. Stengel S, Kemmler W, Pintag R, Beeskow C, Weineck J, Lauber D, Kalender W, Engelke K. Power training is more effective than strength training for maintaining bone mineral density in postmenopausal women. *J Appl Physiol* 2005; 99:181-188.

38. Chilibeck P, Calder A, Sale D, Webber C. Twenty weeks of weight training increases lean tissue mass but not bone mineral mass or density in healthy, active young women. *Can J Physiol Pharmacol* 1996; 74:1180-1185.

39. Brooke-Wavell K, Jones P, Hardman A, Tsuritani I, Yamada Y. Commencing, continuing and stopping brisk walking: Effects on bone mineral density, quantitative ultrasound of bone and markers of bone metabolism in postmenopausal women. *Osteo Int* 2001; 12:581-587.

40. Kemmler W, Engelke K, Von Stengel S, Weineck J, Lauber D, Kalender W. Long-term four-year exercise has a postive effect on menopausal risk factors: The Erlangen Fitness Osteoporosis Prevention Study. *J Strength Cond Res* 2007; 21(1):232-239.

41. Iwamoto J, Takeda T, Ichimura S. Effect of exercise training and detraining on bone mineral density in postmenopausal women with osteoporosis. *J Orthop Sci* 2001; 6:128-132.

42. Larson-Meyer D. Effect of postpartum exercise on mothers and their offspring: A review of the literature. *Obes Res* 2002; 10(8):841-852.

43. Cullinen K, Caldwell M. Weight training increases fat-free mass and strength in untrained young women. *J Am Diet Assoc* 1998; 98:414-418.

44. Park S-K, Park J-H, Kwon Y-C, Kim H-S, Yoon M-S, Park H-T. The effect of combined aerobic and resistance exercise training on abdominal fat in obese middle-aged women. *J Physiol Anthropol* 2003; 22(3):129-135.

45. Velthuis M, Schuit A, Peeters P, Monninkhof E. Exercise program affects body composition but not weight in postmenopausal women. *Menopause* 2009; 16(4):777-784.

46. Lovelady C, Lonnerdal B, Dewey K. Lactation performance of exercising women. *Am J Clin Nutr* 1990; 52:103-109.

47. Dewey K, Lovelady C, Nommsen-Rivers L, McCrory M, Lonnerdal B. A randomized study of the effects of aerobic exercise by lactating women on breast-milk volume and composition. *N Engl J Med* 1994; 330:449-453.

48. Dewey K. Symposium: Maternal body composition, caloric restriction and exercise during lactation. *J Nutr* 1998; 128:386S-389S.

49. Campbell W, Haub M, Wolfe R, Ferrando A, Sullivan D, Apolzan J, Iglay H. Resistance training preserves fat-free mass without impacting changes in protein metabolism after weight loss in older women. *Obesity* 2009; 17(7):1332-1339.

50. Andersen RE, Wadden TA, Herzog RJ. Changes in bone mineral content in obese dieting women. *Metabolism* 1997; 46(8):857-861.

51. Layman DK, Evans E, Baum JI, Seyler J, Erickson DJ, Boileau RA. Dietary Protein and Exercise Have Additive Effects on Body Composition during Weight Loss in Adult Women. *J Nutr* 2005; 135(8):1903-1910.

52. Nakata Y, Ohkawara K, Dong J, Okura T, Tanaka K. Effects of additional resistance training during diet-induced weight loss on bone mineral density in overweight premenopausal women. *J Bone Miner Metab* 2008; 26:172-177.

53. Villareal DT, Fontana L, Weiss EP, Racette SB, Steger-May K, Schechtman KB, Klein S, Holloszy JO. Bone mineral density response to caloric restriction-induced weight loss or exercise-induced weight loss. *Arch Intern Med* 2006; 166:2502-2510.

54. Ryan AS, Nicklas BJ, Dennis KE. Aerobic exercise maintains regional bone mineral density during weight loss in postmenopausal women. *J Appl Physiol* 1998; 84(4):1305-1310.

55. Silverman N, Nicklas B, Ryan A. Addition of Aerobic Exercise to a Weight Loss Program Increases BMD, with an Associated Reduction in Inflammation in Overweight Postmenopausal Women. *Calcified Tissue International* 2009; 84(4):257-265.

56. Redman LM, Heilbronn LK, Martin CK, Alfonso A, Smith SR, Ravussin E. Effect of calorie restriction with or without exercise on body composition and fat distribution. *J Clin Endocrinol Metab* 2007; 92(3):865-872.

57. Gallagher D, Kovera AJ, Clay-Williams G, Agin D, Leone P, Albu J, Matthews DE, Heymsfield SB. Weight loss in postmenopausal obesity: no adverse alterations in body composition and protein metabolism. *Am J Physiol Endocrinol Metab* 2000; 279:E124-E131.

58. Lynch NA, Nicklas BJ, Berman DM, Dennis KE, Goldberg AP. Reductions in visceral fat during weight loss and walking are associated wiht improvements in VO2max. *J Appl Physiol* 2001; 90:99-104.

59. Ryan AS, Nicklas BJ, Berman DM, Dennis KE. Dietary restriction and walking reduce fat deposition in the midthigh in obese older women. *Am J Clin Nutr* 2000; 72:708-713.

60. Bopp MJ, Houston DK, Lenchik L, Easter L, Kritchevsky SB, Nicklas BJ. Lean Mass Loss Is Associated with Low Protein Intake during Dietary-Induced Weight Loss in Postmenopausal Women. *Journal of the American Dietetic Association* 2008; 108(7):1216-1220.

61. Riedt CS, Schlussel Y, von Thun N, Ambia-Sobhan H, Stahl T, Field MP, Sherrell RM, Shapses SA. Premenopausal overweight women do not lose bone during moderate weight loss with adequate or higher calcium intake. *Am J Clin Nutr* 2007; 85:972-980.

62. Hunter G, Byrne N, Sirikul B, Fernández J, Zuckerman P, Darnell B, Gower B. Resistance training conserves fat-free mass and resting energy expenditure following weight loss. *Obesity* 2008; 16(5):1045-1051.

63. Compston J, Laskey M, Croucher P, Coxon A, Kreitzman S. Effect of diet-induced weight loss on total body bone mass. *Clin Sci* 1992; 82(4):429-432.

64. Jensen L, Quaade F, Sørensen O. Bone loss accompanying voluntary weight loss in obese humans. *J Bone Miner Res* 1994; 9(4):459-463.

65. Hyldstrup L, Andersen T, McNair P, Breum L, Transbøl I. Bone metabolism in obesity: changes related to severe overweight and dietary weight reduction. *Acta Endocrinol* 1993; 129(5):393-398.

66. Fogelholm G, Sievanen H, Kukkonen-Harjula T, Pasanen M. Bone mineral density during reduction, maintenance and regain of body weight in premenopausal, obese women. *Osteo Int* 2001; 12:199-206.

67. Van Loan MD, Johnson HL, Barbieri TF. Effect of weight loss on bone mineral content and bone mineral density in obese women. *Am J Clin Nutr* 1998; 67(4):734-738.

68. Fleischer J, Stein EM, Bessler M, Badia MD, Restuccia N, Olivero-Rivera L, McMahon DJ, Silverberg SJ. The Decline in Hip Bone Density after Gastric Bypass Surgery Is Associated with Extent of Weight Loss. *J Clin Endocrinol Metab* 2008; 93(10):3735-3740.

69. Coates PS, Fernstrom JD, Fernstrom MH, Schauer PR, Greenspan SL. Gastric Bypass Surgery for Morbid Obesity Leads to an Increase in Bone Turnover and a Decrease in Bone Mass. *J Clin Endocrinol Metab* 2004; 89(3):1061-1065.

70. Johnson J, Maher J, Samuel I, Heitshusen D, Doherty C, Downs R. Effects of gastric bypass procedures on bone mineral density, calcium, parathyroid hormone, and vitamin D. *J Gastrointest Surg* 2005; 9(8):1106-1110.

71. Carrasco F, Ruz M, Rojas P, Csendes A, Rebolledo A, Codoceo J, Inostroza J, Basfi-fer K, Papapietro K, Rojas J, Pizarro F, Olivares M. Changes in bone mineral density, body composition and adiponectin

levels in morbidly obese patients after bariatric surgery. *Obesity Surgery* 2009; 19(1):41-46.

72. Vilarrasa N, Gómez J, Elio I, Gómez-Vaquero C, Masdevall C, Pujol J, Virgili N, Burgos R, Sánchez-Santos R, de Gordejuela A, Soler J. Evaluation of bone disease in morbidly obese women after gastric bypass and risk factors implicated in bone loss. *Obesity Surgery* 2009; 19(7):860-866.

73. Lovelady C, Garner K, Moreno K, Williams J. The effect of weight loss in overweight, lactation women on the growth of their infants. *N Engl J Med* 2000; 342(7):449-453.

74. McCrory M, Nommsen-Rivers L, Mole P, Lonnerday B, Dewey K. Randomized trial of the short-term effects of dieting compared with dieting plus aerobic exercise on lactation performance. *Am J Clin Nutr* 1999; 69:959-967.

75. O'Toole ML, Sawicki MA, Artal R. Structured diet and physical activity prevent postpartum weight retention. *J Womens Health* 2003; 12(10):991-998.

76. Sowers M, Zhang D, Hollis BW, Shapiro B, Janney CA, Crutchfield M, Schork MA, Stanczyk F, Randolph J. Role of calciotrophic hormones in calcium mobilization of lactation. *Am J Clin Nutr* 1998; 67:284-291.

77. Tworoger SS, Missmer SA, Eliassen AH, Barbieri RL, Dowsett M, Hankinson SE. Physical activity and inactivity in relation to sex hormone, prolactin, and insulin-like growth factor concentrations in premenopausal women. *Cancer Causes Control* 2007; 18:743-752.

78. Consitt LA, Copeland JL, Tremblay MS. Hormone responses to resistance vs. endurance exercise in premenopausal females. *Can J Appl Physiol* 2001; 26(6):574-587.

79. Godfrey RJ, Madgwick Z, Whyte GP. The exercise-induced growth hormone response in athletes. *Sports Med* 2003; 33(8):599-613.

80. Wideman L, Weltman JY, Hartman ML, Veldhuis JD, Weltman A. Growth hormone release during acute and chronic aerobic and resistance exercise. *Sports Med* 2002; 32(15):987-1004.

81. Zofkova I. Pathophysiological and clinical importance of insulin-like growth factor-1 with respect to bone metabolism. *Physiol Res* 2003; 52:657-679.

82. Consitt LA, Copeland JL, Tremblay MS. Endogenous anabolic hormone responses to endurance versus resistance training in women. *Sports Med* 2002; 32(1):1-22.

83. Kraemer WJ, Fleck SJ, Dziados JE, Harman EA, Marchitelli LJ, Gordon SE, Mello R, Frykman PN, Koziris LP, Triplett NT. Changes in hormonal concentrations after different heavy-resistance exercise protocols in women. *J Appl Physiol* 1993; 72(2):594-604.

84. Weltman A, Weltman JY, Watson Winfield D, Frick K, Patrie J, Kok P, Keenan D, Gaesser G, Veldhuis JD. Effects of continuous versus intermittent exercise, obesity, and gender on growth hormone secretion. *J Clin Endocrinol Metab* 2008; 93:4711-4720.

85. Kraemer WJ, Nindl BC, Marx JO, Gotshalk LA, Bush JA, Welsch JR, Volek JS, Splering BA, Maresh CM, Mastro AM, Hymer WC. Chronic resistance training in women potentates growth hormone in vivo bioactivity: Characterization of molecular mass variants. *Am J Physiol Endocrinol Metab* 2006; 291:E1177-E1187.

86. Weltman A, Weltman JY, Schurrer R, Evans WS, Veldhuis JD, Rogol AD. Endurance training amplifies the pulsatile release of growth hormone: Effects of training intensity. *J Appl Physiol* 1992; 72(6):2188-2196.

87. Frystyk J. Exercise and the growth hormone-insulin-like growth factor axis. *Med Sci Sports Exerc* 2010; 42(1):58-66.

88. Borst S, De Hoyos D, Garzarella L, Vincent K, Pollock B, Lowenthal D, Pollock M. Effects of resistance training on insulin-like growth factor-1 and IGF binding proteins. *Med Sci Sports Exerc* 2001; 33(4):648-653.

89. Flood A, Mai V, Pfieffer R, Kahle L, Remaley A, Rosen C, Lanza E, Schatzkin A. The effects of high-fruit and -vegetable, high-fiber, low-fat dietary intervention on serum concentrations of insulin, glucose, IGF-1 and IGFBP-3. *Eur J Clin Nutr* 2008; 62:186-196.

90. Juan WY, Gerrior S, Hiza H. *MyPyramid* tracker assesses food consumption, physical activity, and energy balance status interactively. *J Nutr Educ Behav* 2006; 38:S155-157.

91. US Department of Agriculture 2009. *MyPyramid*. Available at: http://www.mypyramidtracker.gov/planner/launchPage.aspx.

92. Wansink B. Project M.O.M.: Mothers and others and *MyPyramid*. *J Am Diet Assoc* 2008; 108(8):1302-1304.

93. Hornick BA, Krester AJ, Nicklas TA. Menu modeling with MyPyramid food patterns: Incremental dietary changes lead to dramatic improvements in diet quality of menus. *J Am Diet Assoc* 2008; 108(12):2077-2083.

94. Nitzke S, Freeland-Graves J. Position of the American Dietetic Association: total diet approach to communicating food and nutrition information. *J Am Diet Assoc* 2007; 107(7):1224-1232.

95. Bachman J, Reedy J, Subar A, Krebs-Smith S. Sources of food group intakes among the US population, 2001-2002. *J Am Diet Assoc* 2008; 108(5):804-814.

96. US Department of Agriculture 2009. *MyPyramid for pregnancy and breastfeeding.* Available at: http://www.mypyramidtracker.gov/planner/launch.asp.

97. Kalkwarf HJ, Specker B. Bone mineral loss during lactation and recovery after weaning. *Obstet Gynecol* 1995; 86(1):26-32.

98. Bowen J, Noakes M, Clifton P. Effect of calcium and dairy foods in high protein, energy-restricted diets on weight loss and metabolic parameters in overweight adults. *Int J Obes* 2005; 29:957-965.

99. Bowen J, Noakes M, Clifton PM. A High Dairy Protein, High-Calcium Diet Minimizes Bone Turnover in Overweight Adults during Weight Loss. *J Nutr* 2004; 134(3):568-573.

100. Thorpe MP, Jacobson EH, Layman DK, He X, Kris-Etherton PM, Evans EM. A Diet High in Protein, Dairy, and Calcium Attenuates Bone Loss over Twelve Months of Weight Loss and Maintenance Relative to a Conventional High-Carbohydrate Diet in Adults. *J Nutr* 2008; 138(6):1096-1100.

101. Ballor D, Poehlman E. Exercise-training enhances fat-free mass preservation during diet-induces weight loss: a meta-analytical finding. *Int J Obes* 1994; 18:35-40.

102. You T, Murphy KM, Lyles MF, Demons JL, Lenchik L, Nicklas BJ. Addition of aerobic exercise to dietary weight loss preferentially reduces abdominal adipocyte size. *Int J Obes* 2006; 30(8):1211-1216.

103. Häggström M 2009. Description Endocrine growth regulation.svg English: Main pathway in growth regulation by the endocrine system, mediated by growth hormone and insulin-like growth factor 1 (IGF-1), Template talk:Häggström diagrams ed. Wikipedia:Growth hormone#Functions of GH.

CHAPTER III

CHANGES IN MARKERS OF BONE TURNOVER AND HORMONES AND THEIR ASSOCIATION WITH CHANGES IN BONE MINERAL DENSITY IN EXERCISING BREASTFEEDING WOMEN

(formatted for publication in the Journal of Bone Mineral Research)

Introduction

Approximately 10 million Americans have osteoporosis, of which 8 million are women (1). Additionally, one out of two women over the age of 50 will have an osteoporotic-related fracture in their lifetime. An estimated 1.5 million fractures that occur annually: over 300,000 in the hip and 700,000 in the spine. Direct medical costs for osteoporotic-related fractures are as much as $19 billion per year (2005 dollars). By 2025 experts predict costs to rise to approximately $25.3 billion (1). Improving bone health earlier in life may help reduce the financial burden and improve quality of life in later adulthood.

Lactation is a time of rapid bone loss due to hyperprolactinemia, amenorrhea, and increased bone turnover. During peak lactation women transfer approximately 200 mg of calcium per day into breast milk (2-4). In order for the body to meet the extra demands for calcium during lactation, bone resorption increases, which increases calcium in the blood to be actively pumped into the breast milk for the infant (3-4). This loss of maternal calcium over a six-month period is equivalent to approximately a 4% loss in skeletal reserve with 1-10% bone density lost at trabecular rich sites (lumbar spine and hip) (5). Rapid decreases in bone measured by changes in bone mineral density (BMD) or an increase in biochemical markers of bone turnover may indicate fracture risk. An increase in bone markers (resorption and formation) are a more sensitive indicator o bone remodeling sites than changes in BMD measured by dual energy x-ray absorptiometry (DXA) (6).

Lactation-induced bone loss is usually reversed with weaning (decrease in prolactin levels), resumption of normal menses (increase in estradiol), and elevated bone formation with normal bone resorption, making breastfeeding a safe feeding choice for the infant and the mother (3,7-10). However, there is a concern that lactation-induced bone loss may increase a women's risk of osteoporosis during lactation or after menopause; particularly in women with low bone status prior to pregnancy such as adolescent mothers or women who have their children later in life (11-12).

Weight bearing exercise in non-pregnant, non-lactating women with normal estrogen status has been shown to increase BMD in the lumbar spine and hip by increased mechanical stress on bones (13-15). Studies in postmenopausal women (not on hormone replacement therapy) found weight bearing aerobic and resistance exercise to be protective of bone density (14,16-18). Exercises need to be site specific and direct force into the bone to induce bone growth (17,19-22).

There is limited research on the benefits of exercise or physical activity on bone density in women during lactation. To date, three published studies have directly addressed exercise during the postpartum period with respect to attenuation of lactation-induced bone loss (23-25). The changes in bone density observed in two of the studies (23-24) were similar to bone density changes reported in the literature for non-exercising lactating women (26-30). However, both studies were less than 3 months in length and lacked a structured exercise intervention. The third study (25), reported attenuation of the loss of lumbar spine BMD with a 16 week walking and resistance exercise program. No effect was seen in total body or hip BMD.

The results of studies determining the effects of chronic aerobic and resistance training in women on anabolic hormones are equivocal and may depend on a number of factors such as age, fat mass or fat-free mass, estradiol levels, and exercise stimulus (31-35). Acute bouts of aerobic and resistance exercise in eumenorrheic women have been shown to stimulate human growth hormone (hGH) production post exercise and may increase insulin-like growth factor-1 (IGF-1) (31,35). However, the magnitude of hGH increase is related to duration and intensity of exercise (31,35-36). Chronic aerobic exercise has been shown to increase hGH in women depending on intensity of training and IGF-1 levels may or may not be affected (31,37-38). In regards to postpartum women, there are no studies to date that have examined the effects of exercise on anabolic hormones. A chronic exercise program may increase hGH and IGF-1, and given their roles in bone metabolism, may ultimately influence BMD in lactating women.

We previously reported that exercise training resulted in significant attenuation of lactation induced bone loss in lumbar spine BMD, compared to a sedentary lifestyle (25). Further expanding on the results previously reported, the first aim of this paper was to describe the changes in dietary intake, bone turnover markers, hormones related to lactation and exercise, and bone (density, content, and area) during lactation in women whom had undertaken resistance exercise as compared to sedentary controls. The second aim was to determine if exercise, dietary intake, bone turnover markers, and hormones significantly predict changes in BMD.

Methods

Participants

Participants were recruited through prenatal classes and flyers posted at local obstetrician's offices. To be eligible for the study, women were between the ages of 25 to 40, had a self-reported body mass index (BMI) between 20 and 30 kg/m^2, were fully breastfeeding (< 4 oz of formula given to the infant only on occasion), sedentary for the past 3 months (< 3 weekly sessions of moderate aerobic activity), non-smokers, and had a singleton birth. Exclusion criteria for the study were delivery by cesarean section, have medical complications where exercise was contraindicated, or a disease that would affect hormone levels. All eligible participants signed a written informed consent and obtained medical clearance prior to admission into the study (Appendix A). Sample size was based on previous studies that examined bone loss during lactation (23-24). A final sample size of 20 (10 per group) was estimated to provide power to detect a 10% difference in change in lumbar spine BMD between groups.

Randomization into either the intervention group or control group occurred upon the completion of all baseline measurements. Randomization was stratified by parity, since higher prolactin levels are likely in primiparous compared to multiparous women. The study protocol was approved by the Institutional Review Board of The University of North Carolina at Greensboro.

Laboratory measurements at 3$\pm$1 (baseline) and 21$\pm$1 (endpoint) weeks postpartum included: height, weight, blood draws for hormones and bone turnover markers, cardiovascular fitness testing, two 24-hour dietary recalls, bone density, and body composition. Predicted maximal oxygen consumption (VO_2max) was determined using a submaximal treadmill test- modified Balke protocol (39). Maximal strength was determined using the 1-repetition maximum method for the ten strength exercises used for the intervention. Dietary recalls were determined by two 24-hour recalls over the telephone using the Nutrient Data System for Research (NDSR, University of MN) software. Bone area, mineral concentration and density were measured using dual-energy x-ray absorptiometry (DXA, Delphi by Hologic, Version 12.3, Bedford, MA). A detailed description of the laboratory measurements, dietary recall, and DXA protocol was described previously (25).

Assessment of Bone Turnover Markers and Hormones

Serum and urine samples were collected at baseline and endpoint for analysis of bone turnover markers and hormones. A trained phlebotomist drew blood at the same time each morning after an overnight fast to control for diurnal variation. Serum samples were frozen (-70^{o}C) until analyzed. Urine (second void) was collected in the morning on the day of the visit to the lab into a sterile collection cup. Urine was frozen at -70^{o}C until analyzed.

Urine was collected for analysis of pyridinium crosslinks (PYD) [deoxypyridinoline and pyridinoline], a bone resorption marker (Metra PYD EIA kit, Quidel Corporation, San Diego, CA). Pyridinium crosslinks were corrected for urine concentration by measurement of creatinine (mmol/L), which was measured by a standard colorimetric (alkaline picric acid) assay (Oxford Biomedical Research, Oxford, MI). Serum was used to analyze bone-specific alkaline phosphatase (BAP), a bone formation marker (Metra BAP EIA kit, Quidel Corporation, San Diego, CA).

Serum prolactin, estradiol, human growth hormone (hGH), insulin like growth factor-1 (IGF-1) and insulin-like growth factor binding protein-3 (IGFBP-3) were quantified by enzyme-linked immunosorbent assays (ELISA) (prolactin and estradiol- Alpco Diagnostics, Salem, NH; hGH- Diagnostic Systems Laboratory, Webster, TX; IGF-1 and IGFBP-3 Immunodiagnostics Systems Limited, UK). All samples were thawed once and analyzed in duplicate. Additionally, samples for both time points for each participant were analyzed in the same assay to eliminate inter-assay variability.

Study Intervention

Participants walked briskly for 15 minutes initially, then gradually increased their duration to 45 minutes at an intensity of 65-80% of predicted heart rate maximum, three days per week. The intervention also included three days per week of a progressive resistance exercise program. Research assistants traveled to the mother's home to help with childcare and the exercise protocol (Appendix A). The control group was asked to refrain from structured exercise and both groups were instructed to maintain their normal dietary intake. Both groups received multivitamin supplements that contained 100% of the RDA, including 400 IU of vitamin D and 400 mcg of folic acid (Appendix A). No mineral supplements were provided and participants did not consume any other supplements.

Statistical Analysis

Data were analyzed using JMP software (v.6.0.0 SAS Institute Cary, NC). Student's t-test was used to test significance between the control and exercise group for baseline characteristics. Repeated measures analysis of variance (RMANOVA) was used to determine differences in dietary intake (energy, protein, calcium, vitamin D, and macronutrient composition), bone turnover markers (PYD and BAP), hormones (estradiol, prolactin, hGH, IGF-,1 and IGFBP-3), and bone (BMD, bone mineral content- BMC, and area) between groups during the 16 week study. Results are reported as mean (standard deviation-SD), significance set at $p < 0.05$.

In order to determine if exercise, parity, dietary intake, bone turnover markers, and hormones were related to changes in BMD (total body, lumbar spine, and hip), bivariate analysis was performed. Then stepwise regression was performed to determine significant predictors for change in BMD (total body, lumbar spine, and hip), controlling for parity (primi or multi) and baseline values for BMD (total body, lumbar spine, and hip, respectively). The independent variables used to predict changes in BMD were group (control or exercise), dietary intake, changes in bone turnover markers (PYD and BAP), and changes in hormones (estradiol, prolactin, hGH, IGF-1, and IGFBP-3). Independent variables and covariates with $p > 0.10$ were removed and a final model was constructed using standards of least squares. The final significance was $p < 0.05$.

Results

Twenty-four fully breastfeeding women completed baseline measurements [3.6 (0.6) weeks postpartum] and were randomized, stratified by parity, to receive either a 16-week aerobic and resistance exercise program (exercise *n*=11) or minimal care (control *n*=13). During the 16-week study, four women dropped out of the study (exercise *n*=1; control *n*=3) because they returned to work and were no longer able to fully breastfeed. Ten women in each group completed the endpoint measurements [20.8 (1.3) weeks postpartum]. At baseline, the mean age of the control group was 31.6 (2.8) years with a body mass index (BMI) of

24.8 (2.9) kg/m^2 compared to 31.1 (3.0) years with a BMI of 26.1 (3.3) kg/m^2 for the exercise group. There were 6 multiparous and 4 primiparous women in the control group and five of each in the exercise group. There were no significant differences in baseline characteristics (pre-pregnancy weight, age, BMI, and parity) between groups. Baseline characteristics were not statistically different between the four women who did not complete the 16-week study compared to the 20 women who did complete the study. All of the women were Caucasian, except for the two who were African American and Asian.

Changes in Dietary Intake

Both groups significantly reduced energy intake during the 16-week study, $p = 0.005$ (see Table 3.1). This resulted in a weight loss of -3.5 (1.6) kg in the control group and -3.6 (2.5) kg in the exercise group (non-significant between groups, $p = 0.9$). There were no significant differences between groups for reported intakes of energy, protein, calcium, and vitamin D. None of the women reported use of calcium supplements during the intervention. However, there was a significant difference in percent macronutrient composition between the two groups. The control group had a higher percentage of energy from carbohydrates at baseline [52.6 (5.9)%] and a lower percentage of carbohydrates at endpoint [45.5 (7.2)%], $p = 0.03$, compared to the exercise group [51.3 (8.1)% and 51.5 (7.4)%, respectively]. Percentage of energy from protein was lower at baseline and higher at endpoint, $p = 0.005$, in the control group compared to the exercise group. The percentage of energy from fat remained the same in both groups.

Table 3.1. ***Reported Dietary Intake of Exercising and Sedentary Groups***

	Control Group		Exercise Group	
	Baseline (*n*=10)	Endpoint (*n*=10)	Baseline (*n*=10)	Endpoint (*n*=10)
Energy				
kcal [a]	2112 (510)	1690 (375)	2109 (556)	1923 (394)
kcal/kg [a]	31.0 (6.6)	26.0 (3.0)	31.3 (9.0)	30.6 (9.0)
Percent Energy From				
Carbohydrate [b]	52.6 (5.9)	45.5 (7.2)	51.3 (8.1)	51.5 (7.4)
Protein [b]	14.3 (2.6)	19.1 (3.2)	16.8 (4.2)	15.7 (3.6)
Fat	34.8 (4.5)	36.9 (4.8)	33.3 (5.3)	34.1 (5.8)
Protein				
g	74.0 (15.6)	78.9 (13.2)	86.6 (20.0)	75.3 (23.5)
g/kg	1.1 (0.2)	1.2 (0.2)	1.3 (0.3)	1.2 (0.4)
Calcium(mg)	1125 (380)	949 (352)	1360 (555)	1209 (563)
Calcium : Protein Ration	15.2 (3.5)	12.2 (4.5)	15.8 (6.1)	15.3 (5.3)
Vitamin D (mcg)	4.3 (2.1)	4.5 (1.4)	6.3 (3.1)	6.4 (3.9)

Mean (SD)
[a] Significantly decreased over time, $p<0.05$, RMANOVA
[b] Significantly different between groups, $p<0.05$, RMANOVA

Changes in Bone Turnover Markers and Hormones

Data for bone turnover markers (PYD and BAP), lactation hormones (prolactin and estradiol) and the hormones affected by exercise (GH, IGF-1, and IGFBP-3) for the control and exercise group at baseline and endpoint are presented in Table 3.2. PYD levels decreased significantly over time in both the control and exercise group ($p = 0.0004$); whereas, BAP increased in the control group and decreased in the exercise group. This was significant over time ($p = 0.03$), but not by group ($p = 0.08$). The ratio of BAP: PYD increased in both groups significantly over time, $p = 0.002$, but was not different between the groups ($p = 0.7$).

Prolactin levels decreased significantly in both groups during the 16-week intervention [control group -93.0 (62.2) μg/L and exercise group -73.1 (52.4) μg/L], $p = 0.0001$. Estradiol levels were not significantly different over time or between groups ($p = 0.1$). Two women (one in each group) resumed their menses during the intervention. Additionally, three women in the control group and five in the exercise group started hormonal birth control (progesterone-only pill or IUD).

After the intervention, GH levels in the exercise group increased [2.0 (5.6) μg/L] whereas the control group decreased [-1.2 (3.1) μg/L]; however, the difference was not significant between groups or over time ($p = 0.1$). IGF-1 and IGFBP-3 levels remained stable in both groups.

Table 3.2. ***Bone Turnover Markers and Hormones of Exercising and Sedentary Groups***

	Control Group		Exercise Group	
	Baseline (n=10)	Endpoint (n=10)	Baseline (n=10)	Endpoint (n=10)
BAP (U/L) [a]	25.1 (8.6)	28.3 (7.0)	32.0 (6.6)	31.6 (7.9)
PYD (nmol/mmol creatinine) [a]	89.0 (39.5)	41.7 (17.1)	77.2 (35.6)	33.8 (13.5)
BAP:PYD [a]	0.3 (0.1)	0.8 (0.3)	0.5 (0.2)	1.0 (0.3)
Estradiol (pmol/L)	150.6 (68.0)	141.8 (94.4)	88.5 (35.3)	124.6 (56.4)
Prolactin (μg/L) [a]	160.0 (75.7)	67.0 (29.1)	135.9 (45.5)	62.8 (30.1)
hGH (μg/L)	2.2 (2.7)	1.0 (1.6)	2.0 (2.7)	4.0 (4.7)
IGF-1 (μg/L)	93.6 (14.2)	106.1 (31.2)	104.9 (15.8)	108.8 (23.5)
IGFBP-3 (μg/L)	3797 (408)	3922 (1048)	4274 (1631)	4307 (2225)

BAP = Serum Bone-specific alkaline phosphatase; PYD = urine pyridinium crosslinks; hGH = human growth hormones; IGF-1 = insulin-like growth factor-1; IGFBP-3 = insulin-like growth factor binding protein 3

Mean (SD)

[a] Significantly different over time, $p<0.05$, RMANOVA

Changes in Bone

The 16-wk exercise intervention was successful in attenuation of the loss of lumbar spine BMD in the exercise group compared to the control group (-4.8% vs. -7.0%, $p = 0.01$). Both groups significantly decreased total body BMD [control group -0.8 (0.8)% and exercise group -0.6 (1.2)%, $p = 0.03$] and total hip BMD [control group -2.2 (2.9)% and exercise group -2.8 (2.4)%, $p = 0.02$] during the 16-week exercise intervention (see Table 3.3). Bone mineral content (BMC) decreased significantly over time in both the total body ($p = 0.007$) and lumbar spine ($p < 0.001$). There was no difference in hip BMC over time or between groups. However, the control group lost more lumbar spine BMC compared to the exercise group [-7.1 (2.2)% versus -4.0 (1.9)%, respectively, $p = 0.004$]. There were no significant changes in area for the total body, lumbar spine, or hip.

Bivariate Relationships

Four-day averages (2 days at baseline and 2 days at endpoint) of dietary intake (energy, protein, calcium, and vitamin D) were used to determine bivariate relationships. The four-day average dietary calcium intake was highly correlated with the 4-day average dietary protein intake ($R^2 = 0.75$, $p = 0.0001$), 4-day average dietary energy intake ($R^2 = 0.62$, $p = 0.003$), and 4-day average dietary vitamin D intake ($R^2 = 0.92$, $p < 0.0001$). Since the 4-day average dietary calcium intake was highly correlated with other dietary intake variables and to reduce the number of predictor dietary variables, only the four-day average dietary calcium intake was used to determine bivariate relationships with bone and in the prediction model. The 4-day average dietary calcium intake was not significantly different between the control group [1037 (279) mg] and exercise group [1285 (503) mg].

Table 3.3. ***Bone Mineral Density of Exercising and Sedentary Groups***

	Control Group		Exercise Group	
	Baseline (*n*=10)	Endpoint (*n*=10)	Baseline (*n*=10)	Endpoint (*n*=10)
Total Body				
BMD (g/cm2) [a]	1.070 (0.091)	1.061 (0.085)	1.094 (0.079)	1.087 (0.071)
BMC (g) [a]	2093 (85)	2064 (85)	2105 (90)	2076 (92)
Area (cm2)	1954 (51)	1943 (53)	1919 (46)	1904 (50)
Lumbar Spine				
BMD (g/cm2) [b]	1.071 (0.113)	0.996 (0.104)	1.053 (0.129)	1.002 (0.120)
BMC (g) [b]	62 (3)	58 (3)	59 (4)	57 (3)
Area (cm2)	58 (2)	58 (2)	56 (2)	56 (2)
Total Hip				
BMD (g/cm2) [a]	0.952 (0.116)	0.929 (0.098)	0.957 (0.099)	0.931 (0.098)
Hip BMC (g)	30 (2)	30 (1)	29 (1)	29 (1)
Hip Area (cm2)	32 (1)	32 (1)	31 (1)	31 (1)

BMD = bone mineral density; BMC = bone mineral content.
Mean (SD)
[a] Significantly decreased over time, $p<0.05$, RMANOVA
[b] Significantly different over time and between groups, $p<0.01$, RMANOVA

Four-day average dietary calcium intake and changes in total body BMD were significantly correlated ($R^2 = 0.28$, $p = 0.02$). The correlation between changes in estradiol and changes in total body BMD ($R^2 = 0.28$, $p = 0.02$) was also significant. There were no other significant bivariate correlations between the other predictor variables and changes in total body, lumbar spine, or hip BMD.

Prediction Model

Models were constructed to determine significant predictors of change in total body, lumbar spine, and hip BMD, controlling for parity (primi or multi) and baseline values for total body, lumbar spine, and hip BMD, respectively (see Table 3.4). The independent variables used to predict change were group (exercise or control), four day average dietary calcium intake, change in PYD, change in BAP, change in prolactin, change in estradiol, change in hGH, change in IGF-1, and change in IGFBP-3.

While controlling for parity (partial $R^2 = 0.1$, $p = 0.05$) and baseline total body BMD (partial $R^2 = 0.3$, $p = 0.004$), 4-day average dietary calcium intake (partial $R^2 = 0.25$, $p = 0.006$), change in estradiol (partial $R^2 = 0.06$, $p = 0.02$) and IGF-1 (partial $R^2 = 0.07$, $p = 0.04$) were significant predictors of change for total body BMD ($R^2 = 0.82$, $p = 0.0003$). Higher calcium intake, increase in estradiol and IGF-1 levels predicted a gain in total body BMD. After controlling for parity (partial $R^2 = 0.12$, $p = 0.01$), exercise (partial $R^2 = 0.33$, $p = 0.003$) and change in BAP (partial $R^2 = 0.23$, $p = 0.01$) accounted for 75% of the variability of change in lumbar spine BMD ($R^2 = 0.75$, $p = 0.0002$). Exercise and an increase in bone formation predicted a gain in LS BMD.

Table 3.4. Multiple Regression Equations to Predict Changes in BMD[a]

Predictors	Change in TB BMD (g/cm^2) β coefficient (SE)	Change in LS BMD (g/cm^2) β coefficient (SE)	Change in Hip BMD (g/cm^2) β coefficient (SE)
Intercept	0.0348 (0.0201)	-0.0328 (0.0297)	0.0832 (0.0465)
Group:			
control (reference)	-	0	-
exercise	-	**0.0294 (0.0062)** [d]	-
Reference Group *			
4d avg dietary Ca2+ intake (mg/d)	**1.76E-05 (3.91E-060.0)** [c]	-	-
Change in BAP (U/L)	-	**0.0021 (0.0007)** [c]	-
Change in Estradiol (pmol/L)	**6.68E-05 (2.47E-05)** [b]	-	-
Change in hGH (μg/L)	-0.0006 (0.0003)	-	-
Change in IGF-1 (μg/L)	**0.00015 (6.43E-05)** [b]	-	-
Covariates			
Parity:			
primiparous(reference)	0	0	0
multiparous	**0.0062 (0.0028)** [b]	**0.0156 (0.0056)** [c]	**0.0214 (0.001)** [b]
Baseline TB BMD (g/cm2)	**-0.0634 (0.0182)** [c]	-	-
Baseline LS BMD (g/cm2)	-	-0.0536 (0.0264)	-
Baseline Hip BMD (g/cm2)	-	-	**-0.1256 (0.0485)** [b]

Ca^{2+} = calcium; BAP = serum bone-specific alkaline phosphatase; hGH = human growth hormones; IGF-1 = insulin-like growth factor-1BMD = bone mineral density; TB = total body; LS = lumbar spine.

[a] results are shown only for variables with $p < 0.1$ for the final model.
Significant effects in **bold**: [b] = p <0.05, [c] = p < 0.01, [d] = p < 0.001

*Reference values equal means of total sample (n = 20): 4d avg dietary Ca^{2+} intake = 1161 mg/d; Change in BAP = 1.444 U/L; Change in Estradiol = 13.64 pmol/L; Change in hGH = 0.363 μg/L; Change in IGF-1 = 8.24 μg/L; baseline TB BMD = 1.0815 g/cm^2; baseline LS BMD = 1.0621 g/cm^2; baseline Hip BMD = 0.9548 g/cm^2.

After controlling for parity (partial $R^2 = 0.16$, $p = 0.05$) and baseline hip BMD (partial $R^2 = 0.22$, $p = 0.02$), there were no other significant predictors of change for hip BMD ($R^2 = 0.38$, $p = 0.02$). Change in prolactin and PYD were not significant predictors for change in BMD in the total body, lumbar spine, or hip.

Discussion

This was the first study to describe and compare the changes in bone turnover markers, hormones, and BMD in exercising and sedentary women during lactation. Although all participants were asked not to change their normal dietary habits during the 16 week study, both groups reduced their energy intake, which was reflected in the decrease in weight. Calcium and protein intake in both groups remained stable during the 16 week study with no differences between groups. The four day average dietary calcium (1161 mg/d) intake for both groups exceeded the recommended amount of 1000 mg per day. Additionally, none of the participants reported use of calcium supplements during the intervention. Despite adequate calcium intake, both groups lost BMD in both the lumbar spine and hip. These results are comparable to other studies examining the relationship of calcium intake and BMD in non-exercising lactating women (24,26,28,30,40).

In addition to a higher dietary intake of calcium, greater increase in estradiol and IGF-1 levels were protective of total BMD loss during lactation when controlling for parity and baseline values of total BMD. Similar results were reported in a study examining bone calcium turnover in women with low calcium diets (41). They also found higher calcium intake and higher levels of IGF-1 protective against bone loss during lactation.

During the third trimester of pregnancy, bone resorption levels are elevated and bone formation levels are depressed in order to provide minerals to the growing fetus (42-44). Bone resorption levels rapidly decrease in the postpartum period with a slower increase in bone formation levels, ultimately returning to the pre-pregnancy balance (42-44). Lactation induced amenorrhea has been associated with low bone formation levels and elevated bone resorption levels (10). During the first few months of lactation, the hypoestrogen state has a specific influence on bone turnover by reducing levels of markers bone formation. Conversely, higher parity and a history of long duration of previous lactation were associated with lower bone turnover (10).

Weight bearing exercise may have a positive effect on increasing markers of bone formation and lowering markers of bone resorption (45-49). Changes in BAP and exercise were positive significant predictors of change in lumbar spine BMD when controlling for parity. Bone loss was attenuated at the lumbar spine in the exercise group, despite BAP levels remaining stable. However, the ratio of BAP to PYD increased, potentially indicating a slowing of overall bone turnover. Additionally, the exercise group consumed a higher level of calcium (although not statistically significant), which may help preserve bone mass and turnover during periods of weight loss (50-51).

Changes in anabolic hormones (hGH, IGF-1, and IGFBP-3) during lactation with regards to bone and an exercise intervention have not been previously reported. The primary role of hGH and IGF-1 are tissue growth (increase in lean body mass) and bone remodeling (increase in bone formation). Chronic aerobic exercise has been shown to increase hGH in women depending on intensity of training; however, IGF-1 levels may not be affected (31,37-38). Circulating levels of IGF-1 may not increase with exercise training despite the increase in hGH secretion from the pituitary, but rather the IGF-1 increase may be localized to the muscle from an autocrine response (52). Additionally, resistance training increases IGFBP-3 levels, which helps protect IGF-1 from degradation, thus decreasing free IGF-1 (53). In this study, hGH levels in the exercise group increased [2.0 (5.6) μg/L], where as the control group decreased [-1.2 (3.1) μg/L], $p = 0.10$. This sample size was probably too small to detect a difference, given the variation in response of hGH. To have enough power (80%, alpha = 0.05) would be needed to detect change given the results of this study, a sample size of 70 (35 per group).

Most anabolic affects of hGH are thought to be mediated by IGFs. However, there is some direct activation of hGH via the GH receptor and JAK-2 pathway (33-34) to stimulate proliferation of osteoblasts (54). BAP is specific to osteoblasts and bone formation as well as BAP levels tend to rise in response to anabolic therapy (55). Given the upregulation of the bone turnover cycle during lactation, the stabilization of BAP and IGF-1 with an increase in hGH, there may not have been enough power to detect if hGH played a role in the attenuation of the loss of lumbar spine BMD. Despite strength increases by the exercise group (25), IGF-1 levels remained unchanged during the intervention; however, an increase in IGF-1 was found to be protective of total body BMD loss during lactation.

There were limitations to this study. The first limitation was the small sample size; there may not have been enough power to detect differences in bone turnover markers and hormones. The final sample size of 20 (10 per group) was estimated only to provide enough power to detect change in lumbar spine BMD between groups, not hormones or bone turnover markers. The second limitation was that we did not measure hGH profiles in response to exercise in any of the women, but rather collected a resting (non-stimulated) sample before and after the intervention. We recognize that due to the pulsatile nature of hGH secretion, a hGH profile over several hours would have been ideal. However, given the time constraints of mothers with new infants, we felt that hGH profiles would place undue burden on participants. The third limitation was the lack of control for time in the menstrual cycle for the endpoint measurement. However, only two women (one in each group) resumed their menses during the study.

Exercise and a higher dietary calcium intake appear to be protective of bone loss during lactation, when controlling for parity. Since the lumbar spine is comprised of trabecular bone and the exercise program was designed to target the lumbar spine and hip, it was not surprising that the exercise program had a positive effect on lumbar spine BMD compared to total body BMD. Additionally, an increase in bone formation (BAP) was protective of lumbar spine BMD; whereas increased levels of estradiol and IGF-1 were protective of total body BMD. These results suggest that exercise and dietary calcium intake influence the changes in BMD during lactation.

References

1. National Osteoporosis Foundation 2008. *Fast facts on osteoporosis.* Available at: http://www.nof.org/osteoporosis/diseasefacts.htm.

2. Kalkwarf H, Specker B. Bone mineral changes during pregnancy and lactation. *Endocrine* 2002; 17(1):49-53.

3. Kovacs CS. Calcium and Bone metabolism during pregnancy and lactation. *J Mammary Gland Biol and Neo* 2005; 10(2):105-118.

4. Prentice A. Micronutrients and the bone mineral content of the mother, fetus and newborn. *J Nutr* 2003; 133(Suppl 2):1693S-1699S.

5. Kalkwarf HJ. Hormonal and dietary regulation of changes in bone density during lactation and after weaning in women. *J Mammary Gland Biol and Neo* 1999; 4(3):319-329.

6. Ross PD, Knowlton W. Rapid bone loss is associated with increased levels of biochemical markers. *J Bone Min Res* 1998; 13(2):297-302.

7. Larson-Meyer D. Effect of postpartum exercise on mothers and their offspring: A review of the literature. *Obes Res* 2002; 10(8):841-852.

8. Laskey M, Prentice A. Effects of pregnancy on recovery of lactational bone loss. *The Lancet* 1997; 349:1518-1519.

9. Sowers M, Hollis B, Shapiro B, Randolph J, Janney C, Zhang D, Schork A, Crutchfield M, Stanczyk F, Russell-Aulet M. Elevated parathyroid hormone-related peptide associated with lactation and bone density loss. *JAMA* 1996; 276(7):549-554.

10. Holmberg-Marttila D, Leino A, Sievanen H. Bone turnover markers during lactation, postpartum amenorrhea and resumption of menses. *Osteo Int* 2003; 14:103-109.

11. Ritchie L, Fung E, Halloran B, Turnlund J, Van Loan M, Cann C, King J. A longitudinal study of calcium homeostasis during human pregnancy and lactation and after resumption of menses. *Am J Clin Nutr* 1998; 67:693-701.

12. Laskey M, Prentice A, Hanratty LA, Jarjou LM, Dibba B, Beavan SR, Cole TJ. Bone changes after 3 mo of lactation: Influence of calcium intake, breast-milk output, and vitamin D-receptor genotype. *Am J Clin Nutr* 1998; 67:685-692.

13. Bassey E, Rothwell M, Littlewood J, Pye D. Pre- and Postmenopausal women have different bone mineral density responses to the same high-impact exercise. *J Bone Miner Res* 1998; 13(12):1805-1813.

14. Vainionpaa A, Korpelainen R, Leppaluoto J, Jamsa T. Effects of high-impact exercise on bone mineral density: A randomized controlled trial in premenopausal women. *Osteo Int* 2005; 16:191-197.

15. Stewart KJ, Bacher AC, Hees PS, Tayback M, Ouyang P, de Beur J. Exercise effects on bone mineral density: Relationships to changes in fitness and fatness. *Am J Prev Med* 2005; 28(5):453-460.

16. Chubak J, Ulrich CM, Tworoger SS, Sorensen B, Yasui Y, Irwin ML, Stanczyk FZ, Potter JD, McTiernan A. Effect of exercise on bone mineral density and lean mass in postmenopausal women. *Med Sci Sports Exerc* 2006; 38(7):1236-1244.

17. Engelke K, Kemmler W, D L, Beeskow C, Pintag R, Kalender W. Exercise maintains bone density at spine and hip EFOPS: A 3-year longitudinal study in early postmenopausal women. *Osteo Int* 2006; 17:133-142.

18. Park S-K, Park J-H, Kwon Y-C, Kim H-S, Yoon M-S, Park H-T. The effect of combined aerobic and resistance exercise training on abdominal fat in obese middle-aged women. *J Physiol Anthropol* 2003; 22(3):129-135.

19. Chien M, Wu Y, Hsu A, Yang R, Lai J. Efficacy of a 24-week aerobic exercise program for osteopenic postmenopausal women. *Calcif Tissue* 2000; 67:443-448.

20. Cussler EC, Lohman TG, Going SB, Houtkooper LB, Metcalfe LL, Flint-Wagner HG, Harris RB, Teixeria PJ. Weight lifted in strength training predicts bone change in postmenopausal women. *Med Sci Sports Exerc* 2003; 35(1):10-17.

21. Stengel S, Kemmler W, Pintag R, Beeskow C, Weineck J, Lauber D, Kalender W, Engelke K. Power training is more effective than strength training for maintaining bone mineral density in postmenopausal women. *J Appl Physiol* 2005; 99:181-188.

22. Yamazaki S, Ichimura S, Iwamoto J, Takeda T, Toyama Y. Effect of walking exercise on bone metabolism in postmenopausal women with osteopenia/osteoporosis. *J Bone Miner Metab* 2004; 22:500-508.

23. Drinkwater B, Chesnut C. Bone density changes during pregnancy and lactation in active women: a longitudinal study. *Bone and Miner* 1991; 14:153-160.

24. Little K, Clapp J. Self-selected recreational exercise has no impact on early postpartum lactation-induced bone loss. *Med Sci Sports Exerc* 1998; 30(6):831-836.

25. Lovelady CA, Bopp MJ, Colleran HL, Mackie HK, Wideman L. Effect of exercise training on loss of bone mineral density during lactation. *Med Sci Sports Exerc* 2009; 41(10):1902-1907.

26. Chan SM, Nelson EAS, Leung S, Cheng J. Bone mineral density and calcium metabolism of Hong Kong Chinese postpartum women- A 1-y longitudinal study. *Eur J Clin Nutr* 2005; 59(7):868-876.

27. Holmberg-Marttila D, Sievanen H, Tuimala R. Changes in bone mineral density during pregnancy and postpartum: Prospective data on five women. *Osteo Int* 1999; 10:41-46.

28. Kolthoff N, Eiken P, Kristensen B, Nielsen SP. Bone mineral changes during pregnancy and lactation: A longitudinal cohort study. *Clin Sci* 1998; 94:405-412.

29. Lopez JM, Gonzalez G, reyes V, Campino C, Diaz S. Bone turnover and density in healthy women during breastfeeding and after weaning. *Osteo Int* 1996; 6:153-159.

30. Sowers M, Corton G, Shapiro B, Jannausch ML, Crutchfield M, Smith ML, Randolph JF, Hollis B. Changes in bone density with lactation. *JAMA* 1993; 269(24):3130-3135.

31. Consitt LA, Copeland JL, Tremblay MS. Endogenous anabolic hormone responses to endurance versus resistance training in women. *Sports Med* 2002; 32(1):1-22.

32. Consitt LA, Copeland JL, Tremblay MS. Hormone responses to resistance vs. endurance exercise in premenopausal females. *Can J Appl Physiol* 2001; 26(6):574-587.

33. Godfrey RJ, Madgwick Z, Whyte GP. The exercise-induced growth hormone response in athletes. *Sports Med* 2003; 33(8):599-613.

34. Wideman L, Weltman JY, Hartman ML, Veldhuis JD, Weltman A. Growth hormone release during acute and chronic aerobic and resistance exercise. *Sports Med* 2002; 32(15):987-1004.

35. Kraemer WJ, Fleck SJ, Dziados JE, Harman EA, Marchitelli LJ, Gordon SE, Mello R, Frykman PN, Koziris LP, Triplett NT. Changes in hormonal concentrations after different heavy-resistance exercise protocols in women. *J Appl Physiol* 1993; 72(2):594-604.

36. Kraemer WJ, Nindl BC, Marx JO, Gotshalk LA, Bush JA, Welsch JR, Volek JS, Splering BA, Maresh CM, Mastro AM, Hymer WC. Chronic resistance training in women potentates growth hormone in vivo bioactivity: Characterization of molecular mass variants. *Am J Physiol Endocrinol Metab* 2006; 291:E1177-E1187.

37. Weltman A, Weltman JY, Schurrer R, Evans WS, Veldhuis JD, Rogol AD. Endurance training amplifies the pulsatile release of growth hormone: Effects of training intensity. *J Appl Physiol* 1992; 72(6):2188-2196.

38. Tworoger SS, Missmer SA, Eliassen AH, Barbieri RL, Dowsett M, Hankinson SE. Physical activity and inactivity in relation to sex hormone, prolactin, and insulin-like growth factor concentrations in premenopausal women. *Cancer Causes Control* 2007; 18:743-752.

39. Franklin BA. *American College of Sports Medicine's Guidelines for Exercise Testing and Prescription*, 2000. Lipponcott Williams & Wilkins, Philadelphia, PA, USA.

40. More C, Bettembuk P, Bhattoa HP, Balogh A. The effects of pregnancy and lactation on bone mineral density. *Osteo Int* 2001; 12:732-737.

41. O'Brien K, Donangelo CM, Zapata CLV, Abrams SA, Spencer EM, King JC. Bone calcium turnover during pregnancy and lactation in women with low calcium diets is associated with calcium intake and circulating insulin-like growth factor 1 concentrations. *Am J Clin Nutr* 2006; 83:317-323.

42. Black A, Topping J, Durham B, Farquharson R, Fraser W. A detailed assessment of alterations in bone turnover, calcium homeostasis, and bone density in normal pregnancy. *J Bone Min Res* 2000; 15(3):577-563.

43. Naylor K, Iqbal P, Fledelius C, Fraser R, Eastell R. The effect of pregnancy on bone density and bone turnover. *J Bone Min Res* 2000; 15(1):129-137.

44. Yamaga A, Taga M, Minaguchi H, Sato K. Changes in bone mass as determined by ultrasound and biochemical markers of bone turnover during pregnancy and puerperium: A longitudinal study. *J Clin Endocrinol Metab* 1996; 81(2):752-756.

45. Hinton P, Rector R, Thomas T. Weight-bearing, aerobic exercise increases markers of bone formation during short-term weight loss in overweight and obese men and women. *Metabolism* 2006; 55:1616-1618.

46. Lester M, Urso M, Evan R, Pierce J, Spiering B, Maresh C, Hatfield D, Kraemer WJ, Nindl BC. Influence of exercise mode and osteogenic index on bone biomarker responses during short-term physical training. *Bone* 2009; 45(4):768-776.

47. Nakata Y, Ohkawara K, Dong J, Okura T, Tanaka K. Effects of additional resistance training during diet-induced weight loss on bone mineral density in overweight premenopausal women. *J Bone Miner Metab* 2008; 26:172-177.

48. Rector R, Loethen J, Ruebal M, Thomas T, Hinton P. Serum markers of bone turnover are increased by modest weight loss with or without weight-bearing exercise in overweight premenopausal women. *Appl Physiol Nutr Metab* 2009; 34(5):933-941.

49. Waltman N, Twiss J, Ott C, Gross G, Lindsey A, Moore T, Berg K, Kupzyk K. The effect of weight training on bone mineral density and bone turnover in postmenopausal breast cancer survivors with bone loss: A 24-month randomized controlled trial. *Osteo Int* [serial online]. 2009; n.p. Available at: http://www.biomedsearch.com/nih/effect-weight-training-bone-mineral/19802506.html.

50. Riedt CS, Schlussel Y, von Thun N, Ambia-Sobhan H, Stahl T, Field MP, Sherrell RM, Shapses SA. Premenopausal overweight women do not lose bone during moderate weight loss with adequate or higher calcium intake. *Am J Clin Nutr* 2007; 85:972-980.

51. Wagner G, Kindrick S, Hertzler S, DiSilvestro R. Effects of various forms of calcium on body weight and bone turnover markers in women participating in a weight loss program. *J Am Coll Nutr* 2007; 26(5):456-461.

52. Frystyk J. Exercise and the growth hormone-insulin-like growth factor axis. *Med Sci Sports Exerc* 2010; 42(1):58-66.

53. Borst S, De Hoyos D, Garzarella L, Vincent K, Pollock B, Lowenthal D, Pollock M. Effects of resistance training on insulin-like growth factor-1 and IGF binding proteins. *Med Sci Sports Exerc* 2001; 33(4):648-653.

54. Bex M, Bouillon R. Growth hormone and bone health. *Horm Res* 2003; 60(suppl 3):80-86.

55. Korpal-Szczyrska M, Balcerska A. The effect of growth hormone treatment on serum bone alkaline phosphatase in growth hormone deficient children. *Pediatr Endocrinol Diabetes Metab* 2008; 14(4):211-214.

CHAPTER IV

FEASIBILITY OF USING *MYPYRAMID MENU PLANNER FOR MOMS* IN A WEIGHT LOSS INTERVENTION DURING LACTATION

(formatted for publication in the Journal of the American Dietetic Association, Research Brief. Maximum 2 tables allowed)

Introduction

The internet offers a valuable resource for promotion of healthy eating and web-based communication between the practitioner and client (1). The recent launch of *MyPyramid Menu Planner* (March 2008), *MyPyramid for Pregnancy and Breastfeeding for Moms* (August 2008), and recently in 2009 *MyPyramid Menu Planner for Moms* (a combination of the two previous sites) offers a unique opportunity for internet based dietary counseling to help achieve a healthier diet during the postpartum period (2).

MyPyramid Menu Planner interactively notes how well the diet meets the *MyPyramid* recommendations, both graphically and by text, through translation of foods into *MyPyramid* food groups (3). *MyPyramid Menu Planner* provides suggestions on ways to meet recommended levels in areas where the diet fails to meet the recommended food group amounts and tracks changes throughout a seven day period. It allows opportunity for a food and nutrition professional to determine whether a participant's diet over a seven day period meets *MyPyramid* recommendations for their energy intake and food choices. Additionally, it allows for weekly tailoring of dietary counseling. As foods are entered into *MyPyramid*

Menu Planner, the respective food groups are captured in a bar graph format. At the end of the seven days, a summary report displays how well an individual meet the *MyPyramid* food groups guidelines.

The goal of this study was to improve total diet or overall pattern of food eaten with individual counseling by a registered dietitian using *MyPyramid Menu Planner for Moms* during a 16-week exercise and weight loss intervention targeting overweight lactating women beginning at 4 weeks postpartum (baseline). We hypothesized, based on menu modeling with individual counseling and *MyPyramid* (4), the intervention group would improve the quality of their intake by consuming the recommended amounts of food groups established by *MyPyramid* compared to the minimal care group at 20 weeks postpartum (endpoint). To our knowledge, this was the first study to use *MyPyramid Menu Planner for Moms* for dietary counseling using the total diet approach with internet based technology.

Methods

Participants for this intervention were part of a study examining the effects of exercise and weight loss on bone mineral density during lactation in overweight postpartum women. Eligibility criteria were infant's less than three weeks old, mother's between 23 to 37 years of age, self-reported body mass index (BMI) between 25 and 30 kg/m^2, fully breastfeeding, less than three weekly sessions of structured physical activity for the past three months, cleared by their physician to participate in exercise, and agree to randomization. History of smoking in the last six months, cesarean section, medical conditions that affect hormone levels or where exercise was contraindicated excluded participation in the study. Recruitment was done through local prenatal classes and flyers at local obstetrician's offices. Participants were screened via a telephone interview to determine eligibility. Informed consents were signed by eligible participants before baseline measurements (Appendix B). The University of North Carolina at Greensboro Institutional Review Board approved the study protocol.

Study Design. The study was a randomized control trial, where participants were randomized, stratified by parity, into either an intervention or minimal care group after all baseline measurements were completed. The intervention group participated in a 16-week exercise and diet intervention from four to 20 weeks postpartum. The 16-week exercise protocol consisted of strength training three times per week, and walking 10,000 steps or 3,000 aerobic steps per day at least five days per week. Additionally, the intervention group was asked to log their dietary intake into *MyPyramid Menu Planner for Moms* at least three times per week. To promote safe and healthy weight loss, a registered dietitian worked with the participants to reduce their estimated baseline dietary requirements by 500 kilocalories (kcal) per day. The minimal care group was asked not to participate in structured exercise or change their dietary habits for 16 weeks. Standard American Heart Association public health information on nutrition was mailed to the minimal care group at week five and week eleven of the intervention (5-6). Data for the dietary intervention are presented here.

Dietary Recall and Energy Requirements

Dietary intake was assessed by three 24-hour dietary recalls at baseline and endpoint (4 ± 1 and 20 ± 2 weeks postpartum, respectively). Dietary recalls were collected by telephone or in person using the Minnesota Nutrition Data System for Research (NDSR 2008, Nutrition Coordinating Center, University of Minnesota, MN) software, on three separate days in the same week. NDSR manages the collection of dietary data through a series of data-entry windows using a multiple pass system. The interviewer asked the participant what they ate or drank first time in the day, then where that occurred (home, work, etc), and finally at what time it occurred. The series of questions continue until the day's dietary intake was completed. Each recall took approximately 30 minutes. NDSR has been previously validated against doubly labeled water and proved an accurate method to assess energy intake (7-9). Use of dietary supplements was not recorded in NDSR.

NDSR assigns food into nine groups based off *MyPyramid* food groups (fruit, vegetables, grains, meat and beans, milk, oils, extras = sweets, beverages, and miscellaneous) (2,10). Inclusion of food into a group was based on the *Dietary Guidelines for Americans 2005* (11) and *United States Department of Agriculture (USDA) Food Guide Pyramid* (2). NDSR further classifies food into 166 subgroups. The following subgroups were used to better capture dietary intake for this study. The fruit group was further divided into servings of whole fruit. Dark green and orange vegetables were used to further classify the types of vegetables consumed. Total grains were broken down into three subgroups: whole grains, snack grains (crackers, popcorn, snack bars and chips) and grain-based desserts (cakes, cookies, pastries, doughnuts, pies, and cobblers). Servings of frozen dairy desserts (ice cream) were reported to capture the amount ice cream consumed versus milk or cheese. The extra food groups include sweets (syrup, honey, jams, jellies, candy, and sweet sauces), beverages (sweetened fruit drinks, soft drinks, and sweetened tea) and miscellaneous (non sweet sauces and condiments, pickled foods, soup broth, and sugar substitutes). Serving sizes for NDSR and *MyPyramid* food groups were based on the *Dietary Guidelines for Americans 2005* (11) and Food and Drug Administration (FDA) (12).

Energy needs were calculated using the Total Energy Expenditure (TEE) equation from the Dietary Reference Intakes for overweight, non-pregnant, non-lactating women (13). Then 330 kcal was added for breastfeeding. Finally, 500 kcal was subtracted to promote a safe weight loss of one pound per week. A previous study with breastfeeding overweight women found a moderate calorie restriction (500 kcal per day) with exercise had no adverse affects on infant growth (weight or length) (14). Additionally in another study with breastfeeding overweight women, short term (11 days) energy restriction (approximately 1000 kcal/d) had no effect on breast milk composition and volume (15). The minimum energy recommendation for the intervention group in this study was 1800 kcal per day, with a range of 1900 to 2500 kcal per day.

MyPyramid Menu Planner

Individual *MyPyramid Menu Planner for Moms* accounts were created for each participant in the intervention group (a coded user name and password) along with a personal profile (age, gender, weight, height, and physical activity). This allowed the participant and the dietitian to access *MyPyramid Menu Planner for Moms*. *MyPyramid* computes energy needs based on age, weight, height, and lactation status for weight maintenance. For the purposes of this study, the weight of the participant was altered until the energy needs computed by *MyPyramid* was equal to the energy needs determined for weight loss as stated above. Participants were made aware of the alteration in their weight status for energy needs, and that the weight entered into their account was not reflective of their recommended goal weight by the end of the intervention. Additionally, physical activity was entered as less than 30 minutes to avoid over-estimation of energy requirements for weight loss for all participants in the intervention group.

For the initial log in and use of *MyPyramid Menu Planner for Moms*, a 60 minute face-to-face counseling session was used. All participants received a printout from *MyPyramid for Moms*, which graphically displayed their recommended energy needs and amount of servings for food groups. Written on the printout was their user name and password for *MyPyramid Menu Planner for Moms*, web address for *MyPyramid Menu Planner for Moms(16)*, and goal weight (current weight minus 7.2 kg, approximately 0.5 kg/week) for the end of the intervention. Dietary intake from the baseline three day NDSR recalls were entered into *MyPyramid Menu Planner for Moms*. Participants received printed copies of these first three daily reports from *MyPyramid Menu Planner for Moms*. The printed reports were used to help teach participants how to enter foods into *MyPyramid Menu Planner for Moms*.

To assess weight loss progression and allow for additional dietary counseling, participants were asked to log in at least three days per week on *MyPyramid Menu Planner for Moms* and enter their dietary intake. Since *MyPyramid Menu Planner for Moms* allowed for seven days worth of dietary entry, weekly reports were printed every Monday morning, which facilitated face-to-face dietary counseling on Wednesday every week. The average weekly dietary counseling session lasted about 30 minutes; however, participants were encouraged to ask questions during any of the weekly exercise sessions or anytime via email. Compliance was also measured by checking mother's weight (Tanita BWB-800S digital scale) and circumference measurements (gulick tape measure) every two weeks, along with the infant's weight (SECA 334 digital scale).

The minimal care group was asked not to change their dietary habits during the 16-week intervention. Two standard public health nutrition handout from the American Heart Association (Appendix B) were mailed to the minimal care group at 9 weeks ["Eating more nutrient dense foods and less nutrient poor foods" (6)] and 16 weeks ["Healthy Diet and Lifestyle Recommendations" (5)] postpartum.

All participants were contacted bi-weekly to assess the use of formula, use of birth control, return of menses, change in physical activity, and use of dietary supplements (Appendix B). In addition, adverse dietary events (i.e. infant dairy intolerance from the mother's dietary intake) were also recorded. For the intervention group, this information was recorded on the same day as the mothers and infants were weighted. The minimal care group was contacted (via telephone or email) by a research assistant every two weeks. Both groups received a multivitamin without minerals.

Statistical Analysis

Data were analyzed using JMP software (v.6.0.0 SAS Institute Cary, NC). One-way analysis of variance (ANOVA) was used to test significant differences between the intervention and minimal care groups for baseline characteristics [age, pre-pregnancy and baseline weight, pre-pregnancy body mass index (BMI), and height]. Repeated measures analysis of variance (RMANOVA) was used to test for differences over time and between groups for weight, BMI, dietary changes (energy, energy (kcal)/ kg of body weight, fiber, saturated fat, trans fat, sodium, percentage of energy from macronutrients and added sugars, and amount of *MyPyramid* food groups consumed) during the 16-week intervention. The number of weeks of participants recorded their dietary intake divided by the number of total weeks (16) was used to determine compliance to *MyPyramid* for the intervention group. Qualitative data was recorded on the call logs, but not statistically analyzed due to the small number of women (n = 5) who reported information on adverse dietary events. A bivariate correlation was performed to test the relationship between number of weeks *MyPyramid Menu Planner for Moms* was used and the amount of weight loss for the intervention group. Results were reported as mean (standard deviation-SD) and significance was set at $p \leq 0.05$.

Results

Thirty women were randomized to either the intervention group (*n*=16) or minimal care group (*n*=14), with a total of 4 dropouts (2 per group) due to switching to formula feeding or moving out of state. There were no significant differences at baseline between the four women who dropped out compared to the 26 women who completed the study. The intervention group was significantly heavier at baseline compared to the minimal care group (p = 0.03) (see Table 4.1). There were no significant differences between the two groups for other baseline characteristics. All participants except one had at least a college education and access to a computer and internet. The intervention participants stated they were familiar with reading labels and portion sizes. The ethnicity makeup of the two groups was evenly distributed. The majority of the participants were Caucasian (22 out of 26). Two African Americans were in the minimal care group and the intervention group had 1 African American and 1 Latino participant. Two Caucasian and two African American participants (one per group) did not complete the study.

Table 4.1. ***Participants' Characteristics and Nutritional Intake of the Minimal Care and Intervention Groups***

	Minimal Care (n = 12)		Intervention (n = 14)	
	Baseline	Endpoint	Baseline	Endpoint
Age (years)	30.6 (3.7)	-	31.9 (3.1)	-
Pre-pregnancy Weight (kg)	66.2 (12.3)	-	73.7 (10.8)	-
Pre-Pregnancy BMI (kg/m2)	25.4 (4.1)	-	26.9 (4.4)	-
Height (cm)	161.4 (5.9)	-	165.8 (5.4)	-
Weight (kg) [*, **]	72.5 (10.5)	70.1 (13.2)	81.6 (10.1)	75.8 (10.3)
BMI (kg/m2) [***]	27.8 (3.3)	26.9 (4.4)	29.7 (3.6)	27.6 (3.7)
Energy Intake (kcal) [a,**]	2001 (502)	1780 (433)	2383 (510)	1770 (433)
Energy Intake (kcal/kg)	28.0 (8.4)	25.4 (4.6)	29.8 (8.2)	23.7 (6.8)
Fiber (g) a	20.8 (10.4)	18.0 (7.6)	25.5 (11.5)	26.1 (8.8)
Saturated Fat (g) [a,**]	24.5 (9.7)	25.7 (13.6)	34.5 (12.6)	19.6 (8.1)
Trans Fat (g) a	4.1 (3.2)	3.5 (2.3)	4.3 (1.7)	2.4 (1.5)
Sodium (mg) a	3413 (1272)	2993 (1151)	4019 (1023)	3312 (1281)
% Energy from Carbohydrates [a,**]	50.8 (5.7)	50.0 (6.2)	50.5 (4.9)	54.5 (5.2)
% Energy from Added Sugars [a,**]	13.0 (6.2)	14.5 (5.0)	13.4 (4.8)	9.9 (3.0)
% Energy from Protein a	16.2 (3.2)	17.4 (3.3)	16.4 (3.2)	18.3 (3.0)
% Energy from Fat [a,**]	34.3 (5.5)	33.8 (6.5)	34.6 (4.5)	29.1 (5.4)
% Energy from Saturated Fat [a,**]	10.8 (2.9)	11.4 (5.3)	12.8 (3.1)	7.5 (3.0)

BMI, body mass index
Data are mean (SD)

[*] Significantly different between groups at baseline, $p = 0.03$, ANOVA
[**] Significantly different over time and between groups, $p < 0.05$, RMANOVA
[***] Significantly different over time, $p = 0.05$, RMANOVA

[a] Intervention group recommendations: energy, 1900 to 2500 kcal/d; fiber, 25 g/d, saturated fat, 24g; trans fat, limit; sodium, < 2300 mg/d; % energy from carbohydrates (45-65%), added sugars (42 g or < 8%), protein (15-20%), fat (20-35%), and saturated fat (< 10%) [11].

Average baseline energy recommendations for the intervention group were 2,300 kcal. Both groups significantly reduced their caloric intake during the 16-week study; however, the intervention group decreased 613 (521) kcal, whereas the minimal care group decreased 222 (414) kcal, $p < 0.05$ (Table 4.1). The intervention group decreased saturated fat intake [14.9 (14.0) g], compared to the minimal care group who increased [1.2 (14) g], $p = 0.008$. At endpoint, the mean percentage of energy from saturated fat for the intervention group (7.5%) was in agreement with the recommended amount of less than < 10% (11). The intervention group decreased their body weight by -5.8 (3.5) kg (range +0.6 kg to -11.6 kg) or -7%, compared to the minimal care group -2.4 (4.9) kg (range +6.2 kg to -9.3 kg) or -3%. The reduction of body weight was significantly different between groups over time, $p < 0.05$.

At endpoint, the intervention group increased their servings to the amount recommended by *MyPyramid* for dark green and orange vegetables (Table 4.2). They were below the recommended serving sizes for fruits, vegetables, total grains, including whole grains, meats and beans, milk, and fats and oils. There was a significant difference over time and between groups with the whole fruits, total grains group, and milk food group, $p \leq 0.05$. The intervention group increased whereas the control group decreased their consumption of whole fruits (not juice), $p = 0.05$. Servings of the total grain group decreased in both groups and were significantly different between groups, $p < 0.05$. Servings consumed for the milk group decreased in the intervention group, whereas the minimal care group increased, $p = 0.005$. The intervention group decreased servings of milk from frozen dairy desserts (i.e. ice cream) while the minimal care group increased, $p = 0.07$. One woman's infant in the intervention group was diagnosed with a milk protein allergy which required her to eliminate dairy from her diet.

Table 4.2. ***Servings of MyPyramid Food Groups Consumed by the Minimal Care and Intervention Groups***

Food Groups	Daily Recommended Servings [a,b]	Minimal Care (*n* = 12)		Intervention (*n* = 14)	
		Baseline	Endpoint	Baseline	Endpoint
Fruit	4	1.0 (0.9)	0.9 (0.9)	1.9 (2.0)	2.3 (1.6)
Whole Fruit (not juice) *	eat a variety	1.0 (0.9)	0.6 (0.7)	1.2 (1.3)	1.8 (1.5)
Vegetables	6	3.3 (1.6)	3.2 (1.9)	4.2 (3.0)	4.9 (2.4)
Dark Green & Orange Vegetables	1.5	0.7 (0.9)	0.3 (0.4)	1.1 (1.4)	1.5 (0.9)
Total Grains *	7 - 8 oz eq.	6.9 (2.3)	6.5 (2.1)	9.1 (3.2)	6.6 (2.2)
Whole Grains	3.5 – 4 oz eq.	2.1 (2.2)	2.4 (1.7)	3.9 (2.2)	3.0 (1.9)
Snack Grains	limit	0.9 (1.1)	0.6 (0.7)	1.3 (1.1)	0.8 (0.8)
Grain Based Desserts	limit	0.8 (0.8)	0.6 (0.9)	0.8 (0.8)	0.5 (0.4)
Meat & Beans (1 oz = 1 serving)	6 – 6.5 oz eq.	6.0 (2.9)	5.5 (3.2)	5.1 (1.9)	4.6 (1.9)
Milk **	3	1.6 (0.7)	2.0 (0.9)	3.0 (1.4)	2.0 (0.8)
Frozen Dairy Desserts	limit	0.1 (0.2)	0.3 (0.6)	0.7 (1.3)	0.3 (0.4)
Fats & Oils	2-3	3.2 (2.2)	3.7 (2.5)	4.2 (3.9)	3.8 (2.4)
Sweets	limit	1.2 (1.1)	0.8 (0.9)	1.8 (2.1)	1.3 (1.4)
Beverages	limit	1.0 (1.8)	0.8 (1.2)	0.1 (0.2)	0.1 (0.2)
Alcohol	limit	0.2 (0.4)	0.1 (0.3)	0.2 (0.4)	0.1 (0.3)
Miscellaneous ***	limit	2.1 (1.7)	1.0 (0.9)	1.2 (0.9)	0.6 (0.6)

Snack Grains- crackers, popcorn, snack bars and chips; Grain Based Desserts- cakes, cookies, pastries, doughnuts, pies, and cobblers; Frozen Dairy Desserts- ice cream; Sweets- syrup, honey, jams and jellies, candy, sweet sauces; Beverages- sweetened fruit drinks, soft drinks, and sweetened tea; Miscellaneous- non sweet sauces and condiments, pickled foods, soup broth, and sugar substitutes.

Mean (SD)
[*] Significantly different over time and between groups, $p = 0.05$, RMANOVA
[**] Significantly different over time and between groups, $p = 0.005$, RMANOVA
[***] Significantly different over time, $p = 0.01$, RMANOVA

[a] Recommended Servings based on the average participant in the study using MyPyramid Plan for Moms 16. Average participant age 31; breastfeeding only, no formula; infant age of 4 weeks; height 163.8 cm; weight 76.9 kg; physical activity less than 30 minutes; based on 2200 – 2400 kcal pattern.

[b] Serving sizes based on the Dietary Guidelines for Americans 2005 11 and FDA 12. Fruits and Vegetables, 1 serving = 1 medium fruit, 1 cup (c) raw leafy vegetable, ½ c cooked vegetable or fresh/ frozen/ canned fruit, 6 oz fruit or vegetable juice, ¼ dried fruit; Grains, 1 serving = 1 slice of bread, 1 oz dry cereal, ½ c cooked rice or cereal/ pasta, 1 oz equivalent (oz-eq.); Meat and beans, 1 serving = 3 oz cooked meat/ poultry/ fish, 1/3 c (1.5 oz) nuts, 2 T (1/2) seeds, 1/2 c cooked dry beans or peas, 1 oz-eq. = 1 oz lean meat, ¼ c dry beans or tofu, 1 T peanut butter or ½ oz nuts/ seeds; Milk, 1 serving = 8 oz (1 c) milk/ yogurt, 1.5 oz natural cheese, 2 oz processed cheese; Fats and Oils, 1 serving = 29 to 31 g of fat, 1 tsp margarine/ vegetable oil, 1 T low-fat mayonnaise, 2 T light-salad dressing.

Four other women in the intervention group restricted consumption of milk and beans, due to their infants being "fussy" and "gassy." There were no other adverse events reported in either group. The miscellaneous food groups decreased significantly over time in both groups (p = 0.01) with no difference between groups.

MyPyramid Menu Planner for Moms was used by the intervention group for an average of 9.6 (5.9) weeks (range 2 to 16 weeks) during the 16 week intervention (range 2 to 16 weeks). Five of the 14 participants (35.7%) used *MyPyramid Menu Planner for Moms* for only two to four weeks. Three of these five participants were vegetarians. They reported that using MyPyramid was very frustrating and time consuming because of the limited vegetarian items in the program. They changed to recording their intake by pen and paper for the remainder of the 16 weeks. The other two non-vegetarian participants discontinued use of *MyPyramid Menu Planner for Moms* around the fourth week due to reporting familiarity with dietary recommendations and portion sizes. There was no relationship between the number of weeks *MyPyramid Menu Planner for Moms* was used and weight loss (β = 0.06, R^2 = 0.009, p = 0.7).

Discussion and Limitations

The intervention group significantly reduced their energy, saturated fat, and added sugars intake, through use of *MyPyramid Menu Planner for Moms* and weekly counseling by a registered dietitian. Additionally, the intervention group increased their whole fruit, vegetable, and dark green and orange vegetable intake to recommended levels. Although the intervention group was counseled to increase their protein intake (food groups: milk and meat and beans) to help preserve lean mass while decreasing weight, the intake for those food groups decreased.

MyPyramid Menu Planner for Moms was designed for individuals with some food knowledge and computer experience (1). All but one of the participants in this study had at least a college education. The participants in the intervention group stated they were familiar with portion sizes and ability to read food labels. Additionally, they had basic computer skills and convenient access to a computer with internet capabilities.

There are some inherent limitations with both diet recalls and use of *MyPyramid Menu Planner for Moms*. Participants may withhold or alter information based on what they think the interviewer would like to hear, embarrassment of food choices, or poor memory during 24-hour recalls (17). This can lead to under- or over- reporting of the dietary data by the participant. In addition, the 24-hour recall only reflects one day’s intake, and seldom represents the participants usually intake (17). We addressed this limitation through collection of three 24-hour dietary recalls within the same week at baseline and endpoint. Despite collecting three days worth of dietary information, underreporting of normal dietary intake may still have occurred as overweight women are more likely to underreport dietary intake compared to normal weight women (18).

The limitations using internet technology to aid in individual dietary counseling are participants must have computer and internet access, basic computer skills, and basic food knowledge (1). Given the education level of this population the results may not translate into other populations with limited access to computers and the internet. Another limitation was the use of *MyPyramid Menu Planner for Moms* for vegetarians. The limited vegetarian food choices made it difficult to accurately capture the dietary intake of the vegetarians in this study.

Conclusion

The use of *MyPyramid Menu Planner* was a novel tool to aid in weekly individual dietary counseling and weight loss. Participants received immediate dietary guidance feedback from the program as they enter food into the *MyPyramid Menu Planner*. It allowed participants and the dietitian to track dietary habits over time. The results from this study suggest *MyPyramid Menu Planner* was a useful tool to aid in counseling postpartum women to change dietary habits and facilitate weight loss. However, more research designed to compare using *MyPyramid Menu Planner* with counseling to counseling only is needed.

References

1. Juan WY, Gerrior S, Hiza H. MyPyramid tracker assesses food consumption, physical activity, and energy balance status interactively. J *Nutr Educ Behav* 2006; 38:S155-157.

2. US Department of Agriculture 2009. *MyPyramid.* Available at: http://www.mypyramidtracker.gov/planner/launchPage.aspx.

3. Wansink B. Project M.O.M.: Mothers and others and *MyPyramid*. *J Am Diet Assoc* 2008; 108(8):1302-1304.

4. Hornick BA, Krester AJ, Nicklas TA. Menu modeling with *MyPyramid* food patterns: Incremental dietary changes lead to dramatic improvements in diet quality of menus. *J Am Diet Assoc* 2008; 108(12):2077-2083.

5. American Heart Association Inc 2007. *Diet and lifestyle recommendations.* Available at: http://www.americanheart.org/presenter.jhtml?identifier=851.

6. American Heart Association Inc 2007. *Eat less of the nutrient-poor foods.* Available at: http://www.americanheart.org/presenter.jhtml?identifier= 3040349.

7. Blanton C, Moshfegh A, Baer D, Kretsch M. The USDA automated multiple-pass method accurately estimates group total energy and nutrient intake. *J Nutr* 2006; 136:2594-2599.

8. Moshfegh A, Rhodes D, Baer D, Murayi T, Clemens J, Rumpler W, Paul D, Sebastian R, Kuczynski K, Ingwersen L, Staples R, Cleveland L. The US Department of Agriculture automated multiple-pass method reduces bias in the collection of energy intakes. *Am J Clin Nutr* 2008; 88:324-332.

9. Weber J, Reid P, Greaves K, DeLany J, Standford V, Going S, Howell W, Houtkooper LB. Validity of self-reported energy intake in lean and obese

young women, using two nutrient databases, compared with total energy expenditure assessed by doubly labeled water. *Eur J Clin Nutr* 2001; 55:940-950.

10. University of Minnesota Nutrition Data System for Research 2009. *NCC food group serving count system.* Available at: http://www.ncc.umn.edu/ products/database.html.

11. US Department of Health and Human Services and US Department of Agriculture. *Dietary guidelines for Americans,* 6th ed., 2005. US Government Printing Office, Washington, DC, USA.

12. Office of Nutritional Products Labeling and Dietary Supplements in the Center for Food Safety and Applied Nutrition at the US Food and Drug Administration 2010 Title 21: Food and Drugs. In: Electronic Code of Federal Regulations (ed.), vol. Vol 21 CFR 101.122010.

13. Food and Nutrition Board Institute of Medicine. *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids (macronutrients),* 2005. National Academy Press, Washington DC, USA, pp. 107-264.

14. Lovelady C, Garner K, Moreno K, Williams J. The effect of weight loss in overweight, lactation women on the growth of their infants. *N Engl J Med* 2000; 342(7):449-453.

15. McCrory M, Nommsen-Rivers L, Mole P, Lonnerday B, Dewey K. Randomized trial of the short-term effects of dieting compared with dieting plus aerobic exercise on lactation performance. *Am J Clin Nutr* 1999; 69:959-967.

16. US Department of Agriculture 2009. *MyPyramid for pregnancy and breastfeeding*. Available at: http://www.mypyramidtracker.gov/planner/ launch.aspx.

17. Lee RD, Nieman DC. *Nutritional assessment: Chapter 3 measuring diet,* 2003, 3rd ed. McGraw-Hill, Boston, pp. 77-79.

18. Livingstone MBE, Black AE. Markers of the validity of reported energy intake. *J Nutr* 2003; 133(3):895S-920.

CHAPTER V

EFFECTS OF ENERGY RESTRICTION AND EXERCISE ON BODY COMPOSITION IN OVERWEIGHT LACTATING WOMEN

(formatted for publication in the American Journal of Clinical Nutrition)

Introduction

Obesity in America has risen to epidemic proportions over the last 20 years. The 2007-2008 National Health and Nutrition Examination Survey (NHANES) reported that 25.5% of American women between the ages of 20 to 39 are overweight and 34% are obese (1). Childbearing may be one of the causes for the high prevalence of overweight and obesity among women. Some women gain too much weight during pregnancy or are unable to lose the excess weight after childbirth (2). Excessive weight gain during pregnancy has been shown to be a positive predictor in long term postpartum weight retention (3-7). Rooney et al. (8) reported higher pre-pregnancy BMI, excess gestational weight gain, failure to lose weight during the early postpartum period, lack of physical activity, formula feeding, and breastfeeding for less than three months all to be positive predictors of long term postpartum weight retention. Additionally, excess weight retention after pregnancy increases a woman's risk for developing a chronic disease later in life (5).

There are few studies that have directly investigated energy restriction during lactation. McCrory et al. (9) reported that short term (11 days) energy deficit (1000 kcal/d) during lactation had no effect on breast milk composition and volume. Lovelady et al. (10) found a moderate calorie restriction (500 kcal per day) coupled with increased aerobic exercise resulted in significant maternal weight loss and no adverse affects on infant growth (weight or length).

While energy restriction is necessary for weight loss, some researchers report loss of BMD with reduced energy intake. In studies that have investigated extremely low levels of energy intakes (405 to 1000 kcal/d) (11-13) or in studies with rapid weight loss (> 1 kg/week) during short periods of time (less than three months) (14-15) significant reductions in bone density have been reported in both men and women. However, modest restriction in energy intake has been shown in premenopausal women to improve body composition and not affect bone during periods of weight loss (16-18).

This possible decrease in BMD is of concern when recommending energy restriction to postpartum women as women lose BMD during lactation (19-23). Maternal bone is lost at a rate of 1-3% per month, with a greater loss (1-10%) at the trabecular rich sites, lumbar spine and hip (24-26). The bone loss is driven by an increased demand for calcium in breast milk (approximately 200 mg of calcium per day), combined with elevated serum prolactin concentrations, 10 to 20 times above normal (<20 μg/L) and lower levels of estradiol (70 – 300 pmol/L) (25-27). In most women, bone loss is usually reversed when prolactin concentration is decreased (weaning) and estradiol is increased with normal menstruation (26,28-30), making breastfeeding a safe feeding choice. However, not all women return to prepregnancy levels and women with low bone status prior to pregnancy or women who have their children later in life may increase their risk of osteoporosis during lactation or menopause (23,31).

Exercise combined with a modest restriction in energy intake has been shown in pre- and postmenopausal women to improve body composition and protect bone during weight loss (17-18,32-37). Lovelady et al. (38) investigated the effects of exercise (aerobic and resistance training) on bone mineral density in fully breastfeeding women. The exercise group performed three days per week of 45 min of moderate intensity walking and resistance exercise. Compared to the control group, the exercise group slowed the loss of lactation-induced bone loss in the lumbar spine and improved body composition (38). Although the study design did not have an energy restriction component, both groups reduced their dietary intake and lost weight (3.5 kg).

The primary roles of anabolic hormones, such as growth hormone (hGH), are tissue growth and bone remodeling. An increase in hGH concentration is observed after acute bouts of both aerobic and resistance exercise in eumenorrheic women, with the magnitude related to duration and intensity (39-41). For an exercise program to increase hGH concentration chronically, it is dependent on the intensity of training (40,42-43). In regards to postpartum women, there has only been one study that has examined the chronic effects of exercise on anabolic hormones (Chapter III). While the concentration of hGH increased after a 16-week exercise intervention, it was not statistically significant possibly due to the small sample size or that the moderate training intensity was below the threshold needed to elicit a chronic hGH response.

In overweight breastfeeding women, weight loss has been shown to be safe without compromising infant growth (10). Additionally, aerobic and resistance exercise have been shown to slow the loss of BMD (38) during lactation in normal to overweight women. Therefore, the primary purpose of this study was to investigate the effects of energy restriction, walking, and resistance training on body composition and bone in overweight fully breastfeeding women. The second aim was to monitor infant growth (weight and length). The third aim was to describe changes in prolactin and estradiol. The final aim was to describe the acute and chronic response of growth hormone to resistance exercise.

Methods

Subjects

Participants were recruited through prenatal classes and flyers posted within the community and obstetrician's offices. An interviewer determined eligibility by telephoning the women after the birth of their infant. Eligibility criteria included vaginal delivery, less than three weeks postpartum with a self-reported body mass index (BMI) between 25 and 30 kg/m^2, fully breastfeeding, 23 to 37 years of age, and participation in physical activity less than three days per week for the past three months. Potential participants were excluded if they delivered by cesarean section, had a history of smoking during pregnancy, had preexisting medical conditions that affected hormone levels or if exercise was contraindicated. Sample size was determined from the results of two previous studies (10,38). A final sample size of 26 participants (13 per group) was estimated to provide enough power (80%) to detect differences in lumbar spine BMD (5%), fat mass (FM, 4 kg), fat free mass (FFM, 1.6 kg), and hGH (338%) with a two-sided alpha level of 0.05. All participants agreed to randomization, were medically cleared for exercise by their physicians, and signed an informed consent (Appendix B) prior to the baseline (4 ± 1 weeks postpartum) measurements. Participants were randomized, stratified by parity, into either an intervention (diet and exercise) group or minimal care group after completion of baseline measurements. The University of North Carolina at Greensboro Institutional Review Board approved the study protocol.

Laboratory Measurements

Measurements at baseline and endpoint (20 ± 2 weeks postpartum) included maternal and infant anthropometrics, body composition, bone density, dietary intake, cardiovascular fitness test, muscular strength, and basal (non-stimulated) and immediate post 1-repetition maximum exercise testing blood draws for hormone analysis.

Assessment of body composition and bone. Anthropometric measurements included height, weight, waist and hip circumference. Height was measured using a standardized stadiometer (235 Heightronic Digital Stadiometer, Snoqualmie, WA), which was calibrated every time prior to use. Participants were asked removed their shoes and stand parallel to the wall with their heels, hips, and back of their head six inches from the wall where the stadiometer was mounted. Participant's weight was measured on a digital scale (Tanita BWB-800S) with no shoes. A gulick tape measure was used to measure waist and hip circumference. Waist circumference was defined as the narrowest part of the torso above the umbilicus and below the xiphoid process (44). The measurement was taken the same way for baseline and endpoint either under the participant's shirt or over a thin nursing tank-top. Hip circumference was defined as a horizontal measure taken at the maximum circumference the buttocks (44). The measurement was taken around the participant's thin exercise pants.

Infant's weight was measured on a SECA 334 digital scale with the infants wearing only a clean diaper. The weight of the clean diaper was then subtracted from the infant's scale weight to obtain the actual weight of the infant. A length board was used to measure infant length. The mother was instructed to gently hold the infant's head against the head board, while the research assistant gently straighten the infant's right leg and slid the moveable foot board until the infant's foot was flat against the foot board. Two measurements were obtained (+/- 2 cm) and the average was recorded as the infant's length.

Body composition (weight, fat mass, percent body fat, and fat free mass) and bone (density, mineral concentration, and area) and were measured by dual energy x-ray absorptiometry (DXA - Lunar Prodigy Adv., Lunar Radiation Corp, Madison, WI; QDR enCORE software version 11.20.068). A trained DXA technician positioned the subject and performed the scans to ensure precision and accuracy. Additionally, standard scan methods were used. The participant laid in the anteroposterior position, still and flat on an x-ray table, while the fan-beam scanner made a series of transverse scans from head to toe in 0.6 to 1.0 cm intervals. Three total scans were performed: total body (percent body fat, fat mass, fat free mass, total bone density, mineral content, and area,), lumbar spine (L1-L4), and total left hip (femoral neck, trochanter, Ward's triangle). The entire procedure took approximately 30 minutes, depending on height. Participants were exposed to very mild radiation from the DXA scan, equivalent to 1/10 the exposure from a routine chest x-ray, and less than the exposure of a dental x-ray. Since, the DXA was used to estimate body composition changes, quality control checks of body scale weight and the sum of DXA parts agreed within the accepted range of 1 +/- 2 kg (45). Additionally, the time of the last breastfeeding was recorded and the DXA measurement occurred no more than 2 hours since that feeding.

At the endpoint measurement, a pregnancy test by the Student Health Center at UNC-Greensboro was administered to ensure that the participant was not pregnant prior to the DXA scan. A pregnancy test was not necessary at four weeks postpartum (baseline measurement), since after birth, menstruation does not resume for at least 8 weeks in non-lactating women (46). During lactation, menstrual cycles may not resume for 18 months (46). Participants collected a small urine sample in the morning on the day of the visit to the lab; the first void of the morning was preferred. The participant was given a sterile urine collection cup to collect the urine sample, and stored the sample in the home refrigerator until they came into the lab.

Assessment of dietary intake. Dietary intake was assessed by 24-hour dietary recalls at baseline and endpoint. Dietary recalls were collected by telephone or in person using the Minnesota Nutrition Data System for Research (NDSR, Nutrition Coordinating Center, University of Minnesota, MN) software, on three separate days in the same week. NDSR manages the collection of dietary data through a series of data-entry windows, using a multiple pass system. The interviewer asked the participant what they ate or drank first time in the day, then where that occurred (home, work, etc), and finally at what time it occurred. The series of questions continued until the day's dietary intake was completed, which takes approximately 30 minutes. NDSR has been previously validated against doubly labeled water and proved an accurate method to assess energy intake (47-49). This diet record was used to determine each participant's individual nutritional intake. Supplement intake was not recorded in NDSR in order to report nutrient intake from food sources only.

Assessment of cardiovascular fitness. Cardiovascular fitness was determined through a modified Balke protocol using a submaximal treadmill test at baseline and endpoint (44). A heart rate monitor (Polar, Inc., Woodbury, NY) was used to measure resting heart rate (RHR) and heart rate during exercise testing. Blood pressure, using a digital monitor, and resting heart rate were taken prior to the exercise testing. Participants warmed-up on the treadmill for five minutes and were instructed to self-select a "brisk but slightly uncomfortable" speed at either a walk (< 3.7 mph) or jog (> 3.7 mph) pace. The speed remained constant throughout the test. The incline of the treadmill increased in increments of 2.5% every three minutes to ensure heart rate had reached steady state prior to progressing to the next stage. Heart rate and perceived exertion were recorded at the end of the second minute and prior to progression to the next stage. Perceived exertion is a subjective rating based on a Borg scale from 6 to 20 corresponding to descriptive words on how the participant overall was feeling during the treadmill test. A rating of 6 (extremely easy) would be equivalent to sitting on the couch not doing much, whereas 20 (extremely hard) was "I cannot go another step". The test was terminated once the participant's heart rate reached 85% of their predicted heart rate maximum calculated using the heart rate reserve formula [(220-age-RHR) x 85% + RHR] or the participant requested to stop the test. Once the test was terminated, the incline returned to 0% and the speed slowly decreased. The participant was instructed to continue walking until their heart rate dropped below 120 beats per minute, recorded every two minutes. The treadmill test was administered by an American College of Sports Medicine Health Fitness Specialist (ACSM/ HFS) and certified in cardiopulmonary resuscitation (CPR). Predicted VO_2 was calculated based one of the following equations depending on whether the participant walked or jogged for the treadmill test (44):

VO_2 (walking) = (3.5 ml/kg/min) + (speed in m/min * 0.1 m/min) + (grade x m/min * 1.8)

VO_2 (jogging) = (3.5 ml/kg/min) + (speed in m/min * 0.2 m/min) + (grade x m/min * 0.9)

Predicted maximal oxygen consumption (VO_2max) was calculated using a linear regression equation with heart rate as the independent variable and the dependent variable was predicted VO_2.

Assessment of muscular strength and endurance. Muscular strength was assessed using the 1RM method (44). Participants were instructed on the proper technique for each exercise prior to the 1RM test. The 1RM strength exercises were squats, bench press, bent over row, stiff leg deadlift, and seated military press. Adjustable dumbbell weights were used for the strength assessment. One set of ten repetitions of trunk rotations, hip and knee X-chops was used for the warm-up using a 2 kg medicine ball. Prior to each 1-RM test for each exercise, participants performed one set of 10 repetitions. Participants began with weights approximately 50 to 70% of their perceived capacity for one lift. The weight was increased with each lift, with a 1 to 2 minute rest period in between, until the participant could no longer safely perform the exercise with proper technique or requested to stop. The final weight lifted with proper technique was recorded as the participant’s 1RM for that exercise. A National Strength and Conditioning Association Certified Strength and Conditioning Specialist (NSCA CSCS) and ACSM/ HFS, administered the strength test.

Muscular endurance was assessed using the ACSM protocol for abdominal curl-ups and pushups (44). For the abdominal curl-ups, participants were instructed to lay in the supine position on the exercise mat with knees at 90 degrees, arms by their side with palms facing down, and their middle finger touching a piece of masking tape. A metronome was set to 50 beats per minute; the participant slowly curled-up to lift the shoulder blades off the mat in time with the metronome until the hands touch a second piece of tape (10 cm apart from the starting piece of tape). The test was performed for one minute for a maximum of 25 curl-ups or until the participant failed to keep with metronome or requested to stop. For the pushup test, participants lay prone on the mat with hands shoulder-width apart and knees bent. The participants extended their arms keeping their back flat and then bent elbows to return torso to the mat. The movement was repeated until the participant could no longer perform a pushup or requested to stop.

Assessment of hormones. Participants came to the laboratory after an overnight fast and no alcohol consumption and exercise for 24 hours prior to blood draw. A trained phlebotomist drew approximately 4 tablespoons of blood at the same time each visit (4 and 20 weeks postpartum) to control for diurnal variation prior to the 1-repetition maximum (RM) testing. In addition, blood was drawn immediately after the 1RM testing to determine the acute response of hGH to maximum strength exercise. The pre and post exercise blood was collected into vacutainers. After collection, the vacutainers were left at room temperature for 20 minutes to allow the blood to clot, followed by 30 minutes in the centrifuge at 3000 rpm at 4^{o}C. The serum portion was aliquoted into micro-centrifuge tubes (0.5 ml) and stored at -70^{o}C until analyzed. Enzyme linked immunosorbent assays (ELISA) quantization kits (Alpco Diagnostics) were used to quantify hormone levels of prolactin, estradiol, and hGH in the serum.

Study Intervention

Intervention group. The intervention group participated in a 16-week diet and exercise program from four to 20 weeks postpartum. A research assistant traveled to the participant's homes one to three times per week during the 16-week intervention to guide mothers with the exercise program and to ensure dietary compliance. The 16-week exercise protocol consisted of walking 10,000 steps or 3,000 aerobic steps per day at least five days per week and strength training three times per week. The participants used a pedometer (Omron Healthcare, Inc., Bannockburn, Illinois) to monitor the number of steps taken per day. Each participant started with a minimum of 4,000 steps per day and was instructed to increase their daily step count by 100 to 200 steps per day over the first four to six weeks until the goal of 10,000 steps per day was reached. The Surgeon General's recommendation is to "accumulate thirty minutes or more of physical activity on most, if not all, days of the week" (50), which is comparable to walking about 10,000 steps per day (51). Due to time constraints, an alternative option of reaching 3,000 aerobic steps was offered to participants. Aerobic steps were calculated on the pedometer as walking at least 60 steps per minute for at least 10 minutes. Tudor-Locke et al. (52) determined that 3,000 aerobic steps are equivalent to walking 30 minutes at a brisk pace.

The strength exercises were progressive and designed to target the core, which includes the region of the body from the gluteal muscles and hip up to the scapula, in order to stimulate bone formation at the lumbar spine and hip. The progression of the 16-week strength training program is outlined in Appendix B. The combination exercises were variations of the core exercises (squats, bench press, bent-over row, deadlift, and military press) used in 1-RM testing. All of the strength exercises were completed in the home with use of handheld dumbbell weights, a stability ball, and a yoga mat. The addition of 50 vertical jumps per session, three times per week was introduced at week nine of the strength training program to further stimulate bone formation. All exercise sessions were recorded in a logbook in order to assess compliance to the protocol (Appendix B).

To promote a safe and healthy weight loss, a registered dietitian (RD) worked with the participants using *MyPyramid Menu Planner for Moms* (53) to reduce their dietary intake and encourage a healthy eating style. Energy needs were calculated using the total energy expenditure (TEE) equation from the Dietary Reference Intakes for overweight, non-pregnant, non-lactating women (54). An additional 330 kcal was added for breastfeeding, then 500 kcal was subtracted to facilitate a weight loss of one pound per week. The minimum energy intake prescribed was 1800 kcal. The participant's weight and circumference, along with the infant's weight, were measured every two weeks using appropriate portable digital scales (Tanita BWB-800S and SECA 334 infant scale) and a gulick tape measure. To allow for individualized face-to-face dietary counseling, participants were asked to log in at least three days per week on *MyPyramid Menu Planner for Moms* and enter their dietary intake. A detailed description of how *MyPyramid Menu Planner for Moms* was used for the dietary intervention and detailed results are reported elsewhere (Chapter IV).

Minimal care. The minimal care group received standard public health information on nutrition from the American Heart Association (Appendix B) twice during the 16-week intervention. The first handout mailed at 9 weeks postpartum focused on eating more nutrient dense foods and less nutrient poor foods (55). The second handout mailed at 16 weeks postpartum focused on healthy diet and lifestyle recommendations (56). The minimal care group was asked not to participate in structured exercise or change their dietary habits for 16 weeks. Upon completion of the endpoint measurement, the minimal care participants were given all intervention materials, including the exercise equipment, exercise protocol and instruction, as well as the dietary counseling.

All participants in both groups were asked to fully breastfeed their babies throughout the 16-week intervention. Mothers who gave their infants more than four ounces of formula on a regular basis were disqualified from the study. Bi-weekly contact of all participants were done to assess the use of formula, use of birth control, return of menses, change in physical activity, and use of dietary supplements (Appendix B). The minimal care group was contacted (via telephone or email) by a research assistant and the information for the intervention group was recorded on the same day as the mothers and infants were weighted. In addition, adverse dietary events (i.e. infant dairy intolerance from the mother's dietary intake) were also recorded. All participants were provided with a multiple vitamin supplement without minerals (Appendix B).

Statistical Analysis

JMP software (v.6.0.0 SAS Institute Cary, NC) was used to analyze data. Student's t-test was used to test significance between the intervention and minimal care group for baseline characteristics. Repeated measures analysis of variance (RMANOVA) was used to test for differences over time and between groups for body composition (weight, percent body fat, fat mass, fat free mass, waist and hip circumference and waist to hip ratio), bone (density, mineral content, and area) in the total body, lumbar spine, and hip, infant growth (weight and length), hormones (prolactin, estradiol, and basal hGH), dietary intake (energy, protein, calcium intake, vitamin D, and macronutrient composition), cardiovascular fitness (VO_2max), and strength (1RM). The acute response of hGH to exercise was tested using a change variable from basal to immediate post 1-RM at baseline and endpoint. Then RMANOVA tested for time and time by group differences in the acute response to hGH. Results are reported as mean (standard deviation), significance set at $p \leq 0.05$.

Results

One hundred fifty four women were initially screened for eligibility. One hundred twenty three women were determined to be ineligible (32 = birth by cesarean section, 26 = self-reported postpartum BMI $\geq$ 30 kg/m^2 or $\leq$ 24.9 kg/m^2, 25 = unable to contact post-delivery/ infant's health/ multiple births/ lived outside recruitment area, 16 = too young or old, 15 = too active or did not agree to be randomized, and 9 = formula feeding). Thirty one women were randomly assigned, stratified by parity, after completion of baseline measurements [4.3 (0.8) weeks postpartum] into either the intervention group (*n* =16) or minimal care group (*n* = 15). One woman in the minimal care group is still participating. Four women (two in each group) did not complete the study. Three women (interventio*n* = 2, minimal care = 1) stopped breastfeeding and introduced formula (greater than four ounces per day on a regular basis) before completion of the study. The fourth (minimal care) moved out of state and was unable to return to complete endpoint measurements. The baseline characteristics of the four who discontinued the study were not different between the women who completed the study (*n* = 26).

No significant differences were seen between the two groups at baseline, except baseline weight was significantly higher in the intervention group compared to the minimal care group (p = 0.03) (see Table 5.1). The screening for BMI (self-reported height and weight) was between 24.9 and 30 kg/m^2, however when height and weight were measured in the lab, BMI ranged from 24.5 to 35.2

kg/m^2. Two women in the minimal care group actual BMI was greater than 30 kg/m^2 (34.6 and 34.3), whereas six women in the intervention group actual BMI was greater than 30 kg/m^2 (range 31.2 to 35.2).

Table 5.1. *Baseline Characteristics of the Minimal Care and Intervention Group*

Characteristic		Minimal Care (n = 12)	Intervention (n = 14)
Age (yr)		30.7 (3.7)	31.9 (3.1)
Parity (no.)			
	1	6	6
	> 2	6	8
Baseline Wt (kg) [a]		72.5 (10.5)	81.6 (10.1)
Baseline BMI (kg/m^2)		27.8 (3.3)	29.7 (3.6)
Pre-pregnancy Wt (kg)		66.2 (12.3)	73.7 (10.8)
Height (cm)		161.4 (5.9)	165.8 (5.4)
Weight of Infants (kg)			
	Birth	3.3 (0.4)	3.5 (0.4)
	4 wk	4.2 (0.4)	4.3 (0.3)
Gain (4 to 20 wks)		2.5 (0.5)	2.7 (0.5)
Sex of Infant (no.)			
	Female	9	10
	Male	3	4

BMI = body mass index (weight in kilograms divided by the height in meters squared)
Data are mean (SD)
[a] Significantly different between groups, p = 0.03, ANOVA

Twenty-five of the women enrolled were Caucasian, five African American (minimal care group = 3, intervention group = 2) and one Latino (intervention group). Two Caucasian and two African American women (one per group) did not complete the study. All women enrolled had a college education.

The intervention group lost significantly more weight than the minimal care group [-5.8 (3.5) kg versus -2.4 (4.9) kg, respectively, $p = 0.04$] (see Table 5.2). Six of the women in the intervention group lost >7.2 kg, which is equivalent to the weight loss goal of the study of 0.5 kg per week. Both groups significantly improved their BMI ($p = 0.05$), lowered their percent body fat ($p = 0.03$) and reduced fat mass ($p = 0.03$) during the intervention with no difference between groups. The intervention group lost 14.5 (13.1)% of their body fat, and the minimal care group lost 9.8 (14.1)%, $p = 0.1$. Waist and hip circumference significantly decreased in the intervention group [-6.3 (3.3) cm and -5.3 (4.1) cm, respectively] compared to the minimal care group [-2.1 (7.9) cm and -1.7 (5.7) cm, respectively], $p = 0.05$. Total body bone mineral density (BMD), bone mineral content (BMC), and area were similar from baseline to endpoint in both groups (see Table 5.3). BMD and BMC in the lumbar spine and hip significantly decreased over time, $p < 0.01$.

There were no differences in infant growth (weight or length) between the two groups. The infants gained an average of 0.15 (0.03) kg per week from baseline to endpoint in the intervention group, which was similar to the average infant's weight gain in the minimal care group, 0.15 (0.03) kg per week.

Table 5.2. ***Body Composition of the Minimal Care and Intervention Groups***

	Minimal Care Group (n = 12)			Intervention Group (n = 14)		
	Baseline	Endpoint	% Change	Baseline	Endpoint	% Change
Weight (kg) [a]	72.5 (10.5)	70.1 (13.2)	-3.5 (7.1)	81.6 (10.1)	75.8 (10.3)	-7.2 (4.4)
BMI (kg/m2) [b]	27.8 (3.3)	26.9 (4.4)	-3.8 (7.1)	29.7 (3.6)	27.6 (3.7)	-7.2 (4.4)
Body Fat						
kg [b]	30.2 (9.0)	27.6 (10.1)	-9.8 (14.1)	36.4 (7.0)	31.4 (8.3)	-14.5 (13.1)
Percent [b]	41.1 (6.5)	38.4 (7.2)	-6.9 (7.7)	44.4 (4.3)	40.8 (6.3)	-8.2 (11.1)
LBM (kg)	39.6 (3.8)	40.1 (4.6)	1.1 (5.7)	42.3 (4.8)	41.6 (3.4)	-1.0 (6.5)
Fat Free Mass (kg)	42.2 (3.9)	42.6 (4.8)	0.7 (5.0)	45.1 (4.8)	44.4 (3.6)	-1.3 (5.5)
Waist circumference (cm) [a]	80.6 (5.8)	79.1 (10.3)	-2.1 (7.9)	86.3 (9.0)	81.0 (9.8)	-6.3 (3.3)
Hip circumference (cm) [a]	105.4 (7.7)	103.7 (11.3)	-1.7 (5.7)	111.1 (6.4)	105.2 (7.5)	-5.3 (4.1)
WHR	0.77 (0.05)	0.76 (0.06)	-0.5 (3.8)	0.78 (0.05)	0.77 (0.06)	-0.9 (3.6)

LBM = lean body mass (non-bone); Fat Free Mass = LBM + BMC

Mean (SD)

[a] Significantly different over time and between groups, $p < 0.05$, RMANOVA
[b] Significantly decreased over time, $p < 0.05$, RMANOVA

Table 5.3. ***Bone Mineral Density of the Minimal Care and Intervention Groups***

	Minimal Care Group (*n* = 12)			Intervention Group (*n* = 14)		
	Baseline	Endpoint	% Change	Baseline	Endpoint	% Change
Total Body						
BMD (g/cm^2)	1.185 (0.099)	1.177 (0.113)	-0.7 (2.0)	1.227 (0.059)	1.213 (0.057)	-1.1 (0.8)
BMC (g)	2623 (515)	2491 (369)	-4.3 (5.3)	2839 (308)	2742 (263)	-2.9 (8.8)
Area (cm^2)	2199 (256)	2109 (152)	-3.6 (5.9)	2317 (249)	2262 (205)	-1.8 (9.2)
Lumbar Spine						
BMD (g/cm^2) [a]	1.179 (0.171)	1.132 (0.151)	-3.8 (3.4)	1.254 (0.105)	1.211 (0.010)	-3.4 (2.5)
BMC (g) [a]	57 (9)	54 (8)	-4.5 (4.6)	67 (10)	64 (9)	-4.9 (5.6)
Area (cm^2)	49 (4)	48 (4)	-0.8 (1.9)	54 (5)	53 (5)	-1.5 (6.0)
Hip						
BMD (g/cm^2) [a]	1.082 (0.150)	1.047 (0.149)	-3.2 (1.9)	1.056 (0.133)	1.024 (0.134)	-3.1 (1.7)
BMC (g) [a]	32 (4)	31 (4)	-3.2 (2.2)	33 (4)	32 (4)	-3.2 (1.8)
Area (cm^2)	30 (2)	30 (2)	-0.1 (1.0)	31 (2)	31 (2)	-0.1 (0.6)

BMD = bone mineral density; BMC = bone mineral content

Mean (SD)

[a] Significantly decreased over time, $p < 0.01$, RMANOVA

Infants' length was similar between the groups at baseline and endpoint [intervention 53.5 (1.6) cm and 64.4 (2.4) cm; minimal care 52.7 (1.8) cm and 62.6 (2.2) cm, respectively].

Both groups reduced their energy and calcium intake over time. The intervention group significantly reduced their energy intake [- 613 (521) kcal] compared to the minimal care group [- 222 (414) kcal], $p < 0.05$ (see Table 5.4). Additionally, the intervention group reported consuming a higher amount of dietary calcium at both baseline and endpoint compared to the minimal care group, $p = 0.02$. Two women (one in each group) reported taking calcium supplements during the study. Five women in the intervention group restricted their dairy intake which attributed to the decrease in calcium intake. Despite the dairy restriction, the intervention group consumed a higher amount of calcium from their diet than the minimal care group. The percent of energy from carbohydrate significantly increased in the intervention group, while decreasing in the minimal care group, $p = 0.05$. Both groups decreased the percentage from fat from energy, but the intervention group consumed significantly less of their energy from fat [29.1 (5.4)%] compared to the minimal care group [33.8 (6.5)%], $p = 0.04$.

Cardiovascular fitness significantly improved in both groups during the study, but there was no significant difference between the groups (see Table 5.5). One woman in each group was unable to complete the endpoint cardiovascular fitness testing due to illness.

Table 5.4. ***Reported Dietary Intake of the Minimal Care and Intervention Groups***

	Minimal Care Group (*n* = 12)		Intervention Group (*n* = 14)	
	Baseline	Endpoint	Baseline	Endpoint
Energy				
kcal [a]	2001 (503)	1780 (433)	2383 (510)	1770 (433)
kcal/kg	28.0 (8.4)	25.4 (4.6)	29.8 (8.2)	23.7 (6.8)
Percent of Energy From				
Carbohydrate [a]	50.8 (5.7)	50.0 (6.2)	50.5 (4.9)	54.5 (5.2)
Protein	16.2 (3.2)	17.4 (3.3)	16.4 (3.2)	18.3 (3.0)
Fat [a]	34.3 (5.5)	33.8 (6.5)	34.6 (4.5)	29.1 (5.4)
Protein				
g	80.2 (23.7)	77.2 (22.5)	95.2 (16.3)	79.8 (19.7)
g/kg	1.1 (0.4)	1.1 (0.2)	1.2 (0.3)	1.1 (0.3)
Calcium (mg) [a]	941 (228)	917 (204)	1344 (335)	1007 (255)
Calcium:Protein Ratio	12.2 (3.5)	12.7 (4.3)	14.2 (2.8)	13.3 (4.3)
Vitamin D (mcg)	3.5 (1.8)	3.8 (2.6)	5.0 (2.1)	3.7 (1.9)

Mean (SD)

[a] Significantly different over time and between groups, $p < 0.05$, RMANOVA

Table 5.5. ***Cardiovascular Fitness and Muscular Strength of the Minimal Care and Intervention Groups***

	Minimal Care Group (*n*=12)[*]			Intervention Group (*n*=14)		
	Baseline	Endpoint	% Change	Baseline	Endpoint	% Change
VO_2 (ml/kg/min) [a,**]	30.7 (4.0)	33.8 (7.2)	9.3 (16.5)	31.8 (5.3)	34.5 (7.2)	9.0 (14.4)
VO_2 (L/min)	2.2 (0.3)	2.4 (0.8)	4.4 (19.1)	2.6 (0.5)	2.6 (0.7)	0.6 (14.0)
Squats (lbs) [b,***]	88 (15)	100 (15)	17 (21)	88 (18)	124 (19)	47 (30)
Bench Press (lbs)	55 (15)	59 (12)	9 (16)	52 (11)	62 (17)	21 (26)
Bent-over Row (lbs) [c]	50 (11)	55 (14)	10 (23)	53 (16)	72 (14)	48 (53)
Deadlift (lbs) [c]	81 (21)	91 (24)	13 (32)	90 (14)	117 (18)	31 (21)
Military Press (lbs) [c]	42 (9)	43 (10)	2 (23)	40 (12)	49 (9)	28 (28)
ACSM Curl-ups (#) [****]	22 (7)	25 (0)	14 (33)	22 (8)	25 (0)	14 (35)
ACSM Push-ups (#) [b,****]	10 (5)	15 (7)	65 (51)	8 (8)	20 (9)	209 (189)

VO_2 = maximal oxygen consumption

[*] One participant in the minimal care group was unable to perform the fitness testing due to an illness at endpoint.
[**] One participant in the intervention group was unable to perform the treadmill test at endpoint.
[***] One participant in the intervention group was unable to perform the 1-RM test for squats at endpoint due to an unrelated knee injury.
[****] One participant in the intervention group was unable to the curl-up and pushup test due to an illness at endpoint.

[a] Significantly different over time, $p < 0.05$, RMANOVA
[b] Significantly different over time, $p < 0.05$, and over time between groups, $p < 0.05$, RMANOVA
[c] Significantly different over time and between groups, $p < 0.05$, RMANOVA

The intervention group wore their pedometers on average 97.2 (17.5) [range 61 to 112] days out of a possible 112 days. The average daily steps were 4838 (2814) with an average of 917 (561) aerobic steps. Participants reported that bad weather, lack of time, and no childcare were reasons for the low number of steps recorded during the weekly recording of the pedometer log.

The total volume of work performed (sets x repetitions x weight lifted in pounds) by the intervention group over the 16 weeks was 181,467 (40104) pounds, which translates to an average daily workout volume of 3781 (836) pounds. The intervention group had a 91.2 (9.9)% [range 66.7 to 100%] compliance to the resistance training program. The compliance to the program was reflected in the change of muscular strength and endurance (Table 5.5). One woman in the minimal care group was unable to perform the 1 RM test as well as the ACSM curl-ups and pushups due to an illness. One participant in the intervention group was unable to perform the squat 1 RM due to an unrelated knee injury and another participant was unable to perform the ACSM curl-ups and pushups test due to an illness. Both groups improved their strength for squats and push-ups during the study, $p < 0.05$ over time. However, the intervention group significantly improved their strength for squats, bent-over row, deadlifts, military press, and push-ups compared to the minimal care group, $p < 0.05$.

Prolactin levels and estradiol levels significantly decreased in both groups during the intervention, $p < 0.05$ (see Table 5.6).

Table 5.6. ***Description of Hormone Levels of the Minimal Care and Intervention Groups***

	Minimal Care Group (*n* = 12)		Intervention Group (*n* = 14)	
	Baseline	Endpoint	Baseline	Endpoint
Prolactin (μg/L)[a]	278 (221)	94 (64)	190 (119)	73 (29)
Estradiol (pmol/L)[a]	354 (182)	182 (108)	240 (160)	124 (73)
hGH (μg/L)				
Basal state	6.6 (5.9)	6.6 (6.7)	6.4 (4.3)	7.9 (7.5)
Immediate Post 1-RM	12.6 (8.6)*	9.4 (8.2)*	8.0 (6.7)	14.6 (8.2)*
Acute % Change[b]	166 (212)%*	117 (98)%*	34 (90)%	343 (468)%*

hGH = human growth hormone; Basal state = fasted pre-exercise; RM = repetition maximum

Mean (SD)

* Blood samples were not collect at post 1RM measurements in one participant at baseline and two participants at endpoint in the minimal care group and two in the intervention group at endpoint.
[a] Significantly different over time, $p < 0.05$, RMANVOA
[b] Significantly different over time and between groups, $p < 0.05$, RMANOVA

Three women resumed their menses (one in the intervention group at 11 weeks postpartum and two in the minimal care group at 7.3 and 8.1 weeks postpartum) during the study. Five women in each group started birth control during the study (3 per group used the minipill and 2 per group used IUDs). The intervention group started using birth control at 8.9 (2.5) weeks postpartum, whereas the minimal care group waited until 13.9 (6.2) weeks postpartum to start birth control, $p = 0.1$. No change in basal hGH was observed from baseline to endpoint. Additionally, there were no significant increases in hGH immediately post exercise or over the duration of the study for either group. There were five women who had missed blood draws immediately post 1RM due to collapsed veins: one woman in the minimal care group at the baseline post 1 RM and two women in each group at the endpoint post 1RM.

Discussion

This was the first study to describe the effects of energy restriction, walking, and resistance training on body composition and BMD in overweight lactating women. The intervention group throughout the study was heavier, but they were able to reduce their energy intake and lose significantly more weight, primarily from fat mass (-5.1 kg versus -2.7 kg) than the minimal care group. Although the intervention group lost more weight (-5.8 kg versus -2.4 kg), infant growth was not affected.

Similar results were reported in two other studies that examined the effects of energy restriction during lactation (9-10). The first study compared the effects of a reduced energy diet (1900 kcal/d) and a reduced energy diet (2100 kcal/d) with aerobic exercise (i.e. walking, bicycling, swimming), to a control group (2500 kcal/d) (9). The BMI for the women ranged from normal to overweight (21 to 29.4 kg/m^2) and all women were fully breastfeeding. The two groups with energy deficits lost weight (1.9 kg and 1.6 kg), primarily from fat mass. The study was eleven days in length and started around 12 weeks postpartum. No difference was observed with milk volume or composition. The second study in an overweight population started around the fourth week postpartum and was 10 weeks in length with a moderate calorie reduction (-500 kcal/d) combined with aerobic exercise (walking) (10). The diet and exercise group lost 4.8 kg of body weight, primarily from fat mass (4.0 kg), and infant growth was not affected.

In this study, despite reporting a 613 kcal deficit, there was a large range in the amount of weight loss (-2 to 11.6 kg, n =13) with one participant increasing weight (+0.6 kg) in the intervention group. The intervention group failed to achieve an average weight loss of 0.5 kg per week and only 6 of the 14 lost > 7.2 kg during the 16 weeks. Some women may have underreported their dietary intake and did not decrease their energy intake by 500 kcal/ day. Underreporting is more likely to occur in overweight women compared to women of normal weight (57). Additionally, the women were unable to achieve the aerobic exercise prescription of walking 10,000 steps per day, which would have facilitated further weight loss. The participants in the Lovelady et al. (10) study were compliant to the 45 minute aerobic sessions four days per week; however, a research assistant was present for their walking sessions. In this study, the participants were asked to achieve 10,000 steps per day on their own. These factors may have contributed to the women not achieving the weight loss goal for this study.

The bone loss in the lumbar spine from six months of lactation is equivalent to 2 years of bone loss during menopause. Studies in overweight/ obese postmenopausal women (not using hormone replacement therapy) have shown no significant effect of energy restriction and weight loss when combined with weight bearing exercise on bone, specifically the lumbar spine (35,58-60). Other studies have reported an increase in protein (>1 g/kg body weight) and calcium (>1000 mg/d) consumption to be protective of bone and fat-free mass during periods of energy restriction and weight loss (18,33,61), especially when coupled with resistance training exercise (34,58,62). Protein (1.1 g/kg) and calcium intake (1007 mg/d) for the intervention group in this study was above the protective levels other studies have previously shown.

There is limited research into the benefits of exercise or physical activity on BMD in women during the postpartum period. Two studies with a self-reported (not randomized) exercise interventions that were less than three months in duration reported BMD changes during lactation to be similar to non-exercising lactating women (63-64). In a third study, lactating women were randomized around the fourth week postpartum to either an exercise group (45 minutes of walking plus three days per week of resistance training) or control group for 16-weeks (38). The exercise group lost less lumbar spine BMD compared to the control group (-4.8% vs. -7.0%, respectively).

Likewise, this study had both an aerobic and resistance training exercise intervention. However, the loss of lumbar spine BMD was similar between the intervention and minimal care groups (-3.4% and -3.8%, respectively). A potential reason for the lack of differences between groups in this study, or further attenuation exercise may have had on bone loss, may be due to the positive osteogenic effect higher body mass has on bone, coupled with greater calcium reserves and higher estradiol levels.

The loss of lumbar spine BMD was less in the control group of this study (-3.8%) compared to the previous study (-7.0%) (38). The difference might be attributed to the heavier weight of the women in this study (27.8 kg/m^2 versus 24.8 kg/m^2, respectively). Previous studies have shown a positive relationship with BMI and BMD (65-67). In general, the heavier a women is the higher the BMD. Additionally, the minimal care group for this study decreased their energy intake by 222 kcal. This was less than the previous study control group who reduced their intake by 422 kcal (38). Greater energy restriction without exercise may cause to a greater loss of lumbar spine BMD (35).

The cardiovascular fitness levels of the intervention group for this study were similar at 4 and 20 weeks postpartum to a previous study by Lovelady et al. (38) with similar time points (4 weeks 31.8 ml/kg/min versus 31.1 ml/kg/min and

20 weeks 34.5 ml/kg/min versus 34.7 ml/kg/min, respectively). The minimal care group in this study started at a lower baseline fitness levels (30.7 ml/kg/min versus 32.4 ml/kg/min) but improvement was similar as the control group in the Lovelady et al. (38) study (33.8 ml/kg/min versus 34.4 ml/kg/min). An improvement in cardiovascular fitness was most likely attributed to a decrease in body weight for both groups versus exercise.

The intervention group failed to achieve 10,000 steps per day and on average walked 4838 steps per day. In a survey of 200 men and women, the average daily steps were 5210 for American women and the higher the BMI (overweight to obese) the lower the average steps (68). When steps are classified into activity levels, less than 5000 steps was considered to be sedentary (52). A purposeful walk was needed in order to achieve 10,000 steps per day. Participants self-reported that bad weather, lack of time, and no childcare were reasons for the low number of steps recorded during the weekly recording of the pedometer log. There are a number of studies that reported similar results for barriers to change or physical activity (69-73). The most common predictor of change in exercise was support of the woman’s partner (70). Lack of childcare and time are the biggest barriers for postpartum women to overcome (70,73).

The resistance program had a much higher compliance to the training protocol than the daily steps primarily due to a research assistant present for at least one if not all three strength sessions each week. The high compliance was reflected in strength being significantly improved in the intervention group compared to the minimal care group. Additionally, the resistance program was designed to take no more than 20 to 30 minutes or could be done one set or exercise at a time allowing for flexibility around childcare.

When compared to the previous study by Lovelady et al. (38), the women in this study had higher 1-RM values for all exercises at baseline and endpoint. The strength gains were similar in the two studies for squats, military press, and pushups for all groups. Bench press, bent-over row, and deadlift gains were greater in the exercise group in the previous study (38) compared to this study's intervention group due to differences in the resistance training protocol. The weight training protocol for this study focused on challenging the muscle to strain the bone at different angles throughout the 16-week study. The exercises changed and the weight lifted was adjusted accordingly to stay at a 3 set, 12 to 15 repetition protocol. In the previous study (38), the strength exercises remained the same for the entire 16 week study, with the weight lifted increased, with an increase in sets (1 to 5 sets) and a decrease in repetitions (12 to 5). A ceiling effect was seen with the ACSM curl-up test. The participants in both groups were able to achieve 25 curl-ups at baseline (minimal care group 10 out of 12 and intervention group 12 out of 14), which is the maximum amount for the test, allowing for no room for improvement that the endpoint measurement. The ACSM pushup test may not have been the best measure of local muscular endurance for this population as well. Although it allowed for a standardized test, the women were mechanically unable to place their chin on the mat especially at baseline. The chest of the women would touch the mat first prior to their chin, making the test less valid for this population.

Prolactin levels are high during the early postpartum period and decline as lactation continues (19,74). The prolactin levels in this study were elevated at baseline but declined during the 16 weeks, which was to be expected. The estradiol levels were still elevated from pregnancy at baseline. As both groups lost weight, estradiol levels decreased to levels similar to the luteal phase. Similar levels of prolactin, estradiol, and lumbar spine bone loss were observed in a longitudinal study of lactating women. Krebs et al. (19) reported a decrease in prolactin levels 140 μg/L to 50 μg/L and estradiol levels 300 pmol/L to 140 pmol/L from 2 to 20 weeks postpartum. They reported that the change in prolactin and estradiol levels corresponded to a 4% loss in lumbar spine BMD. The decrease in estradiol levels in this study did not decline to as low of levels as those reported by Krebs et al. or in Chapter III, but the changes in lumbar spine BMD were similar (-3.4% intervention group and -3.8% minimal care group).

Acute bouts of aerobic and resistance exercise in eumenorrheic women have been shown to stimulate hGH production post exercise (40-41). However, the magnitude of hGH increase is related to duration and intensity of exercise (40-41). Kraemer et al. (39) found 6 sets of 10 repetition maximum (RM) squats increased the immunoreactive fraction (<30 kDa) of hGH but not the most common measured biological active fraction (30-60 kDa). Chronic aerobic exercise has shown to increase hGH in women depending on intensity of training (40,42-43). Weltman et al. (42) found eumenorrheic women who train above lactate threshold increased hGH secretion and had an amplified pulsatile release of hGH at rest. The women in this study trained below lactate threshold for both aerobic and resistance exercise, which may have contributed to a lack of significance in acute or chronic changes in hGH levels.

The limitations to this study include the use of DXA for body composition and a small sample size. We had previously shown the use of DXA for body composition in this population may lead to an overestimation of fat free mass at baseline due to fluid retention from pregnancy (38). Bioelectric impedance would have been a warranted measurement to quantify changes in tissue hydration from pregnancy to the postpartum period and during the 16 week study (75-77). Additionally in this study's population with a higher BMI and body thickness (> 25 cm), DXA was more likely to be overestimate fat mass (~4%) or fat free mass (~2%) (45). Sagittal diameter measurements along with waist circumference would have been a complimentary measurement to DXA for abdominal visceral fat estimation (78).

In a recent study estimating body fat in collegiate athletes, DXA overestimated the percent of body fat by 5% compared to the five compartment model. In addition, as body fat increased, the overestimation increases, especially in female athletes with greater than 20% body fat (79). A correction factor was suggested to use in athletes whose body fat was greater than 20%.

When the correction factor was applied to this study's population, body fat percentages were 10% lower at baseline [33.6 (3.4)%] and endpoint [31.6 (4.1)%] in both groups.

Another concern is with hydration, especially since the participants were breastfeeding at baseline and endpoint. For normal populations, hydration has little effect on lean tissue mass and generally reflect normal variations that occur throughout the day with no effect on fat mass or bone density (45). An increase or decrease of hydration levels by 5% would bias the percent fat by 1 to 2.5% (45). On average a woman produces 23 to 27 ounces of breast milk per day. If a woman was fully engorged, this would translate into a 1% fluid increase, well below the 5% level which would produce a bias due to breast milk. However, we controlled for this by the time the infant last nursed to the time of the DXA scan was no more than two hours.

The initial sample size calculated was 26 (13 per group). The sample size was estimated based on non-weight loss study (38) to provide enough power (80%) to detect change in lumbar spine BMD. However, the loss of lumbar spine BMD observed in the intervention group was similar to the study the power calculation was based on but the minimal care group lost less BMD than anticipated, perhaps due to higher estrogen levels. Given this study's results, a sample size of 1500 (750 per group) would be needed to provide enough power (80%) to detect change in lumbar spine BMD in overweight lactating women. In order to detect an acute effect of exercise on hGH, a sample size of 100 (50 per group) would provide enough power (80%) to detect a significant difference.

These results suggest moderate energy restriction, walking, and resistance training are safe methods for weight loss in overweight fully breastfeeding women with no adverse affects on BMD and infant growth. Both groups improved their body composition, but the intervention group was able to safely lose more weight through moderate energy restriction and exercise. The intensity of the exercise intervention in this study may have been below the threshold to elicit an acute or chronic response in growth hormone. Further research is needed to examine the effects of the intensity, duration, and frequency of exercise on body composition, bone density, and hormones in normal and overweight lactating women.

References

1. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999-2008. *JAMA* 2010, 303(3):235-241.

2. National Heart Lung and Blood Institute 2010. *Diseases and conditions index: Overweight and obesity.* US Department of Health and Human Services and the National Institute of Health. Available at: http://www.nhlbi.nih.gov/health/dci/Diseases/obe/obe_causes.html.

3. Baker JL, Gamborg M, Heitmann BL, Lissner L, Sorensen TI, Rasmussen KM. Breastfeeding reduces postpartum weight retention. *Am J Clin Nutr* 2008; 88(6):1543-1551.

4. Gunderson E. Childbearing and obesity in women: Weight before, during, and after pregnancy. *Obstet Gynecol Clin North Am* 2009; 36(2):317-332.

5. Walker LO, Sterling BS, Timmerman GM. Retention of pregnancy-related weight in early postpartum: Implications for women's health services. *JOGNN* 2005; 34:418-427.

6. Maddah M, Nikooyeh B. Weight retention from early pregnancy to three years postpartum: A study in Iranian women. *Midwifery* 2009; 25(6):731-737.

7. Amorim A, Linne Y, Lourenco P. Diet or exercise, or both, for weight reduction in women after childbirth. *Cochrane Database Syst Rev* 2007; 18(3):CD005627.

8. Rooney B, Schauberger C. Excess pregnancy weight gain and long-term obesity: One decade later. *Obstet Gynecol* 2002; 100(2):245-252.

9. McCrory M, Nommsen-Rivers L, Mole P, Lonnerday B, Dewey K. Randomized trial of the short-term effects of dieting compared with dieting

plus aerobic exercise on lactation performance. *Am J Clin Nutr* 1999; 69:959-967.

10. Lovelady C, Garner K, Moreno K, Williams J. The effect of weight loss in overweight, lactation women on the growth of their infants. *N Engl J Med* 2000; 342(7):449-453.

11. Compston J, Laskey M, Croucher P, Coxon A, Kreitzman S. Effect of diet-induced weight loss on total body bone mass. *Clin Sci* 1992; 82(4):429-432.

12. Jensen L, Quaade F, Sørensen O. Bone loss accompanying voluntary weight loss in obese humans. *J Bone Miner Res* 1994; 9(4):459-463.

13. Hyldstrup L, Andersen T, McNair P, Breum L, Transbøl I. Bone metabolism in obesity: Changes related to severe overweight and dietary weight reduction. *Acta Endocrinol* 1993; 129(5):393-398.

14. Fogelholm G, Sievanen H, Kukkonen-Harjula T, Pasanen M. Bone mineral density during reduction, maintenance and regain of body weight in premenopausal, obese women. *Osteo Int* 2001; 12:199-206.

15. Van Loan MD, Johnson HL, Barbieri TF. Effect of weight loss on bone mineral content and bone mineral density in obese women. *Am J Clin Nutr* 1998; 67(4):734-738.

16. Bowen J, Noakes M, Clifton PM. A high dairy protein, high-calcium diet minimizes bone turnover in overweight adults during weight loss. *J Nutr* 2004; 134(3):568-573.

17. Gallagher D, Kovera AJ, Clay-Williams G, Agin D, Leone P, Albu J, Matthews DE, Heymsfield SB. Weight loss in postmenopausal obesity: No adverse alterations in body composition and protein metabolism. *Am J Physiol Endocrinol Metab* 2000; 279:E124-E131.

18. Riedt CS, Schlussel Y, von Thun N, Ambia-Sobhan H, Stahl T, Field MP, Sherrell RM, Shapses SA. Premenopausal overweight women do not lose

bone during moderate weight loss with adequate or higher calcium intake. *Am J Clin Nutr* 2007; 85:972-980.

19. Krebs NF, Reidinger CJ, Robertson AD, Brenner M. Bone mineral density changes during lactation: Maternal, dietary, and biochemical correlates. *Am J Clin Nutr* 1997; 65:1783-1746.

20. Kulkarni B, Shatrugna V, Nagalla B, Kumar P, Rani K, Omkar A 2009 Maternal weight and lean body mass may influence the lactation-related bone changes in young undernourished Indian women. *Br J Nutr* 2009; 101:1527-1533.

21. Laskey MA, Prentice A. Bone mineral changes during and after lactation. *Ostet Gynecol* 1999; 94:608-615.

22. More C, Bettembuk P, Bhattoa HP, Balogh A. The effects of pregnancy and lactation on bone mineral density. *Osteo Int* 2001; 12:732-737.

23. Ritchie L, Fung E, Halloran B, Turnlund J, Van Loan M, Cann C, King J. A longitudinal study of calcium homeostasis during human pregnancy and lactation and after resumption of menses. *Am J Clin Nutr* 1998; 67:693-701.

24. Kalkwarf HJ. Hormonal and dietary regulation of changes in bone density during lactation and after weaning in women. *J Mammary Gland Biol and Neo* 1999; 4(3):319-329.

25. Kalkwarf H, Specker B. Bone mineral changes during pregnancy and lactation. *Endocrine* 2002; 17(1):49-53.

26. Kovacs CS. Calcium and Bone metabolism during pregnancy and lactation. *J Mammary Gland Biol and Neo* 2005; 10(2):105-118.

27. Prentice A. Micronutrients and the bone mineral content of the mother, fetus and newborn. *J Nutr* 2003; 133(Suppl 2):1693S-1699S.

28. Larson-Meyer D. Effect of postpartum exercise on mothers and their offspring: A review of the literature. *Obes Res* 2002; 10(8):841-852.

29. Laskey M, Prentice A. Effects of pregnancy on recovery of lactational bone loss. *The Lancet* 1997; 349:1518-1519.

30. Sowers M, Hollis B, Shapiro B, Randolph J, Janney C, Zhang D, Schork A, Crutchfield M, Stanczyk F, Russell-Aulet M. Elevated parathyroid hormone-related peptide associated with lactation and bone density loss. *JAMA* 1996; 276(7):549-554.

31. Laskey M, Prentice A, Hanratty LA, Jarjou LM, Dibba B, Beavan SR, Cole TJ. Bone changes after 3 mo of lactation: Influence of calcium intake, breast-milk output, and vitamin D-receptor genotype. *Am J Clin Nutr* 1998; 67:685-692.

32. Andersen RE, Wadden TA, Herzog RJ. Changes in bone mineral content in obese dieting women. *Metabolism* 1997; 46(8):857-861.

33. Layman DK, Evans E, Baum JI, Seyler J, Erickson DJ, Boileau RA. Dietary Protein and Exercise Have Additive Effects on Body Composition during Weight Loss in Adult Women. *J Nutr* 2005; 135(8):1903-1910.

34. Nakata Y, Ohkawara K, Dong J, Okura T, Tanaka K. Effects of additional resistance training during diet-induced weight loss on bone mineral density in overweight premenopausal women. *J Bone Miner Metab* 2008; 26:172-177.

35. Ryan AS, Nicklas BJ, Dennis KE. Aerobic exercise maintains regional bone mineral density during weight loss in postmenopausal women. *J Appl Physiol* 1998; 84(4):1305-1310.

36. You T, Murphy KM, Lyles MF, Demons JL, Lenchik L, Nicklas BJ 2006 Addition of aerobic exercise to dietary weight loss preferentially reduces abdominal adipocyte size. *Int J Obes* 2006; 30(8):1211-1216.

37. Bowen J, Noakes M, Clifton P. Effect of calcium and dairy foods in high protein, energy-restricted diets on weight loss and metabolic parameters in overweight adults. *Int J Obes* 2005; 29:957-965.

38. Lovelady C, Bopp MJ, Colleran HL, Mackie HK, Wideman L. Effect of exercise training on loss of bone mineral density during lactation. *Med Sci Sports Exerc* 2009; 41(10):1902-1907.

39. Kraemer WJ, Nindl BC, Marx JO, Gotshalk LA, Bush JA, Welsch JR, Volek JS, Splering BA, Maresh CM, Mastro AM, Hymer WC. Chronic resistance training in women potentates growth hormone in vivo bioactivity: Characterization of molecular mass variants. *Am J Physiol Endocrinol Metab* 2006; 291:E1177-E1187.

40. Consitt LA, Copeland JL, Tremblay MS. Endogenous anabolic hormone responses to endurance versus resistance training in women. *Sports Med* 2002; 32(1):1-22.

41. Kraemer WJ, Fleck SJ, Dziados JE, Harman EA, Marchitelli LJ, Gordon SE, Mello R, Frykman PN, Koziris LP, Triplett NT. Changes in hormonal concentrations after different heavy-resistance exercise protocols in women. *J Appl Physiol* 1993; 72(2):594-604.

42. Weltman A, Weltman JY, Schurrer R, Evans WS, Veldhuis JD, Rogol AD. Endurance training amplifies the pulsatile release of growth hormone: Effects of training intensity. *J Appl Physiol* 1992; 72(6):2188-2196.

43. Tworoger SS, Missmer SA, Eliassen AH, Barbieri RL, Dowsett M, Hankinson SE. Physical activity and inactivity in relation to sex hormone, prolactin, and insulin-like growth factor concentrations in premenopausal women. *Cancer Causes Control* 2007; 18:743-752.

44. Franklin BA. American College of Sports medicine’s guidelines for exercise testing and prescription, 2000. Lipponcott Williams & Wilkins, Philadelphia, PA, USA.

45. Heymsfield SB, Lohman TG, Wang Z, Going SB. *Human body composition: Chapter 5 dual-energy x-ray absorptiometry,* 2005, 2nd ed. Human Kinetics, Champaign, IL, USA, pp. 63-77.

46. Olds SB, London ML, Ladewig PW. Pospartal adaptation and nursing assessment. In: VS J, M E (eds.) *Maternal newborn nursing,* 2000, 6th ed. Prentice-Hall, New Jersey, pp. 906-930.

47. Blanton C, Moshfegh A, Baer D, Kretsch M 2006 The USDA automated multiple-pass method accurately estimates group total energy and nutrient intake. *J Nutr* 2006; 136:2594-2599.

48. Moshfegh A, Rhodes D, Baer D, Murayi T, Clemens J, Rumpler W, Paul D, Sebastian R, Kuczynski K, Ingwersen L, Staples R, Cleveland L. The US Department of Agriculture automated multiple-pass method reduces bias in the collection of energy intakes. *Am J Clin Nutr* 2008; 88:324-332.

49. Weber J, Reid P, Greaves K, DeLany J, Standford V, Going S, Howell W, Houtkooper LB. Validity of self-reported energy intake in lean and obese young women, using two nutrient databases, compared with total energy expenditure assessed by doubly labeled water. *Eur J Clin Nutr* 2001; 55:940-950.

50. U.S. Department of Health and Human Services. *Physical activity: A report of the Surgeon General,* 1996. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Atlanta, CA, pp 3-6.

51. Hultquist CN, Albright C, Thompson DL. Comparision of walking recommendations in previously inactive women. *Med Sci Sports Exerc* 2005; 37(4):676-683.

52. Tudor-Locke C, Hatano Y, Pangrazi RP, Kang M 2008 Revisiting "How many steps are enough?" *Med Sci Sports Exerc* 2008; 40(7):S537-S543.

53. US Department of Agriculture 2009. *MyPyramid for pregnancy and breastfeeding*. Available at: http://www.mypyramidtracker.gov/planner/launch.aspx.

54. IOM, FNB 2005. *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids (macronutrients).* National Academy Press, Washington DC, pp. 107-264.

55. American Heart Association Inc. 2007. *Eat less of the nutrient-poor foods.* Available: http://www.americanheart.org/presenter.jhtml?identifier=3040349.

56. American Heart Association Inc. 2007. *Diet and lifestyle recommendations.* Available at: http://www.americanheart.org/presenter.jhtml?identifier=851.

57. Livingstone MBE, Black AE. Markers of the validity of reported energy intake. *J Nutr* 2003; 133(3):895S-920.

58. Campbell W, Haub M, Wolfe R, Ferrando A, Sullivan D, Apolzan J, Iglay H. Resistance training preserves fat-free mass without impacting changes in protein metabolism after weight loss in older women. *Obesity* 2009; 17(7):1332-1339.

59. Lynch NA, Nicklas BJ, Berman DM, Dennis KE, Goldberg AP. Reductions in visceral fat during weight loss and walking are associated with improvements in VO2max. *J Appl Physiol* 2001; 90:99-104.

60. Ryan AS, Nicklas BJ, Berman DM, Dennis KE. Dietary restriction and walking reduce fat deposition in the midthigh in obese older women. *Am J Clin Nutr* 2000; 72:708-713.

61. Bopp MJ, Houston DK, Lenchik L, Easter L, Kritchevsky SB, Nicklas BJ. Lean mass loss is associated with low protein intake during dietary-induced weight loss in postmenopausal women. *Journal of the American Dietetic Association* 2008; 108(7):1216-1220.

62. Hunter G, Byrne N, Sirikul B, Fernández J, Zuckerman P, Darnell B, Gower B. Resistance training conserves fat-free mass and resting energy expenditure following weight loss. *Obesity* 2008; 16(5):1045-1051.

63. Drinkwater B, Chesnut C. Bone density changes during pregnancy and lactation in active women: A longitudinal study. *Bone and Miner* 1991; 14:153-160.

64. Bassey E, Rothwell M, Littlewood J, Pye D. Pre- and Postmenopausal women have different bone mineral density responses to the same high-impact exercise. *J Bone Miner Res* 1998; 13(12):1805-1813.

65. Steinschneider M, Hagag P, Rapoport MJ, Weiss M. Discordant effect of body mass index on bone mineral density and speed of sound. *BMC Musculoskelet Disord* 2003; 4:15.

66. De Laet C, Kanis J, Odén A, Johanson H, Johnell O, Delmas P, Eisman J, Kroger H, Fujiwara S, Garnero P, McCloskey E, Mellstrom D, Melton L, Meunier P, Pols H, Reeve J, Silman A, Tenenhouse A 2005 Body mass index as a predictor of fracture risk: a meta-analysis. *Osteoporos Int* 2005; 16(11):1330-1338.

67. Asomaning K, Bertone-Johnson E, Nasca P, Hooven F, Pekow P. The association between body mass index and osteoporosis in patients referred for a bone mineral density examination. *J Womens Health (Larchmt)* 2006; 15(9):1028-1034.

68. Tudor-Locke C, Bassett DR. How many steps/day are enough? *Sports Med* 2004; 34(1):1-8.

69. Devine CM, Bove CF, Olson CM. Continuity and change in women's weight orientations and lifestyle practices through pregnancy and the postpartum period: the influence of life course trajectories and transitional events. *Soc Sci Med* 2000; 50:567-582.

70. Downs DS, Hausenblas HA. Women's exercise beliefs and behaviors during their pregnancy and postpartum. *J Midwifery Womens Health* 2004; 49:138-144.

71. Keller C, Allan J, Tinkle MB. Stages of change, processes of change, and social support for exercise and weight gain in postpartum women. *JOGNN* 35:232-240.

72. Krummel DA, Semmens E, Boury J, Gordon PM, Larkin KT. Stages of change for weight management in postpartum women. *J Am Diet Assoc* 2004; 104:1102-1108.

73. Pereira MA, Rifas-Shiman SL, Kleinman KP, Rich-Edwards JW, Peterson KE, Gillman MW. Predictors of change in physical activity during and after pregnancy. *Am J Prev Med* 2007; 32(4):312-319.

74. Sowers M, Zhang D, Hollis BW, Shapiro B, Janney CA, Crutchfield M, Schork MA, Stanczyk F, Randolph J. Role of calciotrophic hormones in calcium mobilization of lactation. *Am J Clin Nutr* 1998; 67:284-291.

75. Piccoli A, Rossi B, Pillon L, Bucciante G. A new method for monitoring body fluid variation by bioimpedance analysis: the RXc graph. *Kidney Int* 1994; 46:534-539.

76. Kyle U, Bosaeus I, De Lorenzo A, Deurenberg P, Elia M, Gómez J, Heitmann B, Kent-Smith L, Melchior J, Pirlich M, Scharfetter H, Schols A, Pichard C. Composition of the ESPEN Working Group. Bioelectrical impedance analysis-Part I: Review of principles and methods. *Clin Nutr* 2004; 23:1226-1243.

77. Lukaski H, Hall C, Siders W. Assessment of change in hydration in women during pregnancy and postpartum with bioelectrical impedance vectors. *Nutrition* 2007; 23:543-550.

78. Clasey J, Bouchard C, Teates C, Riblett J, Thorner M, Hartman M, Weltman A. The use of anthropometric and dual-energy X-ray absorptiometry (DXA) measures to estimate total abdominal and abdominal visceral fat in men and women. *Obes Res* 1999; 7(3):256-264.

79. Moon J, Eckerson J, Tobkin S, Smith A, Lockwood C, Walter A, Cramer J, Beck T, Stout J. Estimating body fat in NCAA Division I female athletes: A

five-compartment model validation of laboratory methods. *Eur J Appl Physiol* 2009; 105:119-130.

EPILOGUE

The presented research in this dissertation was the first to describe and compare changes in bone turnover markers, hormones, and bone mineral density in exercising and sedentary normal weight women during lactation. Additionally, it was the first to examine the effects of an exercise and energy restriction intervention on attenuation of lactation-induced bone loss in overweight women as well as anabolic hormones. To our knowledge, this was also the first study to use *MyPyramid Menu Planner for Moms* for dietary counseling using the total diet approach.

The results of the first study suggest that exercise and higher dietary calcium intake may slow the loss of BMD during lactation. The second study expanded on the findings from the first study in this dissertation. The results suggested moderate energy restriction, aerobic exercise, and resistance training are safe methods for weight loss in overweight fully breastfeeding women with no adverse affects on BMD and infant growth. Additionally, the use of *MyPyramid Menu Planner for Moms* appeared to be a novel tool for dietary counseling and weight loss.

The success of the two studies presented in this dissertation was a result of several years of collaboration with the community for recruitment, the women who volunteered their time and opened their homes to our research staff, and the research staff, who traveled to participant's home three times per week to help with childcare, morale support, and progress the exercise programs. Recruitment was one of the biggest problems encountered for the research in this dissertation. About 25% of the women screened were ineligible due to delivery by cesarean section. Previous to recruitment for the second study, medical clearance by a physician for exercise was around six to eight weeks postpartum making women ineligible based on time postpartum. Presently, women are being medical cleared for exercise around the fourth week postpartum after delivery by cesarean section. The exercise protocol for the second study would have been contraindicated after a major surgery in the abdominal region. The program was designed to target the core increasing the chance of slowing the healing process around the incision.

An additional 20% self-reported BMI's outside the BMI eligibility range for the study. The pre-pregnancy BMIs of the women screened ranged from 18 kg/m^2 to 46 kg/m^2. The study design was to promote weight loss through healthy dietary choices and physical activity, which appeals to a wide-range of women. There were a small number of normal weight and active women who were interested in the study to help them return to their pre-pregnancy weight. Whereas, the obese to morbidly obese women were recommended by their physicians to take this opportunity to enroll in a free weight loss study which would help them achieve a healthier lifestyle after their baby was delivered. On a personal note, turning away the obese women from the study was difficult. Many of them were seizing the opportunity to help change their lifestyle not only for themselves, but for their infant. It was hard to tell a pregnant woman she was “too heavy” to participate in a weight loss intervention. In most cases I was able to find other reasons for ineligibility.

Another problem encountered was the woman’s inability to achieve 10,000 steps or 3,000 aerobic steps per day. The commonly reported barriers were time, bad weather, illness, lack of child care and spousal support. Conversely, the compliance to the strength training program was high. Many of the women were able to achieve the strength workouts without the presence of research staff. The difference between the daily steps and strength program was convenience. The women reported it was easier to find 20 minutes during the day for the strength workout, versus 30 minutes to an hour for walking. The strength program was done within their home, compared to the daily steps which meant a purposeful walk outside the home. Multiparous participants reported their toddlers or preschoolers would not want to sit in a stroller but would want to walk with them, slowing the moms walking speed. Additionally, extreme weather (cold, heat, rain, snow, and wind) were real barriers to being able to walk outside with children. On average, the participants who owned treadmills or elliptical or whose spouses would help with childcare were successful in being able to achieve the recommended daily steps. For future studies, perhaps incorporation of a circuit training strength protocol may help with improvement of aerobic compliance.

There are a few areas for future research I would like to see expanded from this dissertation. The first would be to quantify the barriers to postpartum exercise and weight loss. Currently, we are capturing self-efficacy and barrier data in questionnaire form; however, I would like to see this data expanded into motivational interviews of the participants enrolled in the second study. I believe this data would give insight as to why some of the women were successful with losing weight and changing their lifestyle, and others were not. Gaining this insight may better direct future dietary and exercise interventions in overweight lactating women.

The second would be to design a research study further examining the effects of calcium on bone density during lactation. The study would be a four-arm research design from four to twenty weeks postpartum. Prepregnancy and pregnancy calcium intake, including calcium supplements, would determine eligibility for groups. Three of the groups would be women who have a chronically low consumption of calcium (< 500 mg/d). The women with low calcium intakes would be randomized (stratified by parity and BMI) to one of three groups: 1. control (no change in current calcium intake), 2. calcium supplement (diet + supplement = 1000 mg/d) and 3. increase in dietary calcium (dietary = 1000 mg/d). The fourth group would be women who chronically consume > 1000 mg/d of calcium.

The third study would be to further explore hormones that regulate appetite, such as leptin and grhelin, and the effects on exercise and weight loss during lactation. Some studies in women have shown exercise to have an effect on appetite. However, I think more research is needed to examine the effects of the intensity, duration, and frequency of exercise on hormones that regulate appetite in women, particularly during lactation. These hormones may have played a role in why some women successfully lose weight. Lastly, a follow-up at one-year postpartum is currently in progress. It will be interesting to see the change in bone density and body composition, especially in the women who continued to exercise beyond the 16-week intervention, and compare them to the results of our previous study with normal weight women, who stopped exercising after the 16-week intervention.

Overall, this research was extremely rewarding for not only the participants involved but for research staff. The study was designed to promote lifestyle changes in overweight women. We were successful in improving diet and increasing physical activity in this population with no adverse affects on BMD or infant growth. For the first study, I was involved in study implementation, applied and basic (hormone) laboratory assessment, and data analysis. The second study I was involved in every aspect from concept design, recruitment, implementation, applied and basic laboratory assessment, and data analysis. I look forward to seeing the results of the one-year follow-up and comparison of the two studies, as well as future studies examining the effects of exercise on bone density during lactation. I have enjoyed my time spent on these research studies, especially working with the participants and the research assistants.

APPENDIX A

STUDY 1 FORMS

Want to GET IN SHAPE after you have your baby???

* ARE YOU EXPECTING OR DO YOU HAVE A NEW BABY??

* ARE YOU INTERESTED IN PARTICIPATING IN AN *EXERCISE PROGRAM* AFTER YOU HAVE YOUR BABY??

* DO YOU WANT TO *GET IN SHAPE* BY IMPROVING YOUR FITNESS LEVEL AND MUSCULAR STRENGTH??

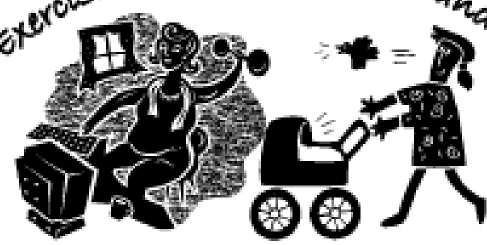
* DO YOU PLAN TO EXCLUSIVELY BREASTFEED FOR THE FIRST 5 MONTHS POSTPARTUM??

YES?

Then GIVE US A CALL!

(You must be pregnant or your baby must be less than 2 weeks old)

Breastfeeding & Exercise for Healthy Infants and Postpartum Moms.



Be-Hip Mom!

<u>Research Study</u>

Lactation and Bone Mineral Density

UNCG Departments of Nutrition and Exercise Science

CALL: Dr. Cheryl Lovelady or Melanie Bopp at **336-256-1090**

Research Study: Effect of Exercise and Weight Loss on Bone during Lactation

First Contact Date:______

Initial Questionnaire

Prenatal

Name__________________________ **Weeks Pregnant**__________________

Phone Number_________________ **Due Date for Infant**________________

Age____________________________ **Number of Children**_______________

Age of children?

Breastfed? C-Sections?

Address____

Prepregnancy Weight ____lbs____kg **Sedentary in 3rd trimester?**_____

Current Weight_____lbs____kg **Smoker?**______________________

Current Height_____ft_____in **Agrees to random assignment?**____

Agrees to multivitamin?______

Any chronic diseases? (DM, HTN, CVD, asthma, bone/joint problems? Medications?____

Plan to breastfeed exclusively for 1st 5 months postpartum?___________

Will you be returning to work outside the home? If so, how many hours a week?____

BMI (prepregnant):_________

Comments:

Postnatal

Infant Birth Weight____________ Infant Birth Length____________

Name of Infant________________ Actual Birth Date for Infant______

Gender of Infant_______________ Name of Physician_____________

Physician's Phone______________

C-section?________________ Delivery/Pregnancy Complications?____

Full term infant?__________Weight After Delivery?______lbs_____kg

Singleton birth?__________ Current Weight_______lbs______kg

BMI___________________ Current Height_______lbs_______kg

How much weight did you gain during pregnancy?_______________

Daily/Weekly Schedule:

Checklist:

- Initial Questionnaire Complete
- Informed Consent
- Medical Clearance Form
- Dietary recall sheets and visuals
- Breast milk sample tubes (2)
- Vitamins
- Next visit scheduled
- Forms for DXA and blood draw instructions
- Directions

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO

Consent to Act as a Human Subject

PARTICIPANT'S NAME ______________________________

DATE OF CONSENT ______________________________

PROJECT TITLE: Effect of Exercise Training During Lactation on Mother's Bone Status

INVESTIGATORS: Cheryl Lovelady Ph.D., R.D., Laurie Wideman Ph.D., Melanie Bopp, and Heather Kennedy

DESCRIPTION AND EXPLANATION OF PROCEDURES: The purpose of this study is to determine the bone status of the lactating mother as a result of resistance and aerobic exercise training. The study will begin two to three weeks after you deliver and will continue until you are at your twentieth week postpartum. If you consent to participate, you will be assigned by chance to one of two groups. The first group will participate in the measurements and the exercise program. If you are assigned to the other, or control group, you will participate in all the measurements described below but will not participate in the exercise program. After completion of the project, the control group will be offered the opportunity to learn the procedures used in the experimental group to promote increased bone status through a personalized exercise prescription.

Participants in both groups will be asked to do the following:

1. Receive medical clearance from your physician, through the form provided, to participate in the exercise program.
2. Participate in three short dietary recall sessions. You will be called three times in one week at your convenience at the beginning and end of the study. This diet record will be used to determine your nutritional intake.
3. At 2 to 3 weeks and at 20 weeks postpartum you will be given a body scan by dual energy x-ray absorptiometry (DXA). This whole-body scan is necessary to determine your bone density. The scan will be completed at the J. Paul Sticht Center on Aging at the Wake Forest University Medical Center in Winston Salem. You will lay still and flat on an x-ray table, and the scanner will move back and forth several feet above you. The entire procedure takes approximately 30-45 minutes, depending on your height. Your breast milk will not be affected by the DXA scan.
4. At 20 weeks postpartum, you will be given a pregnancy test to ensure that you are not pregnant when the DXA scan is administered.
5. Visit the Human Performance laboratory at UNCG for several measurements at the beginning (4 weeks) and end (20 weeks) of the study. This visit should take less than 2 hours.

a) Your height and weight will be recorded first.
b) Then your cardiovascular fitness will be determined through an exercise test on a treadmill. You will walk or run on the treadmill, beginning at a low level, and will increase until you reach 85% of your calculated maximum heart rate. A researcher certified in cardiopulmonary resuscitation (CPR) will be present at the exercise session. Heart rate and rating of perceived exertion will be measured throughout this test.
c) You will be asked to provide approximately 4 tbls of venous blood after an overnight fast (no alcohol for 24 hours prior to blood draw). The blood will be drawn in the morning at the lab. Venipuncture will be performed by a trained phlebotomist. The blood is needed to assess your bone status.

6. Muscular strength will be assessed at the beginning and end of the study. We will be testing the strength of your muscles using hand weights.
7. You will be asked to collect a small urine sample in the morning on the day of your visit to the lab. The first void of the morning is preferable. You will collect the urine sample into a sterile urine collection cup, and will need to store the sample in your home refrigerator until you come into the lab. You will bring the sample with you to the lab.
8. During the morning feeding on the day you visit the lab, you will collect approximately 4 tablespoons of breast milk. While the infant is nursing on one breast, the milk sample will be obtained from your other breast (a breast pump will be provided if needed). All samples must be chilled immediately in household refrigerator. You will bring the sample with you to the lab.
9. After 20 weeks of the study, you will be asked to repeat all of the measurements above.

Those assigned by chance to the exercise group will also be asked to do the following:
1. Participate in resistance exercise sessions (30-45 minutes) three times each week at your home. All necessary equipment will be provided. A video will be provided for instruction on proper weight training technique. You will also participate in aerobic exercise sessions (45 minutes) three times a week. A qualified research assistant certified in CPR and educated on proper resistance training technique will be present at exercise sessions at least 3 times a week to monitor your training technique (to prevent injury), exercise intensity level, and heart rate.
2. Participate in strength tests every six weeks to determine any necessary changes to your personalized resistance-training program.

RISKS AND DISCOMFORTS: The risk of injury during exercise exists for you; temporary muscle fatigue and/or respiratory discomfort may result from the graded exercise test. Exercise sessions may result in temporary muscle soreness. Insertion of the needle during venipuncture may be slightly painful. Every precaution will be taken to minimize the risks involved with venipuncture (air emboli, infection, bruising, and fainting). You will be exposed to very mild radiation from the DXA scan, equivalent to 1/10 the exposure from a routine chest x-ray, and less than the exposure of a dental x-ray. There is no risk to your breast milk.

POTENTIAL BENEFITS: Results of all the tests conducted will be provided to you at no cost. Mothers participating in the study will undergo two free bone density scans, which provide valuable bone density and body composition information. All participants will receive, at no cost, a stability ball, hand weights, and video for home exercise; however, women in the control group will not receive these materials until completion of the study. Benefits to the exercising mothers also include the potential for increased cardiovascular fitness, increased muscular strength, and increased lean muscle tissue.

COMPENSATION/TREATMENT FOR INJURY: In the case of injury, you will be referred to your personal physician for treatment. You are responsible for paying for your treatment for injury. Upon completion of the study, you will receive a $50 stipend.

CONSENT: Your signature on this consent form indicates that you have read the procedures, risks and benefits involved in this research. You are free to refuse to participate or to withdraw your consent to participate in this research at any time without penalty or prejudice; your participation is entirely voluntary. Your privacy will be protected because you will not be identified by name as a participant in this project. All collected data will be stored in a locked file cabinet and will be shredded when it is no longer needed.

The research and this consent form have been approved by the University of North Carolina at Greensboro Institutional Review Board that ensures that research involving humans follows federal regulations. Questions regarding your rights as a participant in this project can be answered by calling Eric Allen at (336) 334-5878. Questions regarding the research itself can be answered by Dr. Cheryl Lovelady by calling (336) 256-0310. Any new information that develops during the project will be provided to you if the information might affect your willingness to continue participation in the project.

By signing this form, you are agreeing to participate in the project described to you by ________

________________________ ________________________

Subject's Signature Witness to Signature

MEDICAL CLEARANCE FORM

APPLICANT'S SIDE

This form is required for acceptance in the lactation study and must be completed by you and your attending physician. This information along with your physician's statement will be used for your participation in a graded exercise test and for prescription of an exercise program. Please check any of the conditions that apply to you.

Name (Print) ______________________________

Age __________ **Weight** __________ **Height** __________

1. Do you have any of the following risk factors for heart disease?

   ______Inactive lifestyle ______High Blood Triglycerides
   ______Stressful lifestyle ______High Blood Cholesterol
   ______Stroke ______High Blood Pressure
   ______Diabetes Mellitus ______Obesity
   ______Smoke Cigarettes (if yes, # per day _____)
   ______Heart disease in family (if yes, please specify ____________________)

2. Have you ever experience any of the following?

   ______Chest pain
   ______Chest Pressure
   ______Palpitations/skipped heart beats

   Discomfort/pain in the: _____throat _____wrist _____elbow _____teeth _____jaw

3. Do you have or has a physician diagnosed you as having any of the following?

   ______Heart murmur ______Chronic Bronchitis ______Musculoskeletal problems
   ______Emphysema ______Arthritis ______Neurological problems
   ______Asthma ______Allergies ______Other (explain) __________

4. Have you ever undergone surgery for any of the following?

   ______Varicose veins ______Leg surgery ______Abdominal Surgery
   ______Hernia repair ______Musculoskeletal ______Other (explain) __________

5. Have you ever had any of the following tests?

   ______Exercise Stress test ______Coronary Angiography ______Echocardiogram
   ______Holter Monitor ______Exercise Stress test with Isotope

6. Please list all medications/supplements that you are taking.

Name of medication	Dosage	Doses/Day
____________________	__________	__________
____________________	__________	__________

7. Are you taking any diet pills or ephedra for weight loss? YES NO

8. Did you exercise vigorously before pregnancy?(circle one) YES NO

9. Did you exercise regularly during your third trimester?(circle one) YES NO

______________________________ __________

Applicant's Signature Date

MEDICAL CLEARANCE FORM

PHYSICIAN'S SIDE

Please check and/or comment on additional history and all pertinent physical findings. This information will be used for the applicant's participation in a graded exercise test and exercise program.

Name of Applicant (print) ______________________________
Name of Physician (print) ______________________________
Physician's Telephone (   ) ______________________________
Physician's Address ______________________________

1. Additional history not mentioned on APPLICANT'S SIDE:
____
____
____
____
____

2. Significant abnormal findings:

HEENT	________	Pulses	________
Chest	________	Extremities	________
Heart	________	Neurologic	________
Abdomen	________	Orthopedic	________
Other	________		

Comments: ______________________________
____
____

3. Please provide the following, if available:

Total cholesterol	______	Blood pressure	____/____
Triglycerides	______	Resting pulse	________
LDL _____ HDL	______		

4. I have examined the above-named individual and find no reason why she should not participate in a graded exercise test or other physical activities.

______________________________ Physician's Signature

______________________________ Date

PARTICIPANTS: PLEASE BRING THIS FORM DIRECTLY TO CHERYL LOVELADY OR HEATHER COLLERAN. PLEASE DO NOT HAVE YOUR PHYSICIAN'S OFFICE MAIL IT TO US. THANK YOU.

For further information, please contact:

Cheryl Lovelady, Ph.D., R.D. OR Heather Colleran, R.D. CSCS
UNCG Department of Food and Nutrition
Phone: (336) 256-0310

Multivitamin given to all participants:

Vitamin A	5000 IU
Vitamin C	60 mg
Vitamin D	400 IU
Vitamin E	30 IU
Thiamin	1.5 mg
Riboflavin	1.7 mg
Niacin	20 mg
Vitamin B6	2 mg
Folic Acid	400 mcg
Vitamin B12	6 mcg
Pantothenic Acid	10mg

Photo Release Form

I am a participant in a study conducted in the Department of Nutrition at The University of North Carolina at Greensboro. I am willing to have my picture taken and have it used in future publications associated with this department. I have been told that my name will not be listed with the picture in the publications.

Name Date

<u>Stages of Exercise:</u>

Week 1: Familiarization

3 days per week, 1 set of all exercises, 60% of One Repetition Max (RM). 3-0-3 tempo: 3 seconds down, hold for 0 seconds, and 3 seconds up. 45-60 seconds between each exercise. 10-15 reps of each exercise.

Weeks 2-6: Hypertrophy

Alternating days of the split routine. 70% 1RM, 10-15 reps per set, 3 sets, 3-0-3 tempo, 45-60 seconds rest. Straight set method (doing all 3 sets of one exercise and then moving onto next exercise) or superset method (doing one set of one exercise and then one set of the next until you have done all exercises for that day and then cycle back through all exercises until you finished all 3 sets for each).

Weeks 7-16: Strength

Alternating days, 85% 1RM, 5-8 reps per set, 4-5 sets, 2-0-2 tempo, 2 minutes rest between each. Superset method.

Day 1 Exercises:

Squats: Start standing up with dumbbells at side with feet shoulder width apart and slowly sit down as if sitting in a chair. Make sure knees do not go in front of ankles. Go down until butt is at a 90 degree angle with knees. Arms can be at side or above shoulders with elbows bent.

Bench Press: Can be done lying on ball or floor. On floor, lay down with back flat on floor and legs straight. Hold dumbbells in each hand and raise arms extending from shoulders, straight up. Arms should be directly over chest with elbows extending as you raise arms and elbows bending as you come back down. On ball, rest upper back on the ball in a backbend position with feet flat on the floor, shoulder width apart and extend arms from shoulders, straight up. Make sure to keep abs parallel with the floor and push hips up toward ceiling.

Standing Military Press: Stand straight up with feet shoulder width apart. Hold dumbbells in each hand and raise arms straight up toward ceiling directly from shoulders (i.e. start with elbows bent and raise arms up).

OR Push Press: Same thing as military press, but for variation add squatting down like as in the squats and as the legs become straight then push arms up in the air overhead.

Abdominal Sit-up: Lay down on floor with feet flat on the floor and knees raised. Raise upper back until elbows (or hands, depending on position) touch knees.

Easiest: Start sitting up and slowly with control lower back to the floor.

Next: Start lying down and go up to knees and back down with arms straight out towards knees.

Next: Same as above, but cross arms over chest.

Next: Same as above, but arms are behind neck with elbows bent. Make sure your arms are not pulling on neck and your stomach muscles are doing the work.

Hardest: Same as above, but do all variations on the ball. Position similar to bench press on the ball (i.e. back bend position). The farther back your back and hips are on the ball, the harder the work-out on the stomach muscles.

OR Crunches: Lay down on floor with knees bent and feet either up in the air or flat on floor. Raise upper back to a slight curl; do not come up all the way. Variations for arms are the same as abdominal sit-ups.

Wall Sits: Position back against a wall as if sitting in a chair. Make sure tops of upper leg is parallel to the floor and calf-side of lower leg is parallel to the wall. Let arms rest against back of the wall (i.e. – do not rest hands on hips or legs). Hold for as long as possible while keeping the correct technique.

Day 2 Exercises:

Stiff Leg Deadlift: Start standing up with feet about six inches apart. Keep knees slightly bent and hold dumbbells in each hand. Slowly bend over as if touching toes.

Pushups: Lay down with stomach on the floor. Feet should be about six inches apart. With hands shoulder width apart at chest/shoulder level, slowly rise up and then back down and repeat. Shoulders and elbows should be at a 90 degree angle and back should remain parallel to the floor, not arched or sagging.

Easiest: Bend knees and let knees touch the floor and back should be at an angle to the floor as you descend, but make sure back never arches. Just do the down motion and then come up to knees to get back up and then repeat the down motion again.

Next: Same position as above but do both ups and downs.

Hardest: First example, on feet (no knees), doing both ups and downs.

High Pulls: With feet shoulder width apart and knees slightly bent start with arms straight by side with dumbbells in hand and lift fists straight up so that elbows are bent and straight out and then go back down to straighten elbows. Like rowing, but pulling up towards ceiling.

Bent Over Dumbbell Row: With back straight, but slightly bent over, hold dumbbells in each hand and keep arms in 90 degree angle, while raising arms straight up, while keeping elbows bent. Feet should be shoulder width apart with knees slightly bent.

Abdominal Plank (or straight leg sit-up): Start with stomach on the floor and place elbows on the floor with arms bent. Elbows should be anywhere from under chest to further out towards the head, but inside the body. Hold body up and keep back straight, not arched or sagging. Hold position for as long as you can. Start with 5-10 seconds and work up to 30 seconds. When you can do that, move up to the next level trying to achieve one minute or more.

Easiest: Elbows under chest and on knees with legs bent and back at an angle.

Next: Extend elbows further out toward head or further out.

Next: Move up to feet only and keep legs straight.

Hardest: On feet and elbows bent on floor under head or further out.

Resistance training Week 1 - Familiarization

3 days per week – 60% - 1 set per exercise **Please record date and weight lifted each day

3 second lift – hold for 0 seconds – lower for 3 seconds 45-60 second rest between exercises

Day 1		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets	1	1	1	1	
	Number of Reps					
	Pounds lifted:					
		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
	Number of Sets	1	1	1	1	1
	Number of Reps					
	Pounds lifted:					
Day 2		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets	1	1	1	1	
	Number of Reps					
	Pounds lifted:					
		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
	Number of Sets	1	1	1	1	1
	Number of Reps					
	Pounds lifted:					
Day 3		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets	1	1	1	1	
	Number of Reps					
	Pounds lifted:					
		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
	Number of Sets	1	1	1	1	1
	Number of Reps					
	Pounds lifted:					

Resistance training Weeks 2-6

ernate days – 70% - 10-15 reps per set   3 sets per exercise

econd lift – hold for 0 seconds – lower for 3 seconds   **Please record date, weight lifted and number of reps each day

-60 second rest between exercises, straight or supersets

WEEK 2

Day 1		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 3

Day 1		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

Day 3		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 4

Day 1		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 5

Day 1		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank

Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 6

Day 1		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

Resistance training Weeks 7-11

Alternate days – 85% - 5-8 reps per set   4-5 sets per exercise
2 second lift – hold for 0 seconds – lower for 2 seconds   **Please record date, weight lifted and number of reps each day
2 minute rest between exercises, supersets

WEEK 7

Day 1		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

Day 2		Squats	Bench Press	Military Press	Sit ups
Date:	Number of Sets				
	Number of Reps				
	Pounds lifted:				

Day 3		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 8

Day 1		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 9

Day 1		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 10

Day 1		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 11

Day 1		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

Resistance training Weeks 12-16

Alternate days – 90% - 3-5 reps per set   5 sets per exercise

3 second lift – hold for 1 second – lower as quickly as possible   **Please record date, weight lifted and number of reps each day

2-3 minute rest between exercises, supersets

WEEK 12

Day 1		Squats	Bench Press	Military Press	Sit ups
Date:	Number of Sets				
	Number of Reps				
	Pounds lifted:				

Day 2		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

Day 3		Squats	Bench Press	Military Press	Sit ups
Date:	Number of Sets				
	Number of Reps				
	Pounds lifted:				

WEEK 13

Day 1		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 14

Day 1		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 15

Day 1		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

WEEK 16

Day 1		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 2		Stiff leg deadlift	Push up	High Pulls	Dumbbell row	Ab plank
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					
Day 3		Squats	Bench Press	Military Press	Sit ups	
Date:	Number of Sets					
	Number of Reps					
	Pounds lifted:					

Walking Log:

** Please record the date each day you exercise aerobically, this should be 3 days/week.
** Please record what you *actually* do, even if it is different from the goal!!!
** The "Range Goal" is the amount of time you should spend in your target heart rate range. Add a 5 minute warm up and a 5 minute cool down to each session.
** Your target heart rate range is: _________

Date:	Time in Range	Total Time	Range Goal	
example				
*10/20/03_*	*___18____*	*__28____*	*18min*	
*10/22/03_*	*___22____*	*___35___*	*21 min*	
__________	___________	_________	5 min	WEEK 1
__________	___________	_________	10 min	
__________	___________	_________	15 min	
__________	___________	_________	18min	WEEK 2
__________	___________	_________	21 min	
__________	___________	_________	24 min	
__________	___________	_________	27 min	WEEK 3
__________	___________	_________	31 min	
__________	___________	_________	34 min	
__________	___________	_________	37 min	WEEK 4
__________	___________	_________	40 min	
__________	___________	_________	43 min	
__________	___________	_________	45 min	WEEK 5
__________	___________	_________	45 min	

APPENDIX B

STUDY 2 FORMS

Get Fit and Lose Weight After You Have Your Baby

- Are you Pregnant or Have a New Baby?
- Did you Gain Too Much Weight During Your Pregnancy?
- Do you Want to Get In Shape and Lose the Pregnancy Weight?
- Are you Interested in Participating in an Exercise and Weight Loss Program?
- Do you Plan on Exclusively Breastfeeding for the First 5 months Postpartum?

If YES to All Then GIVE US A CALL!
(You must be pregnant or your baby must be less than 2 weeks old)

The purpose of this research is to investigate the effects of exercise and weight loss on bone mineral density during lactation.

All eligible women in the study receive a bone density scan, exercise testing, and blood analysis 3 times during the study. Some women in the study may be enrolled in a FREE 16-week intervention, followed by a maintenance phase until 1-year postpartum which includes exercise training and dietary modifications under the supervision of a personal exercise leader and registered dietitian. All participants completing the 20 and 52 week postpartum measurement will receive monetary compensation plus exercise equipment.

For More Information, please contact:
Dr. Cheryl Lovelady or Heather Colleran
at 336.256.1090 or email hldownin@uncg.edu

UNCG Department of Nutrition
Human Performance Laboratory

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO

CONSENT TO ACT AS A HUMAN PARTICIPANT: LONG FORM

Project Title: Effects of Exercise and Weight Loss on Bone Density During Lactation

Project Director: Cheryl Lovelady Ph.D., R.D., Heather Colleran, R.D. CSCS

Participant's Name: ______

DESCRIPTION AND EXPLANATION OF PROCEDURES:
The purpose of this study is to determine the bone status and weight loss of the lactating mother as a result of resistance and aerobic exercise training, and reduced daily calorie intake to promote healthy bodies and prevention of osteoporosis. The study will begin two to three weeks after you deliver your baby and will continue throughout your first year postpartum. If you consent to participate, your baseline measurements will be done at 3 to 4 weeks postpartum. Upon completion of the baseline measurement (described below) you will be assigned by chance to one of two groups. The first group, or intervention group, will participate in the sixteen week (4 to 20 weeks postpartum) exercise and reduced calorie diet program, followed by a maintenance phase from 20 to 52 weeks postpartum. If you are assigned to the other, or control group, you will be asked not to participate in structured exercise or change your current dietary habits for sixteen weeks (4 to 20 weeks postpartum). Upon completion of the second set of measurements, at 20 weeks postpartum, the control group will be given all dietary intervention materials, as well as a consultation with the registered dietitian. Upon completion of the 52 week postpartum measurement, the control group will be offered the opportunity to learn the procedures as well as given all materials used in the intervention group to promote increased bone status and weight loss through a personalized exercise and diet prescription.

Participants in both groups will be asked to do the following:

1. Receive medical clearance from your physician, through the form provided, to participate in the exercise and diet program.
2. Exclusively breastfeed (less than 4 ounces of formula feed occasionally) until the second set of measurements at 20 weeks postpartum.
3. Participate in three short dietary recall sessions. You will be called three times in one week at your convenience at the beginning (3 to 4 weeks postpartum), at the end of the intervention (20 weeks postpartum), and at 52 weeks postpartum for the maintenance phase of the study. This diet record will be used to determine your nutritional intake and develop a reduced calorie diet for the intervention group.
4. Visit the Human Performance laboratory at UNCG for several measurements at the beginning (4 weeks), end (20 weeks), and follow-up (52 weeks) of the study. This visit should take less than 3 hours, including the DXA scan.

(Continued on next page)

a) You will be asked to provide a total of 4 tablespoons of venous blood per laboratory measurement (4 weeks PP, 20 weeks PP, and 52 weeks PP). The blood will be drawn in the morning at the lab. The first blood draw will be after an overnight fast (no alcohol for 24 hours prior to blood draw) and the second blood draw will occur immediately post exercise testing. Venipuncture will be performed by a trained phlebotomist. The blood is needed to assess your bone hormone status.
b) Then your height and weight will be recorded followed by resting heart rate, blood pressure, and waist circumference.
c) Then your cardiovascular fitness will be determined through an exercise test on a treadmill. You will walk or run on the treadmill, beginning at a low level, and will increase until you reach 85% of your calculated maximum heart rate. A researcher certified in cardiopulmonary resuscitation (CPR) will be present at the exercise session. Heart rate and rating of perceived exertion will be measured throughout this test.
d) We will be testing the strength of your muscles using hand weights. A certified strength and conditioning specialist will administer the strength test.
e) And finally, you will be given a body scan by dual energy x-ray absorptiometry (DXA). This whole-body scan is necessary to determine your bone density. You will lay still and flat on an x-ray table, and the scanner will move back and forth several feet above you. The entire procedure takes approximately 30-45 minutes, depending on your height. Your breast milk will not be affected by the DXA scan.
f) At 20 weeks and 52 weeks postpartum, you will be given a pregnancy test to ensure that you are not pregnant when the DXA scan is administered.

5. You will be asked to collect a small urine sample in the morning on the day of your visit to the lab. The first void of the morning is preferable. You will collect the urine sample into a sterile urine collection cup, and will need to store the sample in your home refrigerator until you come into the lab. You will bring the sample with you to the lab. The urine is needed to measure bone turnover markers.
6. During the morning feeding on the day you visit the lab, you will collect approximately 4 tablespoons of breast milk, preferable no more than 2 hours prior to the lab visit. While the infant is nursing on one breast, the milk sample will be obtained from your other breast (a breast pump will be provided if needed). All samples must be chilled immediately in household refrigerator. You will bring the sample with you to the lab. At 52 weeks postpartum, if you are still breastfeeding your baby, you will be asked to provide a breast milk sample.

(Continued on next page)

Those assigned by chance to the exercise group will also be asked to do the following:

1. Participate in resistance exercise sessions (30-45 minutes) three times each week at your home. All necessary equipment will be provided. A qualified research assistant certified in CPR and educated on proper resistance training technique will be present at exercise sessions at least 3 times a week to monitor your training technique (to prevent injury) for the first 16-weeks of the intervention. This will be followed by a "step-down" phase from 20 to 24 weeks postpartum (PP) to transition you from the exercise intervention to the maintenance phase of this study. The 4-week "step-down" phase consists of strength training two times per week with the research assistant present at least once per week. The maintenance phase of this study is from 24 to 52 weeks postpartum. Strength sessions will be at least once per week with the research assistant present at least twice per month to monitor technique and assist with questions.
2. You will also be encouraged to walk briskly with a pedometer every day. You will be asked to record the number of steps in a log book, which will be provided, with the goal of reaching 10,000 steps per day over the first four weeks of the intervention and maintaining 10,000 steps per day for the entire study (8 to 52 weeks PP).
3. In order to assess compliance to the reduced calorie diet, the research assistant will randomly bring a digital scale to record your weight and a Gulick tape measure for waist circumference every two weeks during the intervention and at least once every 2 months during the maintenance phase (24 to 52 weeks PP).

RISKS AND DISCOMFORTS:
The risk of injury during exercise exists for you; temporary muscle fatigue and/or respiratory discomfort may result from the graded exercise test. Exercise sessions may result in temporary muscle soreness. Insertion of the needle during venipuncture may be slightly painful. Every precaution will be taken to minimize the risks involved with venipuncture (air emboli, infection, bruising, and fainting). You will be exposed to very mild radiation from the DXA scan, equivalent to 1/10 the exposure from a routine chest x-ray, and less than the exposure of a dental x-ray. There is no risk to your breast milk.

POTENTIAL BENEFITS:
Results of all the tests conducted will be provided to you at no cost. Mothers participating in the study will undergo two to three free bone density scans, which provide valuable bone density and body composition information. All participants will receive, at no cost, a stability ball, hand weights, exercise mat, and pedometer for home exercise; however, women in the control group will not receive these materials until completion of the study. Benefits to the exercising mothers also include the potential for increased cardiovascular fitness, increased muscular strength, increased lean muscle tissue and weight loss.

(Continued on next page)

COMPENSATION/TREATMENT FOR INJURY:
The University has no policy or plan to pay for any injuries you might receive as a result of participating in this research protocol. Upon completion of the second set of measurements at 20 weeks postpartum you will receive a $50 stipend and upon completion of the follow-up study at 52 weeks postpartum, you will receive a $50 stipend.

By signing this consent form, you agree that you understand the procedures and any risks and benefits involved in this research. You are free to refuse to participate or to withdraw your consent to participate in this research at any time without penalty or prejudice; your participation is entirely voluntary. Your privacy will be protected because you will not be identified by name as a participant in this project. The researchers reserve the right to terminate any participant for failure to exclusively breastfeed (less than four ounces of formula feed occasionally) until the completion of the second set of measurements at twenty weeks postpartum.

The University of North Carolina at Greensboro Institutional Review Board, which ensures that research involving people follows federal regulations, has approved the research and this consent form. Questions regarding your rights as a participant in this project can be answered by calling **Mr. Eric Allen** at (336) 256-1482. Questions regarding the research itself will be answered by **Dr. Cheryl Lovelady** or **Heather Colleran** by calling **(336) 256-0310**. Any new information that develops during the project will be provided to you if the information might affect your willingness to continue participation in the project.

By signing this form, you are agreeing to participate in the project described to you by ______.

______________________________ ____________
Participant's Signature Date

______________________________ ____________
Principal Investigator's Signature Date

Multivitamin given to all participants (365 tablets)

Vitamin A	5000 IU
Vitamin C	60 mg
Vitamin D	400 IU
Thiamin	30 IU
Riboflavin	1.7 mg
Niacin	20 mg
Vitamin B6	2.0 mg
Folic Acid	400 mcg
Vitamin B12	6 mcg
Sodium	10 mg

THE UNIVERSITY of NORTH CAROLINA
GREENSBORO
Human Nutrition Laboratory

Why measure bone density?

Low bone density is the greatest risk factor for spine and hip fractures. Each year there are approximately 700,000 spine fractures and 250,000 hip fractures in the United States. More than 90% of these occur in people with bone density measurement in the osteoporotic range. The association between low bone density and osteoporotic fracture is similar to the association between cholesterol and heart disease, or blood pressure and stroke. Like cholesterol level and blood pressure, bone density is a risk factor that can be changed. You can't do much about other risk factors such as age, sex, race, or genetic background, but low bone mass can be prevented and treated.

What is DXA?

DXA bone density studies of the spine and hip are considered the "gold standard" for diagnosing osteoporosis and following changes in bone density over time. DXA stands for dual x-ray absorptiometry. It was previously known as DEXA, dual energy x-ray absorptiometry. Low dose x-rays of two different energies are used to distinguish between bone and soft tissue, giving a very accurate measurement of bone density at these sites.

How do I prepare for a DXA scan?

No special patient preparation is necessary. We only ask that you don't wear metal jewelry or anything with buttons, snaps, or zippers including under-wire bras. Wearing sports bras without back closures and pants with an elastic waistband will allow you to remain fully clothed during the scan.

What can I expect to happen during the DXA scan?

DXA is a painless, non-invasive test. You will be asked to lie still and quiet on a padded table, but you will be able to breathe normally. The study lasts only a few minutes. The x-ray dose you will be exposed to is extremely low, similar to what you would receive on a long distance airplane flight.

Adapted from http://www.bonedensity.com/about.htm on Aug 16th, 2007

Be-Hip Mom Too!
UNCG Department of Nutrition
Human Performance Laboratory

INSTRUCTIONS FOR COLLECTIONS OF BREAST MILK FOR HEALTH STATUS

In order to get an accurate assessment of your health status, we ask that you do the following:

1. Fast the night before milk, urine, and blood samples are collected. This means no food, supplements, or drink (except water) from 12:00 a.m. until after the collection of the milk and blood the following morning.

   ****We advise frequent consumption of water the night before and during the morning to maintain adequate hydration for proper milk production****

2. If you are currently taking supplements, we request that you no take them after 9:00 pm the night before and any time the morning of the blood draw and milk collection. The supplement can be taken at any time after the blood samples have been obtained.

3. Collect milk sample (~4 tablespoons) the morning of the blood draw. The sample should be obtained at the first feeding after 5:00 a.m. Pour the collected into the tubes provided.

4. Collect urine from the 1st or 2nd void of the morning, into the provided urine cup.

5. The tubes of milk and urine need to be placed in the refrigerator until time for transport to the lab.

****PLEASE try to feed your baby a minimum of 60 to 90 minutes BEFORE your arrival at UNCG****

Instruction for Treadmill and Body Composition Measurements

1. Exercise Testing:
   a. You will need to bring (or wear) with you a pair of comfortable “workout” shorts, T-shirt, pair of socks and tennis shoes.
2. Bring something light to eat when you come to the lab (e.g. bagel and juice) as well as a water bottle.

Your appointment is for____

Be-Hip Mom Too!
UNCG Department of Nutrition
Human Performance Laboratory

Directions to UNCG – Stone Building (Room 341)

from Lee Street coming from 1-40:

- Take a LEFT onto Tate Street at traffic light (will pass Elm/ Eugene St., music store on right)
- Cross over Spring Garden Rd (church on right, Aycock Auditorium on left)
- Take you <u>NEXT</u> LEFT onto Walker Ave (one-way street)
- Drive straight into parking lot directly in front of you…(looks like you will run into a building(
- Stop right in front of the building….someone from the BE HIP Too! study will be waiting for you to show you where to park.

from Wendover/ Spring Garden:

- Follow Spring Garden St. to campus and continue on straight through campus
- Take a LEFT onto Tate Street at traffic light (Aycock Auditorium on left)
- Take you <u>NEXT</u> LEFT onto Walker Ave (one-way street)
- Drive straight into parking lot directly in front of you…(looks like you will run into a building(
- Stop right in front of the building….someone from the BE HIP Too! study will be waiting for you to show you where to park.

****If you need help finding us or have any questions, please don't hesitate to call Heather's cell phone 336.402.5498****

Initial Screening Form (see Appendix A)

- Additional Screening for those participants' whose actual versus self reported BMI was >30kgm^{-2} (1)

Medical Clearance Form (see Appendix A)

Photo Release Form (see Appendix A)

Breastfeeding & Exercise for Healthy Infants and Postpartum Moms

Be-Hip Mom Too!

Initial Visit:

Consent form (2 copies)
Instructions/ Directions
Supplements
Urine cup
Milk tube
Food visuals (NDS sheets)
Medical Clearance Forms

In Lab:

Retrieve milk and urine samples
Retrieve consent form
Retrieve medical clearance form
Blood pressure/ resting heart rate
Blood draw (baseline/ chronic)
1 RM testing (Strength assessment only!)
Blood draw (acute)
Eat (participants come in fasted)
Barriers Questionnaire
Anthropometrics (height, weight, waist and hip circumference)
Treadmill test
DXA
Muscular endurance assessment
NDS dietary recall (x3)
Random assignment
Schedule first visit (exercise only)
Forms to be completed:
    Measurements and CV test
    Strength/ Endurance assessment

First Home Visit:

Weights
Ball
Yoga mat
Pedometer (set stride length) *start with 4000 steps per day increase 100 to 200 steps per day to achieve 10,000 steps per day within 4 to 6 weeks)*
Written instructions
Exercise log sheets (walking and strength)

Weekly Home Visits:
Gulick tape/ scale/ Infant scale (once per month first 16 weeks only!) monthly
Portable scale
Extra weights
Record sheets
Extra written instructions

1-RM Exercise Description:

Squats:
- Starting position: stand with your feet shoulder width apart and grasp a dumbbell in each hand with your arms hanging by your sides
- Looking straight ahead, inhale, slightly arch your back, and squat down (like you are sitting into a chair)
- Once your thighs are parallel to the floor, straighten your legs and return to the starting position
- Exhale as you complete the movement
- Muscles worked: quadriceps femoris (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius) and gluteals (medium, maximus)

Bench Press:
- Lie flat on the bench with your feet on the floor for stability (or on the bench to flatten your back)
- Starting position: your arms are extended upward and your hands facing in towards each other (palms out) holding the dumbbells
- Inhale and lower the dumbbells to chest level, bending elbows and rotating forearms to bring hands into pronation
- Press the dumbbells back up to starting position
- Exhale as you complete the movement
- Muscles worked: pectoralis major, anterior deltoid, triceps brachii, and anconeus

Seated Military Press:
- Sit on a bench with back straight, grasp a dumbbell in each hand with an overhand grip and lift them to your shoulders, palms facing forward
- Inhale as you press your arms to an extended position overhead
- Return dumbbells to shoulder level
- Exhale as you complete the movement
- Muscles worked: deltoids (anterior, posterior, middle)

Stiff-Leg Deadlift (reverse):
- Starting position: stand with your feet shoulder width apart and grasp a dumbbell in each hand with your arms hanging by your sides with palms facing your thighs
- Looking straight ahead, lower weights by flexing torso (keeping shoulders back), inhale as you contract your abdominal and low back muscles
- Exhale and return to starting position
- Muscles worked: quadriceps femoris, hamstrings (bicep femoris- long and short head, semitendinous, semimembranosus), gluteus maximus, pirformis, deep under aponeurosis spinal muscles (quadratus lumborum, serratus posterior inferior, longissimus, intertransversarii laterals lumborum, iliocostalis), latissimus dorsi, teres major, rhomboideus major, trapezius, serratus, levator anguli oris, splenius cervicis

Bent Over Dumbbell Row:

- Starting position: stand in a split stance (either foot forward) and bend forward from the waist
- Grasp dumbbells with palms facing in
- Looking straight ahead, inhale and pull the dumbbells as high as possible, keeping elbows back and wrists flat or straight
- Exhale and return to starting position
- Muscles worked: trapezius, rhomboideus major, latissimus dorsi, teres major, posterior deltoid, arm flexors (biceps brachii, brachialis, brachioradialis)

Situps:

- Lie supine on the mat with knees flex to 90 degrees and hands on floor next to hips
- Inhale and curl your torso off the floor until shoulder blades are off the mat
- Exhale and return to starting position
- Muscles worked: rectus abdominis, quadriceps femoris, tensor facia latae, obliquus externus abdominis

Pushups:

- Lie prone on the mat with hands shoulder width apart and knees bent
- Extend their arms keeping the back flat
- Inhale and bend elbows until torso is near the mat
- Push back up to the extended arm position and exhale
- Muscles worked: pectoralis major, pectoralis major, clavicular part, anterior deltoid, triceps brachii, and anconeus

Be-Hip Mom Tool

UNCG Department of Nutrition
Human Performance Laboratory

Height (in) no shoes ____________________
Weight (lbs) no shoes ____________________
Infant Weight ____________________
Last time Fed ____________________

Waist circumference (cm) ____________________
Hip circumference (cm) ____________________

Name (Participant Code) ____________________
Participant Visit and Date ____________________
Age ____________________
Resting Blood Pressure ____________________
Resting Heart Rate ____________________
Target Heart Rate ____________________
[(220-age)-RHR]x0.85 + RHR

Treadmill Test: Modified Balke Protocol Data Sheet

Stage	Min	% Grade	Speed	HR	RPE
1	1	0.0			
	2	0.0			
	3	0.0			
2	4	2.5			
	5	2.5			
	6	2.5			
3	7	5.0			
	8	5.0			
	9	5.0			
4	10	7.5			
	11	7.5			
	12	7.5			
5	13	10.0			
	14	10.0			
	15	10.0			
6	16	12.5			
	17	12.5			
	18	12.5			
7	19	15.0			
	20	15.0			
	21	15.0			
8	22	17.5			
	23	17.5			
	24	17.5			

Total Test Time

Predicted VO2max ____________________ %tile

	Min	HR	Min	HR
Recovery	1		5	
(slow tread and keep walking	2		6	
until HR <120bpm)	3		7	
	4		8	

Be-Hip Mom Too!
UNCG Department of Nutrition
Human Performance Laboratory

Name (Participant Code) ______________________________
Participant Visit and Date ______________________________

Warmup 1 set 10 reps X chops to hip and knee

1 Repetition Maximum: Exercise Data Sheet

Exercise	Max Amount LIfted (lbs)	60%	70%	85%	90%
DB Squats					
DB Bench					
DB Deadlift					
DB Bent-over Row (square)					
DB Seated Military Press					

Muscluar Endurance: Exercise Data Sheet

	Max Number	
ACSM Situps		
ACSM Pushups		

Call log for BE HIP Mom Too! Study

16 week intervention – follow up with participant 2x per month
Wk 20 to 52 wks PP – follow up with participant 1x per month

ID:______________________ Group:____________________

Call date:__________________

Menses return?_______________ If yes, when? _______________
Hormonal Birth Control?________ If yes, what kind?____________
Taking vitamins?_____________
Exclusively breastfeeding?________________
If control, are you participating in regular (structured exercise)?__________
If yes, what kind? How often?_____________________________

Call date:__________________

Menses return?_______________ If yes, when? _______________
Hormonal Birth Control?________ If yes, what kind?____________
Taking vitamins?_____________
Exclusively breastfeeding?________________
If control, are you participating in regular (structured exercise)?__________
If yes, what kind? How often?_____________________________

Call date:__________________

Menses return?_______________ If yes, when? _______________
Hormonal Birth Control?________ If yes, what kind?____________
Taking vitamins?_____________
Exclusively breastfeeding?________________
If control, are you participating in regular (structured exercise)?__________
If yes, what kind? How often?_____________________________

Call date:__________________

Menses return?_______________ If yes, when? _______________
Hormonal Birth Control?________ If yes, what kind?____________
Taking vitamins?_____________
Exclusively breastfeeding?_____ ___________
If control, are you participating in regular (structured exercise)?__________
If yes, what kind? How often?_____________________________

Documents for all Participants' Folders at baseline (4 wks PP)

Handout #1:

Breastfeeding & Exercise for Healthy Infants and Postpartum Moms.

Be-Hip Mom Too!

Please remember to bring this folder with you to all of your laboratory appointments.

I f you have any questions or concerns, please don't hesitate to call Heather 336.402.5498

- Handout #2: United States Department of Agriculture(USDA) MyPyramid in Action: Tips for Breastfeeding Moms (2).
- Handout #3: Baby's First Year in Food (3).
- Handout #4: Growth Charts (percentiles) Corresponding to Gender
    - World Health Organization Weight-for-age GIRLS Growth Charts: Birth to 6 months (4) OR
    - World Health Organization Weight-for-age BOYS Growth Charts: Birth to 6 months (5)
- Handout #5: Adapted Food Amounts Booklet for NDSR 24 hour dietary recalls (6)
- Handout #6: Directions to the University of North Carolina at Greensboro Department of Nutrition Human Nutrition Laboratory (see above)

Documents for exercise participants' folders

Progression of the 16-week Exercise Program

Week 1-4: Familiarization

3 days per week
1-3 sets of all exercises, 60%-70% of One Repetition Max (1-RM)
10-15 reps of each exercise
45-60 seconds between each exercise
Warmup: Trunk rotation, X-chops (hip and knee), pushups
Exercises: Squats, bench press, one-arm row, deadlift, military press

Weeks 5-8: Combination

3 days per week
2-3 sets of all exercises, 70%-85% of 1-RM
10-15 reps of each exercise
45-60 seconds between each exercise
Warmup: Trunk rotation, X-chops (hip and knee), lunges (front, back, side), pushups
Exercises: Squats with overhead press, bench, alternating bent over rows, deadlift

Weeks 9-12: Jump Training and Progression

3 days per week
1-3 sets of all exercises, 70%-85% of 1-RM
10-15 reps of each exercise
45-60 seconds between each exercise
Warmup: 50 jumps in place, Trunk rotation, X-chops (hip and knee), lunges (front, back, side), pushups
Exercises: Clean and press with a hop, bench, one-arm row, deadlift, military press,

Weeks 13-16: Combinations with jumping

3 days per week
1-3 sets of all exercises, 70%-85% of 1-RM
10-15 reps of each exercise
45-60 seconds between each exercise
Warmup: 50 jumps in place, Trunk rotation, X-chops (hip and knee), speed lunges, pushups
Exercises: Clean and press with a hop, alternating bent-over row with a twist and dip, One-leg deadlifts, alterating split stance squat jumps with a press overhead, alternating bench press

*All combination exercises are variations of the core exercises used from 1-RM testing and the first four weeks of the exercise intervention.

Weeks 21-24 PP: "Step Down" Phase (see Jump Training and Progression) 2 day per week

Weeks 25-52 PP: Maintenance Phase (see Jump Training and Progression) 1 day per week

Measurements

Participant ID

	Date	Weight	Waist Circumference	Hip Circumference	Abdominal Circumference	Baby's Weight
Baseline						
Week 2						
Week 4						
Week 6						
Week 8						
Week 10						
Week 12						
Week 14						
Endpoint						

Be Hip Mom Too!
UNCG Department of Nutrition
Human Performance Laboratory

BE HIP MOM Too! Exercise Sheet

Aerobic Exercise gradually build to 10,000 steps per day over the next four weeks.
Resistance Exercise

Weeks 1- 4: Familiarization

3 days per week (a day off in between lift days)
1-3 sets per exercise
60-80% 1 RM
10-15 reps
Slow and controlled fluid movements
Rest 45-60 sec. between sets

Week 1
Warmup: **1 set 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Pushups**

Day 1		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						

Day 2		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						

Day 3		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						

Week 2
Warmup: **1-2 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Pushups**

Day 1		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						

Day 2		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						

Day 3		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						

Week 3
Warmup: **1-2 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Pushups**

Day 1		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						

Week 4
Warmup: **1-2 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Pushups**

Day 1		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Squats	Bench	Bent-over Row	Deadlift	Seated Military Press
Date:	Sets Reps Lbs Lifted (total)						

Weeks 5- 8: Combination

3 days per week (a day off in between lift days)
1-3 sets per exercise
70-85% 1 RM
10-15 reps
Slow and controlled fluid movements
Rest 45-60 sec. between sets

Week 5

Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Lunges (front, back, side), Pushups**

Day 1		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						

Week 6

Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Lunges (front, back, side), Pushups**

Day 1		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						

Week 7
Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Lunges (front, back, side), Pushups**

Day 1		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						

Week 8
Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Lunges (front, back, side), Pushups**

Day 1		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Squats with Overhead Press	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	
Date:	Sets Reps Lbs Lifted (total)						

Weeks 9-12: Jump Training and Progression
3 days per week (a day off in between lift days)
1-3 sets per exercise
70-85% 1 RM
10-15 reps
Rest 45-60 sec. between sets

Week 9
Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Lunges (front, back, side), Pushups 50 jumps in place**

Day 1		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						

Week 10
Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Lunges (front, back, side), Pushups 50 jumps in place**

Day 1		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						

Week 11
Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Lunges (front, back, side), Pushups 50 jumps in place**

Day 1		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						

Week 12
Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Lunges (front, back, side), Pushups 50 jumps in place**

Day 1		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Clean and Press (hop)	Bench	Alt Bent over Row (twist or twist & dip)	Deadlift	Military Press
Date:	Sets Reps Lbs Lifted (total)						

Weeks 13-16 Combinations with Jumping
3 days per week (a day off in between lift days)
1-3 sets per exercise
70-85% 1 RM
10-15 reps
Rest 45-60 sec. between sets

Week 13
Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Speed Lunges (front, back, side, side, curtsy), 50 jumps in place**

Day 1		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						

Day 2		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						

Day 3		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						

Week 14
Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Speed Lunges (front, back, side, side, curtsy), 50 jumps in place**

Day 1		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						

Day 2		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						

Day 3		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						

Week 15

Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Speed Lunges (front, back, side, side, curtsy), 50 jumps in place**

Day 1		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						

Week 16

Warmup: **2-3 sets 10 reps of each Exer.: Trunk Rotation, Hip X Chops, Knee X Chops, Speed Lunges (front, back, side, side, curtsy), 50 jumps in place**

Day 1		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						
Day 2		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						
Day 3		Warmup	Clean and Press (hop)	Alternating Bench	Alt Bent over Row (twist or twist & dip)	One-Leg Deadlifts	Alternating Split Stance Squat Jumps with Overhead Press
Date:	Sets Reps Lbs Lifted (total)						

Weekly Pedometer Log

Date	Day	Distance (miles)	Steps	Aerobic Steps
	Monday			
	Tuesday			
	Wednesday			
	Thursday			
	Friday			
	Saturday			
	Sunday			
Average				

Date	Day	Distance (miles)	Steps	Aerobic Steps
	Monday			
	Tuesday			
	Wednesday			
	Thursday			
	Friday			
	Saturday			
	Sunday			
Average				

Nutritional handouts given to the exercise group after randomization and to the control group after endpoint measurement:

- Handout #1: “The 10 Nutrition Rules to Live By” (7)
- Handout #2: “Protein Basics” (8)
- Handout #3: “What’s In Season? North Carolina Fruit and Vegetable Availability” (9)
- Handout #4: “Goodness Grows in Living Color!” (10)
- Handout #5: “How Much Do YOU Eat?” (11)
- Handout #6: “Portion Distortion” (12)
- Handout #7: “Nutrition Fact Sheet: What’s a Mom to Do?” (13)
- Handout #8: “Too Tired to Cook” (14)
- Handout #9: “Nutrition Fact Sheet: 25 Healthy Snacks for Kids” (15)
- Handout #10: “Fit Facts: Healthy Hydration” (16)
- Handout #11: “Fit Facts: Strength Training 101” (17)
- Handout #12: “Fit Facts: A Walk a Day” (18)
- Handout #13: “Step Equivalents” (19)

Documents for control participants' folders:

- Handout #1 sent to participants at week 5 of the intervention: "American Heart Association: Eat Less of the Nutrient-Poor Foods" (20)
- Handout #2 sent to participants at week 11 of the intervention: "American Heart Association: Our 2006 Diet and Lifestyle Recommendations" (21)

References

1. Franklin BA. *American College of Sports Medicine's Guidelines for Exercise Testing and Prescription*, 2000. Lipponcott Williams & Wilkins, Philadelphia, PA, USA.

2. US Department of Agriculture 2007. *MyPyramid in Action: Tips for Breastfeeding Moms*. Available at: http://www.mypyramid.gov/mypyramidmoms/more_info.html.

3. Bazarte M, Beseler L 2008. *Baby's first year in food.* Available at: http://www.RD411.com.

4. World Health Organization 2010. *WHO child growth standards: Weight-for-age girls birth to 6 months (percentile).* Available at: http://www.who.int/childgrowth/standards/chts_wfa_girls_p/en/index.html.

5. World Health Organization 2010. *WHO Child Growth Standards: Weight-for-age boys growth charts: Birth to 6 months (percentiles).* Available at: http://www.who.int/childgrowth/standards/chts_wfa_boys_p/en/index.html.

6. VanHorn L, Stumbo P, Moag-Stahlberg A, Obarzanek E, Hartmuller V, Farris R, Kimm S, Frederick M, Snetselaar L, Luiu K. The dietary intervention study in children (DISC): Dietary assessment methods for 8- to 10- year olds. *J Am Diet Assoc* 1993; 93(12):1396-1403.

7. Carlson A 2008. The 10 nutrition rules to live by (adapted). Available at: http://www.rd411.com/index.php?option=com_content&view=article&id=163:_10-nutrition-rules-to-live-by&catid=78:sports-nutrition&Itemid=357.

8. RD411.com 2008. *Protein basics.* Available at: http://www.rd411.com/index.php?option=com_content&view=article&id=628:protein-basics&catid=102:protein,-fats-and-carbohydrates&Itemid=396.

9. North Carolina Department of Agriculture and Consumer Services 2008. What's in season? North Carolina fruit and vegetable availability. Available at: http://www.ncagr.gov/freshconnect/achart.htm.

10. North Carolina Department of Agriculture and Consumer Services 2008. *Goodness grows in living color!* Available at: http://www.ncagr.gov/markets/gginc/nutrition/synergycolorwheel.htm.

11. United States Department of Agriculture Food and Nutrition Service 2006. *How Much Do YOU Eat?* Available at: http://teamnutrition.usda.gov/Resources/howmuch.html.

12. RD411.com 2008. *Portion distortion.* Available at: http://www.rd411.com/index.php?option=com_content&view=article&id=126:overweight-and-healthy-an-oxymoron&catid=75:obesity-and-weight-control--&Itemid=354.

13. American Dietetic Association 2006. *What's a mom to do?* Available at: http://www.eatright.org.

14. RD411.com 2007. *Too tired to cook.* Available at: http://www.rd411.com/index.php?option=com_content&view=article&id=568:too-tired-to-cook&catid=96:grocery-shopping-and-food-preparation&Itemid=390.

15. American Dietetic Association 2008. *25 healthy snacks for kids.* Available at: http://www.eatright.org.

16. American Council on Exercise 2008. *Fit facts: Healthy hydration.* Available at: http://www.acefitness.org/fitfacts/fitfacts_display.aspx?itemid=2639.

17. American Council on Exercise 2001. *Fit facts: Strength training 101.* Available at: http://www.acefitness.org/fitfacts/fitfacts_display.aspx?itemid=2661.

18. American Council on Exercise 2008. *Fit facts: A walk a day.* Available at: http://www.acefitness.org/fitfacts/fitfacts_display.aspx?itemid=2549.

19. Health Partners Inc. 2010. *10,000 steps and count on feeling great!* Available at: http://www.10k-steps.com/content/pedometer.aspx?owt=1.

20. American Heart Association Inc. 2007. *Eat less of the nutrient-poor foods.* Available at: http://www.americanheart.org/presenter.jhtml?identifier=3040349.

21. American Heart Association Inc. 2007. *Diet and lifestyle recommendations.* Available at: http://www.americanheart.org/presenter.jhtml?identifier=851.