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Obesity among women is a public health problem in the United States. Pregnancy may be one of the causes of this, with 56% of women of childbearing age being overweight or obese. Excessive weight gain during pregnancy and postpartum weight retention may increase a woman's risk of obesity and chronic disease later in life. Moderate calorie restriction and exercise interventions have been shown to reduce body weight and improve body composition during the postpartum period. While weight loss interventions have been successful, high attrition rates limit the widespread effectiveness of these interventions. Furthermore, there is a lack of research examining the effects of a weight loss program on cardiometabolic risk factors in this population. Therefore, the primary aim of the studies in this dissertation were: 1) To determine the effect of a diet and exercise intervention on weight, body composition, and cardiometabolic risk factors, 2) to improve lifestyle behaviors through improved diet quality and cardiovascular fitness, and 3) to describe the relationship between chronic inflammation and bone mineral density (BMD) in overweight and obese postpartum women.

The first study concluded that a home-based diet and exercise program resulted in greater reductions in weight, waist circumference, sagittal diameter, and abdominal fat mass compared to a control group. Additionally, the intervention resulted in a significant improvement in cardiovascular fitness. The second study concluded that the intervention improved triglyceride concentrations, decreased insulin resistance, and improved metabolic syndrome risk factors. Finally, the third study concluded that the intervention

resulted in less loss of BMD at the total body and hip and less loss of BMC at the hip, lumbar spine, and femoral neck after controlling for lactation status and weeks postpartum at baseline. Change in cardiovascular fitness was a predictor of change in total hip and femoral neck BMD, while change in inflammation was a predictor of change in total body BMD.

These results suggest that a home-based, diet and exercise intervention is effective in improving body composition, cardiovascular fitness, and some cardiometabolic risk factors in overweight and obese postpartum women. Additionally, moderate aerobic activity may attenuate bone loss during a weight loss program.

THE EFFECT OF A DIET AND EXERCISE INTERVENTION ON
BODY COMPOSITION AND CARDIOMETABOLIC
RISK FACTORS IN POSTPARTUM WOMEN

by

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CHAPTER I

INTRODUCTION

Excessive weight gain during pregnancy and postpartum weight retention increase a woman's risk of obesity later in life. When compared with other age groups, women during the childbearing years have demonstrated the greatest increase in obesity prevalence in the past 10 years (1). Women who retain some pregnancy weight are more likely to weigh more later in life compared to women who lose all of their pregnancy weight (2). This is important because obesity is related to the development of metabolic syndrome (MetSyn), which is categorized by abdominal obesity, impaired lipids, and elevated glucose and blood pressure (3). It is also associated with increased systemic inflammation (4). Together, MetSyn and inflammation increase the risk of chronic disease. Postpartum women are at risk of MetSyn due to increased weight retention and metabolic changes that occur during pregnancy (5). Increased inflammation may also impact bone mineral density (BMD), particularly in breastfeeding women (6). While weight loss interventions have been successful in postpartum women, high attrition rates and labor-intensive strategies limit the widespread effectiveness of these interventions. Furthermore, there is limited research examining the effects of a weight loss program on cardiometabolic risk factors in this population. Finally, the relationship between changes.

in inflammation, body composition, and aerobic exercise with BMD as a result of a weight loss intervention has not been examined in postpartum women

The long-term goal of this research is to determine strategies that will effectively reduce postpartum weight retention and prevent obesity among women in order to improve health outcomes later in life. The objective of the first study was to determine the effects of a diet and exercise intervention on weight loss and body composition in postpartum women. The objective of the second study was to determine the effect of this intervention on MetSyn, cardiometabolic risk factors, and inflammation in postpartum women. The objective of the third study was to examine the relationship between changes in inflammation, body composition, and cardiovascular fitness to changes in BMD after weight loss.

In order to test these objectives, we addressed three specific aims:

1. **Determine changes in healthy behaviors as a result of a weight loss intervention**
 - *Hypothesis:* Women in the intervention group would have greater reductions in energy intake, greater improvements in diet quality (Healthy Eating Index score), and cardiovascular fitness (predicted VO₂max) than the control group.
2. **Determine the effect of a 12-week nutrition and physical activity intervention on weight, body composition, and cardiometabolic risk factors in postpartum women.**
 - *Hypothesis 1:* Women in the intervention group would lose more weight and fat mass than those in the control group.

- *Hypothesis 2:* Women in the intervention group would experience greater reductions in blood lipids, inflammatory markers (C-reactive protein), glucose, insulin, blood pressure, and waist circumference than the control group.
3. **Determine the effect of the intervention on BMD and the association between inflammation, body composition, and cardiovascular fitness and BMD.**
- *Hypothesis 1:* Women in the intervention group would lose less BMD compared to women in the control group controlling for breastfeeding status.
 - *Hypothesis 2:* Women with higher levels of inflammatory markers would have lower bone mineral density (BMD) compared to women with lower levels of inflammatory markers.
 - *Hypothesis 3:* Women with the greatest improvements in cardiovascular fitness would have less loss of BMD compared to women with decreases in fitness level.

This research presents the results of a 12-week, home-based diet and exercise program, utilizing time and labor-saving strategies, such as individualized diet and exercise recommendations, self-monitoring, and regular follow up with a registered dietitian (RD) by phone or email. Additionally, it describes the changes in cardiometabolic risk factors and inflammation. Finally, it is the first study to our knowledge to describe the relationship between inflammation and BMD during weight loss in postpartum women.

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CHAPTER II

REVIEW OF THE LITERATURE

Effect of Diet and Exercise Interventions on Weight and Body Composition in Postpartum Women

According to the 2009-2010 National Health and Nutrition Examination Survey, 23.9% of women between the ages of 20 and 39 years were overweight, and 31.9% were obese (1). Excessive weight retention during the postpartum period may be a contributing factor to the development of obesity in this population (2). Postpartum weight retention varies greatly among women, and although most women retain just 0.5 to 3 kg postpartum (3), approximately 14 to 20% of women retain 5 kg or more at 6 months postpartum (4). Women who gained the recommended amount of weight during pregnancy weighed 6.5 kg more at a 10 year follow up, while women who gained above the recommendation gained 8.4 kg (2). Women who lost all of their pregnancy weight by 6 months postpartum gained 2.4 kg 10 years later compared to 8.3 kg for those who retained some pregnancy weight (2). Interventions targeted toward weight loss during the postpartum period may play a role in promoting long-term weight management in women of child-bearing age. To date, there have been few randomized controlled trials of weight loss interventions in postpartum women. A recent review of the literature found that interventions focusing on diet alone and diet plus exercise were equally successful in reducing postpartum weight retention (5). The first randomized weight loss trial in this

population was conducted by Leermakers et al (6). Ninety postpartum women who had retained at least 6.8 kg after pregnancy were recruited between 3 to 12 months postpartum. The intervention was a behavioral weight loss program via correspondence over six months, which emphasized nutrition, physical activity, and behavior change strategies. The participants attended two group sessions, received 16 lessons by mail, and were contacted regularly by phone. Women in the treatment group lost significantly more weight than women in the control group (7.8 kg vs. 4.9 kg; $p < 0.03$, respectively). Additionally, 33% of the women in the correspondence group returned to their pre-pregnancy weight compared to 11.5% of women in the control group ($p < 0.05$). These results suggest that a correspondence-based intervention is effective in reducing postpartum weight retention. However, this study observed a high attrition rate of 27%.

Lovelady et al examined the effect of weight loss in 48 overweight, fully breastfeeding women on the growth of their infants (7). Women randomized to the intervention group were instructed to reduce calorie intake by 500 kcal/day and exercise 45 minutes four days a week for 10 weeks to achieve a weight loss of 0.5 to 1.0 kg per week. Women in the intervention group lost significantly more weight than the control group (4.8 kg vs. 0.8 kg). There were no differences in weight or length of the infants. This study suggests that modest weight loss of 0.5 kg per week in overweight, fully breastfeeding women is safe for the growth of their infants.

Another study by Kinnunen et al examined the efficacy of a weight loss intervention targeting postpartum women at primary health clinics (8). Ninety-two primiparas were recruited from 6 child health clinics in Finland. Intervention participants

received individual dietary and physical activity counseling at the child's 2, 3, 5, 6, and 10 month visits. Dietary counseling focused on four strategies to reduce weight retention: having a regular meal plan, consuming at least five servings of fruits and vegetables, increasing consumption of high fiber breads, and limiting high sugar snacks to less than one portion/day. As a result of the intervention, 50% of the women in the intervention group and 30% of the control group returned to pre-pregnancy weight by 10 months postpartum, but these results were not significant ($p = 0.06$). These results suggest that regular diet and physical activity counseling at primary health care visits is successful in reducing postpartum weight retention. However, the dietary changes recommended in the intervention may not have adequately reduced caloric intake. Energy intake was not reported.

O'Toole et al studied the effects of a structured diet and exercise intervention on postpartum weight retention (9). Forty overweight women between 6 weeks and 6 months postpartum, who gained more than 15 kg during pregnancy and had retained more than 5 kg of weight after delivery were randomly assigned to a structured intervention (STR) or a self-directed intervention (SELF). The STR group received individual diet and exercise prescriptions, was instructed to keep daily food and activity records, and participated in regular group education sessions up to 1 year postpartum. Participants in the SELF group met individually with a dietitian and exercise physiologist at baseline only. Women in the STR group had a weight loss of 5.6 kg at 12 weeks and 7.3 kg at 1 year postpartum ($p < 0.001$). No significant changes in weight were observed in the SELF group. While calorie intake was reduced in both groups, there were no

significant differences between STR and SELF at any time point. However, energy expenditure from physical activity was significantly increased in the STR group, but not the SELF group. This study indicates that a structured diet and exercise intervention is effective in reducing postpartum weight retention. While both groups reduced energy intake, regular contact with mothers was shown to be beneficial in increasing physical activity. However, participant retention was low with only 58% of participants remaining until 1 year postpartum.

A larger randomized, controlled weight loss intervention was conducted by Ostbye et al (10). A total of 450 overweight and obese women were recruited at 6 weeks postpartum. The 9 month intervention consisted of 8 healthy eating classes, 10 exercise group classes, and 6 telephone counseling sessions focusing on decreasing intake of total calories and calorie-dense foods and increasing fruits, vegetables and physical activity. Total weight loss was small overall, with no significant differences between groups. Additionally, changes in caloric intake and physical activity did not differ between groups. Of note, participation in intervention sessions was low, with participants attending an average of 3.8 classes and 3.3 counseling calls. An open-ended survey at the completion of the study found that time constraints made it difficult for mothers to attend the classes. However, class participation was found to be significantly associated with weight loss. These results suggest that while group weight loss classes are successful in reducing weight during the postpartum period, the demands of childcare present a burden for new mothers to attend classes.

More recently, several studies have been conducted examining the feasibility of conducting weight loss interventions in lower income, postpartum women. Craigie et al examined the effect of a 12-week individualized diet and exercise intervention in overweight women between 6 and 18 months postpartum ($n = 52$). This study involved three face-to-face consultations and three structured phone calls. Participants in the intervention group received a personalized diet prescription with a 500 kcal/day deficit and a pedometer with instructions to achieve 150 minutes of moderate to vigorous activity per week. While this study was not powered to detect change in weight, the intervention had small, but significant weight loss of 1.6 kg compared to weight gain in the control group of 0.2 kg (11). The attrition rate in this study was 31%. Another study conducted by Krummel et al with 151 WIC participants up to 2 years postpartum found that facilitated group discussions targeting diet and physical activity changes at WIC offices was not successful in reducing weight, and participants in both the self-guided and peer-guided groups gained 1.3 kg over one year (12). Participants in this study attended an average of 3.6 out of 10 discussion sessions.

Physical activity may play a role in promoting weight loss during the postpartum period. A recent study examining the impact of a 12 week pedometer-based intervention found that breastfeeding women provided with a pedometer and an individualized plan to incrementally increase steps to 10,000 daily, resulted in a significant weight loss of 2.1 kg compared to no weight change in a usual care control group (13). This study also found significant reductions in BMI and waist circumference as a result of the study,

suggesting that a pedometer-based intervention may be beneficial to improving physical activity and promoting weight loss in postpartum women.

The addition of an energy restriction to an exercise intervention may have additional benefits in this population. A study by Davenport et al randomized 40 women to one of two walking interventions (30% or 70% of heart rate reserve [HRR]) for 16 weeks (14). Participants walked three to four days weekly, with at least one supervised session per week. Participants also received an individualized nutrition plan designed to reduce weight by 0.5 kg/week. Weight loss did not differ between the 30% and 70% HRR groups (-5.0 vs. 4.2 kg respectively). However, weight loss was significantly higher than the control group. This suggests that an aerobic exercise intervention, combined with an energy restriction may be successful in reducing postpartum weight retention.

Similarly, Colleran et al examined the effects of and energy restriction combined with resistance exercise on weight loss in overweight and obese, lactating women ($n = 31$) (15). Women were randomized to either the intervention or control groups for 16 weeks. Women in the intervention group were provided with an individualized diet plan and asked to track their diet three days a week online. They were also given a pedometer with a goal of walking 10,000 steps daily. Finally, they participated in three supervised strength training sessions weekly. Women in the intervention group lost significantly more weight than the minimal care control group (-5.8 kg vs. -1.6 kg).

The most recent study was conducted by Bertz et al. This study aimed to determine the effects of diet, exercise, and a combination of the two on weight loss in overweight and obese, lactating women (16). Sixty-eight lactating women between 10

and 14 weeks postpartum were randomized to one of four groups for 12 weeks: a control group, a dietary modification group, an exercise group, and a diet plus exercise group. Participants in both the dietary and diet plus exercise groups received 2.5 hours of individual counseling. The dietary group was instructed to reduce calories by 500 kcal per day using four key steps. They were also given an electronic scale to self-monitor weight. The exercise group was instructed to walk 45 minutes four days weekly. The diet and exercise group received both treatments and a total of five hours of individualized counseling. For analysis, both groups that received the dietary intervention (diet only and diet plus exercise) were pooled together. They found a significant effect of diet on weight loss (diet only: -8.3 kg, diet plus exercise: -6.9 kg) compared to the control group (-0.8 kg). This study did not find an effect of exercise or an interactive effect between diet and exercise on weight loss in overweight, lactating women. These results suggest that weight loss interventions in lactating women should be focused primarily on dietary strategies, as the addition of exercise did not impact changes in body composition.

Randomized controlled trials of weight management interventions in postpartum women have demonstrated that programs providing individualized diet and physical activity education are successful in reducing body weight among postpartum women. Interventions that target dietary interventions alone or combine diet and exercise may be successful in reducing weight retention. Additionally, a modest weight loss of 0.5 kg does not appear to be detrimental to lactation performance and infant growth. Some of these studies are limited by a low rate of participant retention (6, 9, 11), while two others had low rates of compliance with group-based interventions (10, 12). Other studies that

involved supervised exercise sessions resulted in significant weight loss (14-16).

However, these types of interventions are labor-intensive, and may not be practical to implement on a large scale. This suggests that while the postpartum period may be ideal for weight loss interventions, time constraints associated with caring for an infant and returning to work may limit a woman's ability to attend group educational classes, follow a diet plan, and exercise regularly. Therefore, it is important to design an intervention that is individualized to the participant and reduces the time burden on a woman.

Effects of Weight Loss on Inflammation

Overweight and obesity increase the risk of developing chronic disease, including cardiovascular disease, type 2 diabetes, and certain types of cancer (17). Elevated inflammatory proteins secreted by adipose tissue are responsible for this increased risk (18). In 1993, tumor necrosis factor alpha (TNF- α) was found to be secreted by adipocytes (19). Since then, over 50 inflammatory proteins have been discovered to be produced by adipose tissue, including adiponectin, leptin, C-reactive protein (CRP), and interleukins (IL) (20). Obesity is now characterized as a condition of low-grade inflammation resulting from increased adipocyte size and quantity (17), with overweight and obese individuals having higher plasma concentrations of inflammatory proteins than leaner individuals. Since excess adipose tissue is responsible for this increased inflammation, previous research has sought to determine if weight loss exerts an anti-inflammatory effect (18). While the association between obesity and inflammation is well defined, the effect of weight loss on these biomarkers in humans remains unclear (21). Therefore, it is important to determine if weight loss reduces obesity-induced

inflammation in order to develop effective strategies to reduce the incidence of chronic disease.

Several observational studies have examined the association of body weight and inflammatory protein levels in humans. One study found that CRP was positively associated with weight category (22). Compared to participants in the normal BMI category, CRP level increased as BMI category increased. Another study examined the effects of body weight and metabolic syndrome on inflammatory biomarkers among post-menopausal women (23). Participants ($n = 1,889$) were stratified into four body size phenotypes based on weight status (normal weight vs. overweight/obese) and presence of metabolic syndrome risk factors or diabetes. Being overweight or obese and having at least two metabolic risk factors were independently associated with increased CRP, IL-6, and TNF- α . However, these risks diminished when adjusted for waist circumference, suggesting that while body weight and metabolic syndrome independently increase inflammation in post-menopausal women, abdominal obesity is a stronger predictor of increased inflammation.

These results demonstrate the link between excess body fat, specifically visceral fat, and systematic inflammation. From these results, it can be inferred that a reduction in body weight will alleviate this response. However, intervention studies in humans have found mixed results. Additionally, while several studies have examined the effects of weight loss on inflammation, dietary recommendations have varied widely, and there are few randomized, controlled trials.

Zahorska-Markiewicz et al aimed to determine the effects of a calorie restricted diet on TNF- α (24). Twenty-three obese women and 17 lean control women were recruited. Obese women were instructed to follow a 1000-1200 kcal diet and exercise daily for 3 months. The intervention resulted in a mean weight loss of 11.4 kg and a significant decrease in TNF- α in the obese group. Sheu et al (25) conducted a similar study with 21 obese women. Ten lean women served as controls. Participants were instructed on consuming a diet with a 500 to 1000 kcal/day deficit for 12 weeks. Weight loss of 5% body weight was observed. Serum high sensitivity CRP (hs-CRP), TNF- α , and IL-6 were significantly higher in the obese group than the lean controls at baseline. However, hs-CRP was significantly reduced after the intervention. This study shows that obesity is associated with increased inflammatory markers, and moderate calorie restriction is adequate to reduce these effects in obese individuals. Finally, Heilbronn et al studied the effects of a 1400 kcal, 15% fat diet on inflammation in 83 obese women (26). The intervention resulted in a 7.9 kg weight loss, which was associated with a reduction in CRP (5.56 mg/L to 4.12 mg/L). This study also found that CRP was correlated with degree of weight loss ($r = 0.27, p = 0.01$).

The previous studies demonstrate that dietary changes have an impact on inflammatory markers. Fisher et al (27) aimed to determine if exercise exhibits this same effect. Overweight, premenopausal women ($n = 213$) were randomized to either a diet only, diet plus aerobic exercise, or diet plus resistance exercise group in order to determine the differential effects of two types of exercise on inflammatory markers. An 800 kcal very low calorie diet (VLCD) was provided for participants until they reached a

BMI less than 25 kg/m². IL-6 was reduced only in the diet plus resistance exercise group, while CRP decreased in the diet only and diet plus resistance exercise group.

Additionally, all markers were associated with total and abdominal fat, which explains differences among groups. This study shows that a VLCD only and combined with resistance exercise result in reductions in some inflammatory markers. However, these results are likely related to changes in body fat composition and distribution rather than the type of exercise.

Another randomized study examined the independent and joint effects of calorie-restriction and exercise on inflammatory and metabolic markers (28). Participants ($n=79$) were obese, physically inactive men and women and were randomized to one of three interventions for 8 weeks: exercise only (EXO), VLCD diet only (DIO), and VLCD plus exercise (DEX). The EXO group lost 3.5% body weight, while the DIO and DEX groups lost 10.5% and 11.1% respectively. Inflammatory markers were not changed in the EXO group. However, both the DIO and DEX groups experienced significant and similar reductions in IL-18 and IL-15. IL-6 was only reduced in the DEX group, while adiponectin was significantly increased in DIO and DEX. Weight loss with both calorie restriction and exercise induced a reduction in inflammatory proteins in obese individuals with diet plus exercise leading to greater changes in IL-6. This study suggests weight loss, regardless of the method, is responsible for changes in inflammatory markers.

To date, only two randomized, controlled trials have been conducted examining the effect of a moderate energy restriction on inflammation. Nicklas et al randomized 316 obese, older adults to receive either a normal diet or behavioral counseling to achieve and

maintain a 5% weight loss over 18 months (29). This study found that the intervention group was successful in reducing weight by 5.1% compared to 1.8% in the control group. CRP was reduced by 3%, while IL-6 was reduced by 11% in the intervention group. Another study randomized 120 obese women to either a normal diet or a 1300-1500 kcal Mediterranean-style diet for two years (30). The intervention group had a weight loss of 14.7% compared to 3.2% in the control group. CRP was reduced by 34% and IL-6 reduced by 33% in the intervention group compared to no changes in the control group.

The degree of weight loss may play a role in reducing inflammation, with greater changes in weight necessary to observe a significant reduction in inflammatory proteins. A systematic review compared the results of weight loss interventions, and found that for every 1 kg weight lost, there was a 0.13 mg/L decline in CRP (31). However, Madsen et al found that weight loss greater than 10% may be necessary to induce changes in CRP (32).

The current literature investigating the effects of calorie restriction on inflammation has produced conflicting results. Variations in dietary intervention, duration, inflammatory markers measured, and degree of weight loss make it difficult to assess which interventions have a positive effect on inflammation. Additionally, many studies utilize a VLCD to induce weight loss. While this diet is successful in inducing substantial weight loss, it is not a realistic diet to follow in the long term. There is a need for randomized, controlled trials comparing the effects of a modest energy-restriction diet on weight loss and inflammation. Finally, the effect of weight loss on inflammation in postpartum women is unclear.

Pregnancy is also associated with elevated inflammatory cytokines, specifically, CRP. However, there is a large variation in patterns of change among studies. Some studies suggest that CRP increases gradually over the duration of pregnancy (33, 34). Others found that CRP is elevated in early pregnancy and remains elevated throughout gestation (35) or peaks during the second trimester (36). Variations in CRP concentrations may be related to pre-pregnancy BMI and gestational weight gain. However, few studies have examined this relationship during the postpartum period. Inflammation may remain high during the early postpartum period due to the immunologic stress of delivery (27). Kuzawa et al compared CRP level in women during various stages of the reproductive cycle (34). Compared to nulliparous women (0.2 mg/L), women during the second (1.5 mg/L) and third trimester (2.0 mg/L) had higher CRP levels. CRP was decreased in women during the first year postpartum. Women who breastfed tended to have lower CRP levels than women who formula fed, but this difference was not significant. However, sample size was small and variability was large in the population studied. In contrast, Groer et al found that exclusively breastfeeding women tend to have a higher pro-inflammatory response in the first 4 to 6 weeks after delivery than formula feeding women (38). However, a longitudinal study conducted over 5 months postpartum found no significant differences in CRP between breast and formula feeders (39). CRP was significantly associated with BMI, which may explain why no differences were observed.

Excessive weight gain during pregnancy and obesity during the postpartum period may exacerbate elevations in CRP, and weight loss may improve inflammation in these

women. However, few studies have examined the impact of weight loss on inflammation in postpartum women. A study of 129 overweight and obese postpartum women between 2 weeks and 6 months postpartum compared the effects of an energy-restricted Mediterranean diet to a USDA MyPyramid diet on weight loss and inflammation (40). Both groups lost a similar amount of weight and had similar reductions in TNF- α over the 4 month intervention. However, there were no differences between dietary interventions. This study did not have a control group, so it is unclear whether these results are due to weight loss or normal reductions that occur during the postpartum period.

Another study randomly assigned 68 fully breastfeeding women with a BMI > 25 kg/m² to one of four groups for 12 weeks: control, diet only, exercise only, diet plus exercise (41). While both diet intervention groups lost significantly more weight than the control and exercise only groups, there were no significant changes in CRP, TNF- α , or IL-6. This may be related to large variations in concentrations of these inflammatory markers or the natural immunologic changes that occur after delivery. The current studies are of relatively short duration. Studies examining longer duration weight loss interventions may yield greater changes in inflammation. Also, the role lactation plays in altering inflammation during weight loss in postpartum women remains unclear.

Effects of Weight Loss on Metabolic Syndrome

Metabolic syndrome (MetSyn) is a cluster of symptoms that have been shown to increase the risk of cardiovascular disease and type 2 diabetes (42). The National Cholesterol Education Program III defines MetSyn in women as (1) abdominal obesity greater than 80 cm, (2) triglycerides greater than 150 mg/dL, (3) HDL cholesterol less

than 50 mg/dL, (4) blood pressure greater than 130/85 mm Hg, and (5) fasting glucose greater than 100 mg/dL (43). A diagnosis is made if 3 or more of the above criteria are met. In the United States, 21.8% of women meet the criteria for MetSyn (44).

Furthermore, MetSyn is associated with systemic inflammation. A study by Ridker et al found that CRP levels increased as the number of MetSyn characteristics increased, with CRP of 3.01 mg/L associated with a diagnosis of MetSyn (45).

Childbearing has been shown to increase a woman's risk of developing MetSyn later in life. Gunderson et al found that compared to nulliparous women, the risk of developing MetSyn was 1.33 times higher in woman who gave birth once and 1.62 times higher in women who gave birth at least two times during the 20 year follow-up (46). In addition to this, women who are overweight or obese during the postpartum period may be at increased risk of MetSyn. A recent study compared the prevalence of MetSyn in overweight and obese, fully breastfeeding women (47). Of the 68 participants in this study, 6.2% were classified as having the metabolic syndrome, meeting the criteria with high waist circumference and blood pressure and low HDL cholesterol. Additionally, obese women had higher waist circumference, fasting insulin, and triglycerides compared to overweight women.

Lactation may protect women against development of MetSyn by lowering risk factors in the postpartum period. Cholesterol and triglycerides are elevated during pregnancy, but decline during the postpartum period (48). A study by Darmady and Postle found that triglyceride levels fell to baseline 13 weeks earlier in breastfeeding women compared to formula feeding women (49). Another study found that HDL levels

were higher in lactating women (50). This reduction in lipids is likely due to secretion into breast milk. During lactation, physiologic changes result in the secretion of 10 to 20 mg/L of cholesterol and 3.5 to 4.6 g/L of triglycerides into breast milk (51). HDL levels remain elevated due to increased VLDL transport during lactation (52).

Lactation has also been shown to reduce insulin resistance and improve glucose homeostasis in women with and without gestational diabetes. Kjo et al examined 809 postpartum women with recent gestational diabetes and found that area under the glucose tolerance curve was significantly lower in lactating women compared to non-lactating women (50). Fasting glucose and 2-hour postprandial glucose levels were lower in breastfeeding women. Another study among healthy postpartum women found that insulin resistance as measured by insulin-glucose ratio was lower in lactating compared to non-lactating women at 3 months (10 ± 5 vs. 15 ± 5) and at 6 months postpartum (12 ± 6 vs. 15 ± 5) (53). The reason for improved blood glucose and insulin sensitivity is that glucose is used as a precursor for lactose and lipids, with increased glucose utilization and insulin sensitivity in mammary tissue (54).

In addition to reducing risk factors during the postpartum period, breastfeeding may also reduce the risk of developing MetSyn later in life. A cross-sectional study by Ram et al examined the association between lactation and MetSyn among women in midlife (55). This study found that the duration of lactation was inversely correlated with systolic and diastolic blood pressure, fasting glucose, triglycerides, total cholesterol, and LDL cholesterol, and positively correlated with HDL cholesterol. Additionally, duration of breastfeeding was associated with a reduced risk of developing MetSyn in midlife with

an OR for each year of lactation of 0.88 (95% CI: 0.77, 0.99). These studies suggest that lactation may protect against dyslipidemia and insulin resistance during the postpartum period, which reduces the risk of developing MetSyn during midlife.

Studies that examine the effect of a weight loss intervention on MetSyn are few, focus on manipulations of dietary macronutrients, and lack a usual care control group. A study by Noakes et al of 100 obese women compared the effects a 12-week dietary intervention using either an energy restricted, high-protein, low-fat diet or an isocaloric high-carbohydrate, low-fat diet on cardiovascular risk factors (56). Both groups lost 7.3 kg, with similar changes in HDL and LDL cholesterol, glucose, and insulin. However, TG decreased significantly more in the high protein group compared to the high carbohydrate group (-0.30 vs. -0.11 mmol/L). Another study examined the effect of an energy restricted, high protein diet with and without exercise on MetSyn (57).

Overweight and obese women ($n = 44$) were randomized to either a control diet (1:3 protein to carbohydrate), control diet plus exercise, high protein diet (1:1 protein to carbohydrate), or a high protein diet plus exercise group for 12 weeks. Weight loss was greatest in the high protein with exercise group, while reductions in total cholesterol were greatest in the control plus exercise and high protein groups. A significant reduction in triglycerides was observed only in the high protein plus exercise group. These studies suggest that while a high protein diet may be beneficial for improving triglycerides, changes in other MetSyn criteria may be more dependent on weight loss.

Another study examined the effect of aerobic exercise on cardiovascular risk factors during a weight loss intervention (58). Seventy-seven overweight and obese post-

menopausal women were randomized to either a weight loss alone or weight loss plus aerobic exercise intervention for six months. Both groups had similar reductions in weight, waist circumference, systolic blood pressure, triglycerides, insulin, and insulin resistance. However, the exercise group had significantly greater increases in HDL cholesterol, suggesting that the addition of exercise to a weight loss intervention may help reduce the risk of MetSyn.

There have been several studies examining the effects of diet and exercise interventions on cardiovascular risk factors in postpartum women. The first study by Lovelady et al randomized 33 fully breastfeeding women between 6 to 8 weeks postpartum to either an exercise or a control group for 12 weeks (60). The exercise intervention consisted of 45 minutes of supervised aerobic exercise 5 days weekly. There were no differences between groups for total cholesterol, LDL, triglycerides, and insulin and glucose response to a test meal. There was a trend for an increase in HDL in the exercise group, but this was not significant. However, weight loss was the same for both groups. Another study examining the effects of an exercise intervention (50-60 minutes of supervised aerobic exercise 3 days per week) on cardiovascular risk factors in lactating women 4 to 6 weeks postpartum found no significant differences between groups for weight loss or lipid concentrations (61). Women in both of these studies were normal weight, which may have limited the effectiveness of the interventions.

Interventions that combine an energy restriction with exercise have observed greater changes in MetSyn risk factors. Davenport et al randomized 40 overweight and obese women who were 7 to 8 weeks postpartum to one of two exercise groups, with an

additional 20 women in a control group (14). Women in the intervention groups walked 45 minutes/day on 3 to 4 days/week at either 30% or 70% of heart rate reserve (HRR) for 16 weeks. They were also given individualized dietary recommendations in order to reduce weight by 0.5 kg/week. Both groups had significant reductions in weight (30%: -4.2 kg, 70%: -5.0 kg), waist circumference, glucose, and LDL cholesterol compared to the control group. However, differences between groups were not significant.

Recently, Brekke et al examined the effect of diet alone, exercise alone, or diet plus exercise on weight loss and cardiovascular risk factors in 68 overweight, lactating women between 10 and 14 weeks postpartum (41). Women in the diet and diet plus exercise groups lost significantly more weight compared to the control or exercise alone groups. Additionally, the two diet groups had significantly greater reductions in waist circumference, total cholesterol, LDL, and insulin after the 12 week intervention. These studies suggest that a diet and exercise intervention is necessary to achieve the weight loss needed to reduce MetSyn risk factors in postpartum women.

While childbearing is associated with an increased risk of MetSyn (46), lactation may reduce risk factors that contribute to development of MetSyn and chronic disease. Research on the impact of diet and exercise interventions on risk factor in overweight and obese, postpartum women are conflicted. However, previous studies suggest that physical activity, in addition to an energy restriction diet may be beneficial in reducing weight and improving MetSyn risk factors.

Effect of Systemic Inflammation on Bone Mineral Density

While obesity has been shown to be associated with elevated bone mineral density (BMD) and protective against bone loss, (61) obese individuals exhibit elevated levels of inflammatory cytokines, such as IL-6, TNF- α , and CRP. These cytokines are also involved in bone remodeling. Bone mass undergoes continuous remodeling during adulthood. In typical bone remodeling, osteoclasts adhere to the bone, and dissolve old bone. Then, osteoblasts attach to the resorbed bone, promoting the deposition of osteoid, which mineralizes into new bone tissue (62). Thus, bone mass is maintained by a balance between osteoclast and osteoblast activity. When this balance is interrupted, bone loss will occur. IL-6 has been shown to be involved in maintaining this balance. It is produced by stromal-osteoblastic precursor cells and acts to stimulate osteoclastogenesis and bone resorption (63). This production is stimulated by IL-1 and TNF- α . Lactation is associated with a decrease in BMD, with peak bone loss of 1 to 3% per month (64). After weaning, BMD rapidly returns to baseline levels (65). However, it is unclear if inflammation associated with obesity exacerbates this bone loss or inhibits the gains observed after weaning.

There have been several studies that have examined the relationship between low-grade systemic inflammation and BMD in postmenopausal women with conflicting results. Scheidt-Nave et al examined 89 overweight postmenopausal women and found that serum IL-6 was predictive of femoral bone loss, adjusted for menopausal age, BMI, serum PTH, and other factors (66). This effect was most prominent during the first 10 years after menopause. Gertz et al examined the relationship between various

inflammatory markers and change in BMD over one year in 235 postmenopausal women. IL-6 and TNF- α were significantly associated with BMD at the hip, lumbar spine, femoral neck, trochanter, whole body, and distal tibia (67). In a regression analysis, a combination of inflammatory markers (IL-6, TNF- α , IL-1 β , and CRP) contributed to change in hip, lumbar spine, trochanter, and whole body BMD, while CRP contributes to change in lumbar spine, whole body, and trochanter BMD, and TNF- α and IL-6 contribute to change in hip BMD. Ding et al found that hs-CRP at baseline and change in hs-CRP were associated with change in total body BMD in older men and women (68). Additionally, baseline IL-6 and change in IL-6 were associated with change in total body and spine BMD. Quartiles of TNF- α were associated with change in total body and spine BMD. Finally, Papadopoulous et al found that BMD at various sites (lumbar spine, femoral neck, Ward's triangle, shaft, radius, and ultradistal) were negatively correlated with IL-6 (69).

However, several studies found no significant association between inflammatory markers and BMD. Kania et al found that there was no correlation between IL-6 and BMD at the lumbar spine or femoral neck in postmenopausal women (70). Similarly, Ganesan et al found that CRP was not associated with BMD when controlling for confounders that may also impact BMD, including age, ethnicity, BMI, hormonal replacement therapy use, and immobility (71).

Koh et al studied the relationship between hs-CRP and bone mineral density in pre- and postmenopausal women. CRP levels were significantly higher in women with osteoporosis and osteopenia (72). Further, the highest quintile of hs-CRP was associated

with significantly lower femoral neck BMD compared to the lowest quintile. The relationship was observed in both pre- and postmenopausal women. However, this population was within a normal BMI range and CRP levels were low, with 0.7 and 1.0 mg/L in pre- and postmenopausal women respectively.

Salamone et al aimed to determine this relationship in 50 premenopausal women. TNF- α was modestly correlated with femoral neck BMD ($r = -0.30$, $p < 0.05$) (73). Additionally, women in the 75th percentile of IL-6 and TNF- α had lower lumbar spine BMD (0.963 ± 0.18 g/cm²) than women with lower levels of these proteins (1.08 ± 0.07 g/cm²). Finally, the annual rate of bone loss at the lumbar spine tended to be greater in women with higher IL-6, but this was not significant.

Finally, De Pablo et al examined data from the NHANES survey to determine the relationship between CRP and BMD (74). Men and women ($n = 10,475$) with ages ranging from 20 to 85 years were studied. They found a significant inverse, dose-dependent association between CRP and total body and lumbar spine BMD among women. In this study, average BMI for women was 28.7 kg/m², with a median CRP of 1.29 mg/dL.

Two studies in premenopausal women did not find a significant association between inflammation and BMD. Jeon et al studied the relationship between BMD and metabolic syndrome in 2,165 pre- and postmenopausal women (75). This study found that premenopausal women with metabolic syndrome had lower BMD at the lumbar spine after adjusting for age, height, weight, CRP and other covariates, while postmenopausal women had lower lumbar spine and femoral neck BMD compared to

women without metabolic syndrome. CRP was found to be a significant predictor of femoral neck BMD in postmenopausal, but not premenopausal women, with higher CRP associated with lower BMD ($\beta = -0.064$, $p = 0.001$). Hwang et al examined 2,558 women 18 years and older to compare the relationship between metabolic syndrome and CRP with BMD. They found that women with abdominal obesity and hypertriglyceridemia had significantly lower vertebral BMD (76). Also, vertebral BMD was lower in women with metabolic syndrome ($0.858 \pm 0.007 \text{ g/cm}^2$) compared to women without ($0.925 \pm 0.004 \text{ g/cm}^2$). However, CRP was not significantly correlated with BMD.

Studies examining the relationship between inflammation and BMD are conflicting. IL-6, TNF- α , and CRP may be associated with loss of BMD in older adults, with higher levels of inflammation predicting reduced BMD. However, this same relationship is less clear in premenopausal women, who are at a lower risk of bone loss and osteoporosis. Women with the metabolic syndrome may be at an increased risk of bone loss due to increased inflammation.

Effect of Weight Loss on Bone Mineral Density

Weight loss is a desirable outcome for overweight and obese individuals, as it may decrease systemic inflammation. However, modest weight loss has been shown to increase bone turnover and decrease BMD, particularly at the hip and lumbar spine. Several studies have examined this relationship and found that small weight loss in overweight and obese women over 3 to 18 months resulted in small, but significant reduction of BMD at the total body (77, 78), lumbar spine (77), and hip (79).

Exercise may help attenuate this loss of BMD. In a study by Fogelholm et al, 82 obese, premenopausal women followed a very low energy, weight reduction diet for 3 months (80). After the weight loss phase, they were randomized to either a control group or one of two exercise groups consisting of walking in order to expend 1,000 or 2,000 kcal/week for 9 months. Weight loss of 14.3% after the first three months resulted in a significant decrease in total body, spine, and femoral neck BMD. After 9 months of exercise, there was a significant decrease in BMC, but no changes in BMD in both exercise groups. However, differences between groups were not significant. Similarly, a study by Rector et al randomized 36 overweight and obese premenopausal women to one of three groups in order to induce a 5% weight loss: energy restriction only, energy restriction plus nonweight-bearing exercise (cycling), and energy restriction plus weight-bearing exercise (treadmill running) (81). This study found that while markers of bone turnover, osteocalcin and C-terminal telopeptide of type I collagen, were significantly increased, there was no difference between groups. These studies suggest that aerobic exercise may not be adequate to prevent weight-loss induced changes in BMD in premenopausal women.

Due to its impact on bone health, resistance training may reduce the bone loss observed with weight loss. A study by Nakata et al examined this relationship in 43 overweight, premenopausal women (82). Participants were randomized to one of two groups. The diet only group consisted of a 1,200 kcal/day dietary restriction, while the diet plus resistance training incorporated three 90 minute resistance training sessions per week for 14 weeks. While there was a significant reduction in total body BMD, no

significant differences were observed between groups. However, the resistance exercise group lost significantly more weight and fat mass, which may have contributed to these results.

Resistance exercise may also be beneficial to BMD during lactation. Lovelady et al randomized 20 fully breastfeeding women at 4 weeks postpartum to either the exercise or control group (83). Women in the exercise group participated in weight-bearing aerobic exercise and resistance training 3 days/week. The exercise group lost less lumbar spine BMD compared to the control group, despite similar weight loss. Another study by Colleran et al aimed to determine if resistance exercise would slow bone loss during weight loss in overweight, fully breastfeeding women (15). Thirty-one women were randomly assigned to either the minimal care group or the intervention group for 16 weeks. The intervention group was prescribed a 500 kcal/day deficit, asked to walk at least 10,000 steps daily, and participated in supervised resistance training sessions 3 days weekly, targeting core strength. Total body, lumbar spine, and total hip BMD decreased significantly over time, but there were no differences between groups. However, the intervention group lost significantly more weight than the minimal care group, suggesting that resistance exercise is protective against increased bone loss in lactating women during weight loss.

Calcium intake during weight loss may also be protective against bone loss during diet-induced weight loss. Shapses et al examined 60 obese, premenopausal women, and randomly assigned them to receive either a 1,000 mg calcium supplement or placebo during the 6 month weight loss study (84). They found that moderate energy restriction

yielding at least 5% weight loss in both groups did not significantly alter total body BMD or BMC. However, BMD at the lumbar spine significantly increased in the calcium group, compared to a decrease in the placebo group, suggesting that adequate calcium during weight loss can prevent bone loss. Similarly, Riedt et al found that there was no change in BMD with moderate weight loss at either high (1.8 g calcium/day) or adequate (1.0 g calcium/day) calcium intakes (85). There was an increase in BMD at the one-third radius, and a trend for an increase in femoral neck BMD with the high calcium group.

The mediating effect of systemic inflammation on BMD during weight loss is not well understood. A study by Silverman et al in 86 overweight and obese postmenopausal women examined the effect of aerobic exercise in combination with moderate weight loss on circulating inflammatory proteins in order to determine its impact on BMD (86). Subjects were randomized to either a moderate energy restricted diet or an energy restriction plus walking for 45 to 60 minutes three days weekly. This study found that femoral neck BMD was increased in the exercise group compared to diet alone. Additionally, change in femoral neck BMD was negatively correlated with change in TNF- α receptor 1. However, there was no correlation between other inflammatory proteins. Change in femoral neck BMD was positively correlated with change in VO₂ max, while VO₂ max was negatively associated with change in sIL-6 receptor, suggesting a possible mediating relationship between aerobic exercise, BMD, and inflammation.

A recent study in 51 overweight and obese premenopausal women was conducted to determine if adequate dairy consumption attenuates the loss of BMD during a weight loss intervention and to determine the association between inflammatory markers and

BMD (87). The dietary intervention was designed to achieve an energy reduction of 500 kcal/day. Participants were randomized to either an adequate or low dairy group. This study found that lumbar spine BMD was higher in the adequate dairy group (0.5% increase vs. 1.4% decrease). Additionally, there was a negative association between inflammatory proteins (IL-1 β , TNF- α , and CRP) with markers of bone turnover. Regression analysis found that post-weight loss inflammatory and endocrine factors accounted for 19.6% of the variance in hip BMD.

These studies suggest that systemic inflammation may negatively impact BMD by stimulating bone resorption. Additionally, weight loss may lead to decreases in BMD. However, these relationships are inconsistent across studies. While studies in postmenopausal women show a benefit to adding aerobic or resistance exercise to moderate energy restriction and maintaining an adequate intake of calcium, these results are inconclusive in overweight and obese premenopausal women. Furthermore, the relationship between inflammation and BMD during weight loss is not well understood. While obesity appears to be protective against bone loss, elevated circulating inflammatory proteins may blunt this effect. No studies have looked at this relationship in lactating women, who experience reductions in BMD. Elevated inflammation in lactating women may exacerbate this bone loss during weight loss.

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CHAPTER III

EFFECTS OF AN RD-GUIDED DIET AND EXERCISE INTERVENTION ON WEIGHT AND BODY COMPOSITION IN POSTPARTUM WOMEN

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Introduction

Obesity is a public health problem in the United States. According to the 2009-2010 National Health and Nutrition Examination Survey, 23.9% of women between the ages of 20 and 39 years were overweight, and 31.9% were obese (1). Excessive weight retention during the postpartum period may be a contributing factor to the development of obesity in this population (2). Postpartum weight retention varies greatly among women, and although most women retain just 0.5 to 3 kg postpartum (3), approximately 14 to 20% of women retain 5 kg or more at 6 months postpartum (4). In a long-term examination of postpartum weight retention, women who gained the recommended amount of weight during pregnancy weighed 6.5 kg more at a 10 year follow up, while women who gained above the recommendation weighed 8.4 kg more (2). In addition, women who lost all of their pregnancy weight by 6 months postpartum gained 2.4 kg 10 years later compared to 8.3 kg for those who retained some pregnancy weight (2). Interventions targeted toward weight loss during the postpartum period may play a role in promoting long-term weight management in women of child-bearing age.

To date, several randomized, controlled trials utilizing individual diet and/or exercise counseling for postpartum women have been conducted, showing moderate, short-term weight loss (5-9). A more recent study by Bertz et al examined the effects of diet, exercise, or a combination on weight loss in postpartum women (10). They found that dietary intervention alone was successful in reducing weight, with no additional benefits to adding exercise. Furthermore, a study by Lovelady et al found that modest weight loss of 0.5 kg/week, through dietary restrictions and aerobic exercise, resulted in significant weight loss with no adverse effects on lactation performance and infant growth (8). Finally, a recent review of the literature found that interventions combining diet and exercise are successful in reducing postpartum weight retention (11). This review also found that home-based interventions utilizing technology-based correspondence, such as text messages, emails, and phone calls may increase weight loss.

While these studies show that modest calorie restriction, combined with physical activity, may be successful in reducing weight in postpartum women, several other studies had high drop-out rates (31% to 42%) (5, 6). Additionally, compliance with an intervention may be limited, due to the time constraints associated with caring for an infant. This may affect a woman's ability to follow a diet plan and exercise regularly. Several studies utilizing supervised, home-based exercise sessions observed higher compliance and significant weight loss (7, 8). However, these are labor-intensive and may not be feasible to implement in a larger population. Furthermore, another study that required participation in classes was not successful in promoting weight loss due, in part, to low participant attendance rates (9). This suggests that time-intensive interventions

may not fit into the busy schedules of new mothers. Therefore, there is a need to develop a weight loss intervention that does not require class participation or regular, labor-intensive supervised home visits, but is tailored to the needs of individual participants. Thus, the purpose of this study was to determine the effects of a home-based diet and exercise intervention, guided by a registered dietitian (RD), on weight and body composition in postpartum women.

Methods

Study Participants

Participants were recruited from pre- and postnatal classes and flyers posted in obstetrician's offices and in community settings in Greensboro, NC. Women were screened by telephone or email after the birth of their infant. They were eligible if they were between 6 to 14 weeks postpartum, had a self-reported BMI between 25 and 35 kg/m² or were at least 4.5 kg heavier than self-reported pre-pregnancy weight at the time of screening, were 18 years and older, and sedentary (participation in physical activity < 3 days per week). Participants were excluded if they were smokers, had a multiple-birth, or had a preexisting medical condition. Women who had a cesarean section were eligible to participate at 14 weeks postpartum. All participants were medically cleared for a diet and exercise intervention by their physician. Sample size was determined using the results from two previous studies (8, 9). A sample size of 26 (13 per group) was estimated to provide 80% power with a two-sided α level of 0.05 to detect a 2.5 kg change in weight.

Study Design

Participants were stratified based on pre-pregnancy BMI (BMI <30.0 kg/m² and ≥30.0kg/m²) and time from childbirth (< 10 weeks and ≥ 10 weeks). Computer-generated block randomization with a block size of 4 was used within each stratum to divide participants into either the intervention or control group. Group assignment was concealed in individually sealed envelopes by a third party. Participants were randomized after all baseline measurements were completed. The study protocol was approved by The University of North Carolina at Greensboro Institutional Review Board. It is registered with ClinicalTrials.gov (NCT01668316).

Study Intervention

Intervention Group. The intervention group participated in a 12-week diet and exercise program starting at 6 to 14 weeks postpartum. Participants worked with the RD to reduce energy intake and improve diet quality. The intervention focused on components of the cognitive behavioral theory (CBT) to facilitate behavior change. Briefly, CBT is designed to aid in overcoming psychological barriers to behavior change. Components of this behavior change theory include self-monitoring of thoughts and behaviors, problem solving, realistic goal setting, cognitive restructuring, stimulus control, and relapse prevention (12). This intervention utilized self-monitoring of diet and exercise habits, goal-setting, and problem-solving. Stimulus control was also utilized as needed by individual participants. This theoretical framework has been shown to be successful in improving lifestyle behaviors to facilitate weight loss (13).

Participants were provided with an individualized energy prescription, calculated with the National Academy of Sciences/Institute of Medicine (NAS/IOM) total energy expenditure prediction equation: $(TEE = 387 - (7.31 \times \text{age}) + \text{physical activity (PA)}[(10.9 \times \text{weight(kg)}) + (660.7 \times \text{height})] \pm 160)$, using a PA of 1.14, which corresponds to a low activity level (14). An additional 330 kcal were added for fully breastfeeding women and 150 kcal for women who were combining breastfeeding and formula feeding. A reduction of 500 kcal/day was added to achieve a goal weight loss of 0.5 kg/week.

At the start of the intervention, the RD made a home visit to participants in the intervention group to review study procedures. Participants were provided with their recommended energy intake based on the NAS/IOM TEE equation. This value ranged from 1800 to 2200 kcal per day. Participants were given a sample meal plan for this energy level with recommended number of servings from each food group based on the USDA MyPlate recommendations for lactating women. Several participants restricted dietary intake of certain foods or food groups (dairy, animal proteins, grains) due to maternal or infant intolerances and allergies, vegetarianism, or personal preferences. In these instances, the RD instructed the participant on alternative ways to meet nutritional needs (calcium, protein, fiber).

Participants were instructed to record dietary intake at least three days weekly for the duration of the study using the online USDA SuperTracker program (15). Participants were instructed on how to track their diet using this tool at the initial home visit. Instruction included how to enter daily food intake, including portion size, creating

recipes, adding frequently consumed foods, and creating food combinations.

SuperTracker provides a chart diagramming intake of each food group, oils, saturated fat, sodium, and empty kilocalories. Participants were instructed to aim to meet recommendations for each food groups, and stay below maximum levels for oils, saturated fat, sodium, and empty kilocalories. An educational handout was provided to participants with screenshots of the website and step-by-step instructions.

At this home visit, participants were provided with a pedometer (Omron Healthcare, Inc., Lake Forest, IL) and instructed to work up to a goal of 10,000 steps daily. Women were instructed to increase steps from baseline amounts by 1,000 steps every week until the goal was met. Participants were also provided with an alternative goal of walking at least 3,000 aerobic steps daily. Aerobic steps are classified as walking at least 100 steps per minute for at least 10 minutes. Walking 3,000 aerobic steps has been shown to be the equivalent of 30 minutes of brisk walking (16). Participants were instructed to wear the pedometer on a daily basis and were instructed to record daily steps, aerobic steps, and other aerobic activity. Pedometer logs were reported by participants to the RD every two weeks. Participants were provided with an educational handout at the initial visit, which provided step goals, as well as suggestions on how to increase daily steps.

Dietary intake records were reviewed by the RD every two weeks, and individualized dietary recommendations were provided to participants by telephone or email. Recommendations focused on strategies to reduce energy intake, balance intake of all food groups, and reduce portion size. Barriers to compliance were also addressed at

this time. Participants also received educational handouts every two weeks, focusing on portion control, intuitive eating, meal planning, grocery shopping, and dining out. Pedometer logs were reviewed by the RD every two weeks. Recommendations were made to participants on ways to increase daily steps.

Control group. Participants in the control group were instructed to not change their dietary habits or engage in a structured exercise program for 12 weeks. After completion of the endpoint measurements, control group participants received all intervention materials, including the pedometer, educational materials, and individualized dietary prescription. Participants in both groups were contacted biweekly by telephone or email and asked about breastfeeding status, birth control use, nutritional supplement use, return of menses, and physical activity.

Laboratory Measurements

Laboratory measurements were obtained for all eligible participants at baseline and after the 12-week intervention. These measurements included anthropometrics, body composition, and cardiovascular fitness. Participants were randomized after both dietary recalls were obtained.

Anthropometrics. Height was measured using a digital stadiometer (235 Heightronic Digital Stadiometer, Snoqualmie, WA). Weight was measured without shoes and in light clothing using a calibrated digital scale (Tanita BWB-800S, Arlington Heights, IL). A Gulick tape was used to measure waist and hip circumference to the nearest 0.1 cm. Waist circumference was measured at the narrowest point of the torso, above the umbilicus and below the xiphoid process (17). Hip circumference was

measured at the maximum circumference of the hip (17). Sagittal diameter was measured using abdominal calipers (Lafayette Instrument Company, Lafayette, IN) at the largest diameter between the umbilicus and xiphoid process (17).

Body Composition. Percent body fat, fat-free mass, and trunk fat were measured by dual-energy x-ray absorptiometry (DXA: Lunar Prodigy Advance, GE Healthcare, Madison, WI). Trunk fat included the neck, chest, abdominal, and pelvic areas. A trained DXA technician conducted all measurements. Participants were placed in a supine position on the 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. Body composition was analyzed using enCORE 2011 software version 13.60.

Cardiovascular Fitness. Cardiovascular fitness was determined through a modified Balke protocol using a submaximal treadmill test (17). Participants wore a heart rate (HR) monitor (Polar, Inc., Woodbury, NY) to determine resting heart rate (RHR) and HR throughout the exercise testing. Participants warmed up on the treadmill for three minutes, then selected a brisk, but slightly uncomfortable speed at either a walk (< 3.7 mph) or a jog (> 3.7 mph). The treadmill speed remained constant throughout the test. Starting with an incline of 0%, the incline of the treadmill was increased by 2.5% every three minutes. Heart rate and perceived exertion were recorded every minute during the test. Perceived exertion is a subjective rating of effort from 6 to 20. A rating of 6 corresponds with an extremely easy effort, while a rating of 20 corresponds with an extremely hard effort. The test was terminated once the participant's heart rate reached 85% of their predicted heart rate maximum (calculated using the heart rate reserve (HRR))

formula: $HRR = [(220 - \text{age} - RHR) \times 85\% + RHR]$ or if the participant asked to stop.

Predicted VO_2 max was calculated using one of the following equations based on whether the participant walked or jogged for the test (17):

$$VO_2 \text{ (walking)} = 0.1[\text{speed (m}\cdot\text{min}^{-1})] + 1.8[\text{speed (m}\cdot\text{min}^{-1}) \times \text{grade}] + 3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$$

$$VO_2 \text{ (jogging)} = 0.2[\text{speed (m}\cdot\text{min}^{-1})] + 0.9[\text{speed (m}\cdot\text{min}^{-1}) \times \text{grade}] + 3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$$

Predicted VO_2 max was calculated using a linear regression model with HR as the independent variable and predicted VO_2 max as the dependent variable. Fitness percentile values for VO_2 max by age for women were determined using American College of Sports Medicine guidelines (17).

Dietary Intake

Dietary intake was assessed in the week following laboratory assessments by two 24-hour dietary recall sessions collected by telephone or in person using the Minnesota Nutrition Data System for Research (NDSR, Nutrition Coordinating Center, University of Minnesota, MN) software, on two separate days of the same week. Attempts were made to include one weekend day. However, this was not always feasible due to participants' schedules. This program utilizes a multipass procedure to obtain an accurate record of dietary intake. This method has been previously validated against doubly labeled water as an accurate measure of energy intake (18, 19). Data from the two days of diet recall were averaged and used to determine the Healthy Eating Index (HEI) score. The HEI measures compliance with dietary recommendations based on the 2010 Dietary Guidelines for Americans. It consists of 12 components: total fruit, whole fruit, total vegetables, greens

and beans, whole grains, dairy, total protein foods, seafood and plant proteins, fatty acids, refined grains, sodium, and empty calories (20). Maximum scores for components are 5, 10, and 20, depending on the component, with a maximum score of 100.

Lactation Status

Participants in both groups were asked biweekly how they were feeding their infant. A lactation score was calculated for all participants as follows: for every week since delivery, a score of 2 was assigned for fully breastfeeding (less than 4 ounces of formula daily), a score of 1 for mixed feeding (breastfeeding and formula feeding), and a score of 0 for fully formula feeding, for a maximum score of 36 to 52 depending on when the participant entered the study. The total lactation score at each time point was divided by the maximum possible score to determine a lactation score percentage. Women were considered: 1) predominantly formula feeding if they had a score less than 25% of the maximum, 2) low intensity, low duration breastfeeding with a score between 25-75% of the maximum or 3) high intensity, high duration breastfeeding with a score greater than 75% of the maximum.

Perceived Stress Scale

Perceived stress levels of participants were measured using the Perceived Stress Scale at baseline (21). This scale measures the degree to which an individual perceives life situations as stressful, unpredictable, or uncontrollable, using 10 questions about feelings and thoughts over the last month. Participants rate how often they feel a certain way in response to the questions on a 5-point Likert scale from 0 (never) to 4 (very

often). Total scores are the sum of all questions, with a maximum score of 40. Higher scores indicate higher levels of perceived stress.

Statistical Analysis

Data was analyzed using JMP software (v.11.0.0, SAS Institute, Cary, NC). Student's *t*-test (continuous variables) and χ^2 analysis (categorical variables) were used to compare differences in baseline characteristics between the intervention and control groups. Repeated measures ANOVA was used to test for time by group interaction for weight, body composition, waist and hip circumference, sagittal diameter, cardiovascular fitness, and dietary intake. Data are reported as mean \pm SEM, with significance set at $p \leq 0.05$.

Results

Seventy-eight women were screened for eligibility; 43 were ineligible to participate (Figure 3.1). Baseline measurements were conducted on 35 participants. However, only 34 participants were randomized after baseline measurements (11.1 ± 2.8 weeks postpartum) into the intervention group ($n = 17$) or control group ($n = 17$). Three participants did not complete the endpoint measurement (two in the control group, one in the intervention group). Baseline characteristics of the women who discontinued the study did not differ from the women who completed the study. However, women who dropped out of the study were more likely to be low intensity, low duration breastfeeding compared to women who completed the study ($\chi^2 = 4.7, P = 0.03$).

There were no significant differences between groups at baseline (Table 3.1). Three women in the intervention group and four women in the control group had

measured BMI ≥ 30 kg/m². One woman in the intervention group and four women in the control group had measured BMI < 25 kg/m², but were at least 4.5 kg heavier than they were pre-pregnancy. Baseline BMI ranged from 23.5-33.1 kg/m² in the intervention group and 23.4-34.1 kg/m² in the control group. In the intervention group, 100% of the participants were high intensity, high duration breastfeeding (lactation score percentage range 79-100%), compared to 80% in the control group (lactation score percentage range 50-100%).

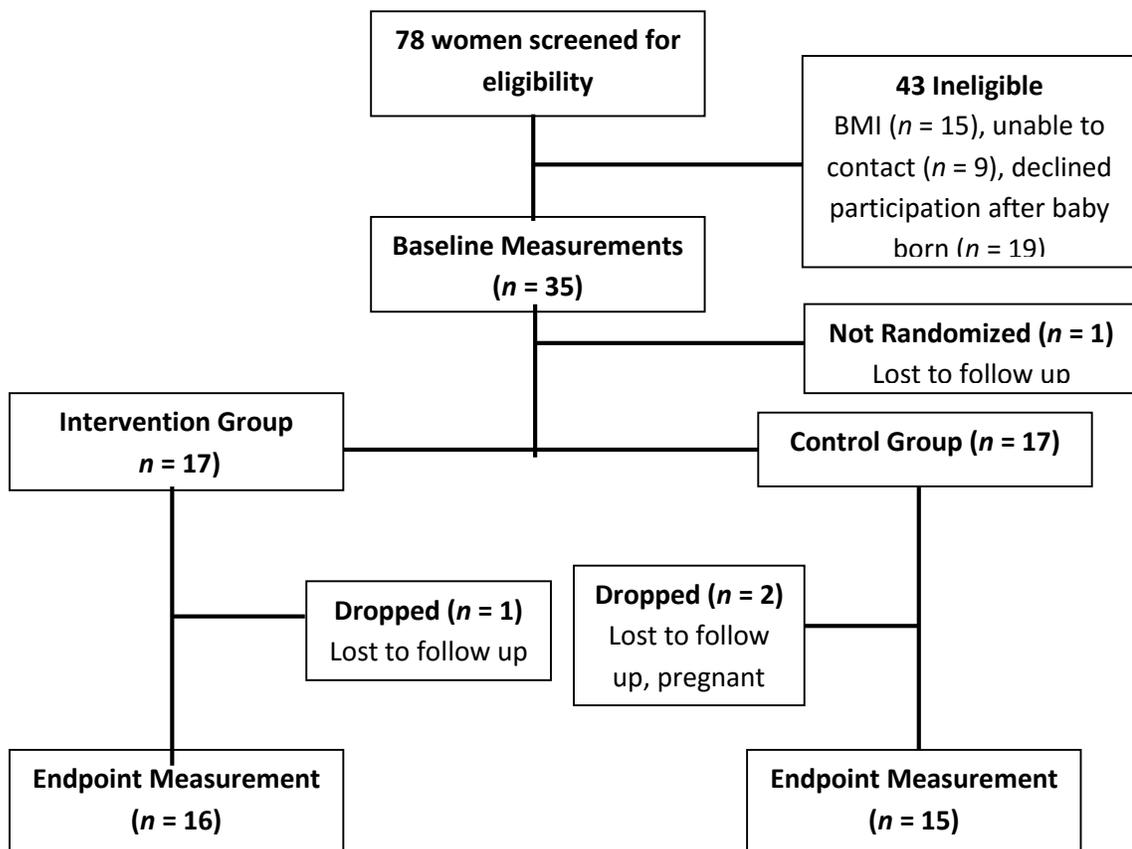


Figure 3.1. Study Enrollment Flow Chart.

Table 3.1. Baseline Characteristics of the Intervention and Control Groups.

	Intervention (<i>n</i> = 16)	Control (<i>n</i> = 15)
Age (yr)	31.4 (1.0)	31.1 (1.0)
Pre-pregnancy BMI (kg/m ²)	26.2 (0.9)	24.8 (1.0)
Time since delivery (wk)	11.6 (0.7)	10.5 (0.7)
Pregnancy weight gain (kg)	17.6 (1.6)	18.6 (1.7)
Postpartum weight retention (kg) ^a	6.1 (1.9)	6.5 (2.0)
Weight loss delivery to start of study (kg)	4.9 (0.8)	5.2 (0.9)
Parity		
Primiparous	12	8
Multiparous	4	7
Education		
Some college	2	2
College degree	7	9
Graduate degree	7	4
Marital status		
Married	16	13
Single	0	2
Breastfeeding		
High intensity, high duration BF	16	12
Low intensity, low duration BF	0	3
Formula feeding	0	0
Race		
White	15	14
Black	1	1
Employment status		
Working at least part-time	12	10
Not working	4	5
Income		
< \$20,000	0	1
\$20,000-29,999	0	1
\$30,000-39,999	3	0
\$40,000-49,999	1	2
\$50,000-59,999	0	2
> \$60,000	12	9

Data are mean (SEM)

BF, breastfeeding

^a Postpartum weight retention is defined as weight at baseline above pre-pregnancy weight.

Table 3.2 Body Composition and Cardiovascular Fitness in the Intervention and Control Groups.

	Baseline	Endpoint	Change	Time	Interaction
Weight (kg)*					
Intervention	76.7 (2.2)	72.9 (2.4)	-3.8 (0.7)	<0.001	0.043
Control	74.2 (2.3)	72.3 (2.7)	-1.8 (0.7)		
BMI (kg/m²)*					
Intervention	28.4 (0.7)	27.0 (0.8)	-1.4 (0.2)	<0.001	0.034
Control	27.1 (0.8)	26.5 (0.9)	-0.7 (0.3)		
WC (cm)**					
Intervention	86.5 (1.8)	82.1 (1.9)	-4.4 (0.6)	<0.001	0.004
Control	86.6 (1.9)	84.9 (2.0)	-1.7 (0.6)		
HC (cm)					
Intervention	107.0 (2.1)	102.1 (2.1)	-4.1 (0.7)	<0.001	0.107
Control	104.8 (2.2)	102.2 (2.6)	-1.9 (0.7)		
SD (cm)*					
Intervention	24.3 (0.6)	22.5 (0.7)	-1.8 (0.3)	<0.001	0.049
Control	24.8 (0.7)	23.8 (0.7)	-1.0 (0.3)		
Fat mass (kg)					
Intervention	32.2 (1.7)	28.6 (1.7)	-3.5 (0.6)	<0.001	0.053
Control	30.3 (1.8)	28.6 (2.1)	-1.8 (0.6)		
Fat free mass (kg)					
Intervention	44.5 (1.0)	44.2 (1.0)	-0.3 (0.2)	0.312	0.473
Control	43.8 (1.0)	43.8 (1.1)	0.0 (0.3)		
% Body fat (%)					
Intervention	41.7 (1.2)	38.9 (1.3)	-2.8 (0.5)	<0.001	0.085
Control	40.5 (1.3)	39.0 (1.5)	-1.4 (0.6)		
Trunk fat (kg)*					
Intervention	16.0 (1.0)	14.2 (1.1)	-1.8 (0.4)	<0.001	0.039
Control	15.6 (1.0)	14.9 (1.2)	-0.7 (0.4)		
VO₂ max (mL/kg/min)*					
Intervention	30.6 (1.3)	33.2 (1.4)	2.6 (1.0)	0.156	0.043
Control	31.1 (1.4)	30.6 (1.1)	-0.5 (1.1)		
VO₂ max (L/min)					
Intervention	2.3 (0.1)	2.4 (0.1)	0.1 (0.1)	0.761	0.109
Control	2.3 (0.1)	2.2 (0.1)	-0.1 (0.1)		

WC: waist circumference; HC: hip circumference; SD: sagittal diameter

Data are mean (SEM)

Significant time by group interaction, * $p < 0.05$, ** $p < 0.01$, RMANOVA

The intervention group lost significantly more weight than the control group (Table 3.2). Weight change in the intervention group ranged from -8.6 to 1.2 kg, while weight change in the control group ranged from -5.4 to 2.2 kg over 12 weeks. Seven women (44%) of the women in the intervention group and 2 women (13%) in the control group lost greater than 5.0 kg. Eight women (50%) in the intervention group and two women (13%) in the control group returned to their pre-pregnancy weight by endpoint. The intervention group had significantly greater reductions in BMI, trunk fat mass, waist circumference, hip circumference, and sagittal diameter than the control group.

The intervention group reduced their energy intake by -29 ± 143 kcal per day, while the control group reduced energy intake by -81 ± 148 kcal per day. This difference was not significant over time or by group. However, the average energy deficit at baseline for the intervention group was -529 ± 111 kcal. There was no significant time by group interaction for macronutrient content (Table 3). However, the percent of energy from protein increased significantly over time for both groups ($P = 0.03$). Both groups had reductions in HEI scores, but the differences were not significant between groups or over time. The number of women meeting the recommendation for good diet quality (score over 80) in the intervention group increased from 3 to 5 (17% to 27%), while the number of women meeting the recommendations in the control group decreased from 4 to 3 (31% to 20%).

Predicted VO_2 max improved by $9.3 \pm 3.5\%$ for the intervention group, while decreasing by $0.5 \pm 3.1\%$ in the control group ($P = 0.03$). This represents a significant increase in VO_2 max percentile by age in the intervention group of $12.5 \pm 4.4\%$ compared

to a reduction of $1.3 \pm 4.5\%$ in the control group ($P = 0.03$). Change in predicted VO_2 max was not associated with change in weight. In order to eliminate the effect of weight loss on VO_2 max, baseline predicted VO_2 max was divided by endpoint weight to determine predicted endpoint VO_2 max. This was compared to the observed VO_2 max at endpoint. The intervention group had observed values 0.2 L/min higher than compared to values 0.2 L/min lower than expected in the control group ($P = 0.02$). Average 12 week pedometer steps for the intervention group was 6937 ± 647 steps per day. There was a significant increase in pedometer steps over the 12 week intervention (Figure 3.2) from $6,942 \pm 691$ steps at 2 to $7,316 \pm 786$ steps at week 12 ($P = 0.04$).

Table 3.3. Dietary Intake of Intervention and Control Groups at Baseline and Endpoint.

	Intervention ($n = 16$)		Control ($n = 15$)	
	Baseline	Endpoint	Baseline	Endpoint
Energy				
Kcal	2052 (117)	2023 (87)	2130 (120)	2049 (123)
kcal/kg	26.8 (1.6)	27.9 (2.3)	29.2 (1.7)	28.6 (1.7)
CHO				
grams	254.7 (17.0)	238.4 (23.9)	277.0 (17.6)	250.4 (16.1)
% of kcal	49.9 (1.7)	47.4 (2.0)	51.9 (1.8)	49.0 (2.0)
Fat				
grams	82.4 (7.6)	78.0 (8.3)	81.9 (7.9)	81.5 (7.5)
% of kcal	35.4 (1.7)	34.3 (1.7)	34.3 (1.7)	35.4 (1.8)
Protein				
grams	78.3 (5.6)	88.1 (9.6)	84.7 (5.7)	87.5 (4.6)
% of kcal*	15.5 (0.9)	17.5 (1.0)	16.1 (0.9)	17.4 (0.8)
g/kg	1.03 (0.08)	1.21 (0.12)	1.17 (0.09)	1.22 (0.06)
HEI Score	67.7 (3.4)	66.9 (3.5)	66.0 (3.6)	62.3 (4.4)

Data are mean (SEM)

Significantly different over time, $*p < 0.05$, RMANOVA

Participants were asked to wear the pedometer and record steps daily for 12 weeks with a total of 84 days to meet 100% compliance. The intervention group recorded pedometer steps an average of 75 ± 2 days out of a possible 84 days (89% compliance, range 77-100%). Two participants met the recommended 10,000 steps daily, while an additional three participants walked over 9,000 steps daily. Participants who walked the most steps lost significantly more weight than those who walked less ($r = -0.57$, $P = 0.03$).

By the end of the intervention, three women in the intervention group and three women in the control group had moved to the low intensity, low duration breastfeeding category. One woman in the control group began fully formula feeding her infant.

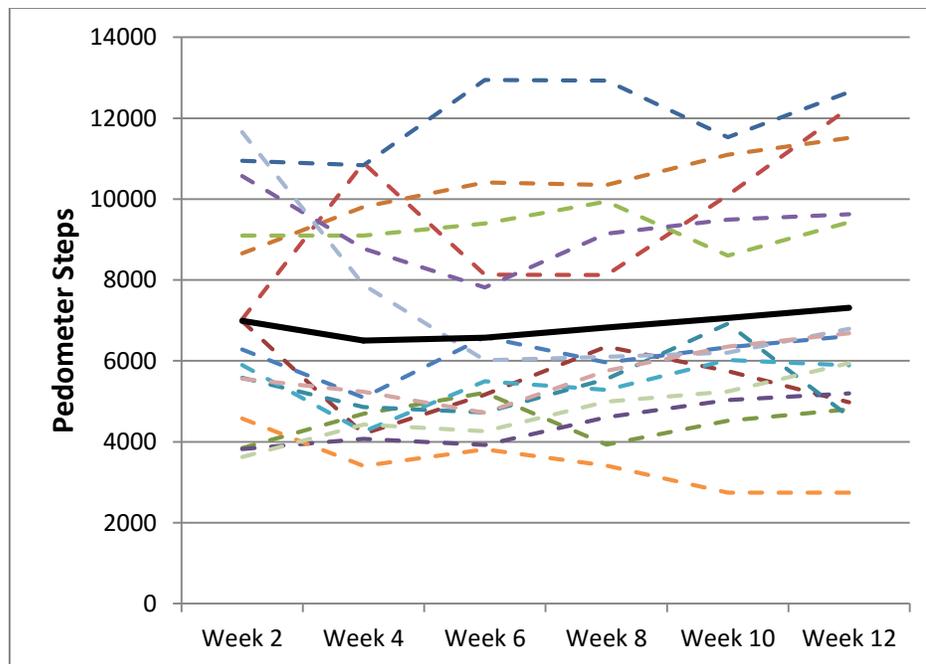


Figure 3.2. Pedometer Steps of the Intervention Group over the 12 Week Intervention.

Bolded line: average steps of all participants.

Discussion

Women in the intervention had significantly greater reductions in weight and BMI compared to women in the control group. However, their average weight loss (3.8 ± 0.7 kg) was less than the range of 4.8 to 8.3 kg reported in some other studies in postpartum women (5-10). Women lost an average of 0.3 kg/week, which was lower than the target weight loss of 0.5 kg/week. Other studies reported an average weekly weight loss ranging from 0.3 to 0.7 kg/week. Three of these studies recruited exclusively breastfeeding women (7, 8, 10). Since lactation increases energy expenditure (22), this may have contributed to increased postpartum weight loss. Additionally, the exercise sessions were supervised in the home in two studies (7, 8), which may have facilitated compliance with the exercise prescription, leading to increases in weight loss.

Our results are consistent with a study by Leermaker et al of 92 postpartum women (5). Their study utilized a correspondence-based intervention over 6 months, and included self-monitoring of dietary intake, and moderate aerobic activity. Weight loss in the intervention group was 0.3 kg/week and 0.2 kg/week in the control group. Additionally, most women in this study returned to work during the intervention, limiting compliance with the intervention, particularly the exercise component. Other studies recruited women who were not working at the time of the intervention (7, 10).

While we did not observe significant differences in total and percent fat mass loss between groups, the intervention group had significantly greater reductions in abdominal obesity, as measured by waist circumference, sagittal diameter, and trunk fat. Waist circumference has been found to be a better predictor of cardiovascular disease risk and

metabolic syndrome compared to BMI (23). Whereas increased visceral adiposity increases the risk of cardiovascular diseases, reductions in abdominal obesity decrease the risk of chronic disease (24).

Despite no differences in energy intake between groups over time, a weight loss of 0.3 kg/week was observed. This is in contrast with other interventions, which observed reductions of energy intake ranging from 382 to 721 kcal (5-8, 10). One reason for this is that compliance with the intervention (monitoring dietary intake and step count) decreased after 6 to 8 weeks for many participants. This corresponded with participants returning to work. However, the average calorie prescription for 0.5 kg/week weight loss was 2081 kcal for intervention participants. So, despite the lack of change in energy intake, participants were already reporting energy intakes at baseline that were 529 kcal lower than energy needed to maintain their weight. Additionally, the average weight loss from baseline to the 6 week midpoint measurement was -2.5 kg in the intervention group, while weight loss from 6 weeks to endpoint was -1.7 kg. Weight loss slowed during the second half of the intervention, with several participants re-gaining some weight. Rapid initial weight loss in the first few days or weeks of energy restriction is related to a reduced energy content of weight change (4,858 kcal/kg), comprised mainly of glycogen, protein, and water (25). However, metabolic adaptations occur over the next few months, resulting in reduced energy expenditure and increased fat oxidation requiring greater energy deficits, which explains the slower weight loss observed over time (25). Therefore, the generally practiced rule that a reduction in energy intake of 500 kcal per day will result in a steady-state weight reduction of 0.5 kg per day is inaccurate,

overestimating expected weight loss over time. The National Institute of Health Body Weight Planner is a new online tool, which more accurately predicts weight change over time (26). This may be a useful tool for setting realistic, personalized goals for future interventions.

Another explanation for the greater weight loss observed in the intervention group may have been related to increased energy expenditure from physical activity. Participants in this study were unable to achieve the aerobic exercise goal of 10,000 steps per day. However, the intervention group increased steps over the 12 week intervention, averaging 6,937 steps per day. This is above the average among American women of 5,210 steps daily (16). Additionally, 13% of women in the intervention group averaged over 10,000 steps. Aerobic exercise in this intervention was not supervised, with participants working toward the step goal on their own. This may have contributed to the inability to meet the goal. A previous study reported that when given a pedometer with an aerobic exercise goal of 10,000 steps daily, postpartum women were only able to achieve 4,838 steps daily (8). However, meta-analysis of physical activity interventions found that participants given a pedometer increased their activity by 2,004 steps per day more than control participants, and having a step goal and recording steps in a diary were predictors of increased activity (27). This suggests that using a pedometer is a valid strategy for increasing physical activity. Additionally, in this study, participants who walked more steps lost the greatest amount of weight. This may be related to increased physical activity in the intervention group as observed by a significant increase in VO_2 max of 2.6 mL/kg/min in the intervention group and a decrease of 0.5 mL/kg/min in the

control group. This represents a 12.5% increase in percentile for age in the intervention group and a 1.3% decrease in percentile for age in the control group. These results suggest that physical activity, in addition to energy restriction, may be beneficial to weight loss in postpartum women.

Diet quality, as measured by the Healthy Eating Index, did not change in either group as a result of the intervention. The mean diet quality score at baseline for the entire sample was 66.3, which is below the recommended HEI score for good diet quality of more than 80 (20). However, this is above the national average of 53.5 according to the 2007-2008 National Health and Nutrition Examination Survey (28). One study in low income, early postpartum women found a lower HEI score of 42.8 (29). However, our results are consistent with the KAN-DO study, which found an average baseline HEI score for overweight and obese postpartum women of 64.4 (30). Diet quality in their study did not change after a family-based diet and exercise intervention, and they found that baseline energy intake was a stronger predictor of weight change in the postpartum period. During a weight loss intervention in postpartum women, it may be challenging to meet recommendations for all food groups related to decreased energy intake, as well as lack of time to prepare healthy foods. In addition, breastfeeding women may intentionally restrict consumption of certain food groups, such as milk, beans, dairy, and grains due to infant intolerance (31). While improving diet quality should be an important priority in the postpartum period, focusing on reduction of energy intake has a greater impact on weight change.

This study used individualized dietary prescriptions, biweekly telephone or email counseling, self-monitoring of dietary intake using the USDA SuperTracker program, and self-monitoring of physical activity using pedometers. Our results were similar to a recent study of low-income, postpartum women that used a technology-based intervention, which included self-monitoring of weight and physical activity, biweekly telephone calls, daily text messages, and a social media support group. They reported that women in the intervention group lost 3.6 kg more than a usual care group (32).

Another study in overweight and obese fully breastfeeding women utilized the online USDA MyPyramid tool, a precursor to SuperTracker, and reported that the intervention group significantly reduced energy intake compared to the control group (31). Participants in this study used MyPyramid an average of 9.6 weeks of the 16 week intervention. However, similar to the present study, there was no association with weeks used and weight loss. This study also incorporated weekly face-to-face dietary counseling with a RD. These studies suggest that online diet tracking tools may be beneficial to reducing energy intake when combined with individualized dietary counseling via telephone, text messaging, or email. These types of interventions are time and labor-saving, and may be a more practical method for delivering individualized recommendations in order to promote weight loss in postpartum women.

Overall, compliance with the study intervention was good, with a high percentage of participants completing dietary and physical activity records. Participant retention was high, with a 9% attrition rate, suggesting that this type of intervention is feasible for this population. Other studies experienced attrition rates of 31% (5) and 42% (6). This may

reflect a longer study duration or the use of group classes, which are time intensive. Ostbye et al found that participants attended an average of 3.8 out of 8 classes and 3.3 out of 6 counseling calls (9). They did not observe significant weight loss between groups. This suggests that a class format may not be a feasible strategy for postpartum women. Studies that utilize home-based activities and self-monitoring have lower dropout rates and greater weight loss among intervention participants (7, 8, 10), indicating that this type of intervention may be more appropriate for postpartum women due to the increased time constraints of caring for an infant. Furthermore, self-monitoring of diet and physical activity has been shown to have a positive impact on weight loss (33).

In this study, increased perceived stress was associated with smaller reductions in weight. PSS scores in this study population (12.9) were lower than in other postpartum populations, which ranged from 15.8 to 18.3 (34-36). However, this is similar to average PSS scores among women of 13.7 (37). While there are no studies examining the relationship between perceived stress and weight change in postpartum women, increased stress levels have been associated with increased BMI (38), higher fat intake (39), and lower physical activity (38,40). Additionally, scores on the PSS have been found to be associated with increased risk of the metabolic syndrome (41) and cardiovascular disease (42).

Limitations to this study are the small sample size and lack of long-term follow up. Also, the study participants were mostly white and college educated, limiting the generalizability of the results to women of other race or ethnic groups and lower education levels. Finally, we did not have information on physical activity in the control

group. Determining the number of steps at baseline and endpoint in the control group, would allow for comparisons with the intervention group. Strengths of this study include the randomized, controlled design of the study, low dropout rate of participants, and high compliance with self-monitoring.

In conclusion, a RD-guided diet and exercise intervention was successful in promoting modest weight loss and loss of abdominal fat in postpartum women. In addition, this intervention increased physical activity and improved cardiovascular fitness levels, which may be responsible for the increased weight loss observed in the intervention group. While weight loss in this study was lower than in previous studies, the strategies used in this intervention were time and labor-saving. These strategies may be a practical method for reducing postpartum weight retention, lowering the risk of obesity among women of childbearing age.

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CHAPTER IV

EFFECTS OF A WEIGHT LOSS PROGRAM ON METABOLIC SYNDROME RISK FACTORS AND INFLAMMATION IN POSTPARTUM WOMEN

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Introduction

Metabolic syndrome (MetSyn) is a cluster of symptoms that have been shown to increase the risk of cardiovascular disease and type 2 diabetes (1). The National Cholesterol Education Program III (NCEP III) defines MetSyn in women as waist circumference greater than 88 cm, triglycerides greater than 150 mg/dL, HDL cholesterol less than 50 mg/dL, blood pressure greater than 130/85 mm Hg, and fasting glucose greater than 100 mg/dL (2). A diagnosis is made if 3 or more of the above criteria are met. In the United States, 23.4% of women meet the criteria for MetSyn (1). Obesity, specifically abdominal obesity, increases the risk of developing MetSyn (3).

Obesity is also associated with low grade, systemic inflammation (4). Adipose tissue has been found to secrete pro-inflammatory cytokines, including IL-6 and TNF- α (5). These cytokines stimulate production of a circulating inflammatory protein, C-reactive protein (CRP) (6), which is associated with MetSyn. A study by Ridker et al found that CRP levels increased as the number of MetSyn characteristics increased, with CRP of 3.01 mg/L associated with a diagnosis of MetSyn (7). .

Pregnancy is associated with physiologic changes, including insulin resistance (8), elevated cholesterol and triglycerides (9, 10), and increased inflammation (11-15). While these changes typically return to pre-pregnancy levels after delivery, excessive weight retention associated with pregnancy may delay this response, increasing the risk of MetSyn and chronic disease later in life (16). Increasing parity has also been associated with increased risk of obesity, elevated lipid profile, and diabetes (17). A study by Gunderson et al found that parity is associated with an increased risk of developing MetSyn (18).

Lactation may protect women against development of MetSyn by lowering risk factors during the postpartum period. Triglyceride levels return to baseline 13 weeks earlier in breastfeeding women compared to formula feeding women (10), while HDL levels are higher in lactating women (19). Lactation has also been shown to reduce insulin resistance and improve glucose homeostasis in women with and without a history of gestational diabetes (8, 19).

In addition to reducing risk factors during the postpartum period, breastfeeding may also reduce the risk of developing MetSyn later in life. A cross-sectional study by Ram et al found that the duration of lactation was inversely correlated with systolic and diastolic blood pressure, fasting glucose, triglycerides, total cholesterol, and LDL cholesterol, and positively correlated with HDL cholesterol, while the duration of breastfeeding was associated with a reduced risk of developing MetSyn in midlife (20).

Few studies have examined the impact of weight loss on MetSyn risk factors and inflammation in postpartum women. Studies that examined the effect of exercise on risk

factors found that moderate exercise alone did not improve blood lipids (21, 22), but there was a significant correlation between change in VO₂ max and change in insulin response (21). Women in both these studies had a normal BMI, and changes in body weight did not differ between the intervention and control groups. Studies that combine an energy restriction with moderate exercise have found greater reductions in waist circumference (23, 24), LDL cholesterol (23, 24), total cholesterol (24), insulin (24) and glucose (23), and increased HDL cholesterol (24) and adiponectin (23). However, they did not observe changes in inflammatory proteins. Stendell-Hollis et al found that TNF- α levels were reduced with a Mediterranean-style and MyPyramid diet, but no significant differences were observed between groups (25). These studies show that weight loss associated with dietary or dietary plus exercise interventions may improve cardiometabolic risk factor and inflammation. However, no studies to our knowledge have compared the impact of body composition changes on the occurrence of MetSyn in postpartum women.

In a randomized, controlled trial, we found that a 12-week, home-based diet and exercise intervention reduced weight by 5% in postpartum women, with reductions in waist circumference, sagittal diameter, and abdominal fat mass, and improvements in cardiovascular fitness. In this paper, we examine the effects this intervention on MetSyn, cardiometabolic risk factors, and inflammation among postpartum women.

Methods

Study Participants

Participants were part a home-based, self-monitoring weight loss intervention. Women were recruited from the Greensboro, NC community. Research staff distributed recruitment flyers at pre- and postnatal classes at the local Women's Hospital. Flyers were also posted in obstetric and pediatric medical offices. Women with a BMI between 25 to 35 kg/m² or who were at least 4.5 kg heavier than their pre-pregnancy weight were eligible to participate when they were between 6 and 14 weeks postpartum. Other eligibility criteria include sedentary lifestyle, age 18 years and older, non-smoker, singleton birth, and free of chronic disease. Women were screened by telephone or email after the delivery of their baby. Eligibility was determined by self-reported weight. Participants were required to receive medical clearance from their physician before starting the intervention.

Study Design

This was a 12-week randomized, controlled clinical trial (ClinicalTrials.gov NCT01668316), approved by the University of North Carolina at Greensboro Institutional Review Board. Participants were randomized using block randomization, and stratified by baseline BMI and weeks postpartum.

A more detailed description of the intervention is presented in Chapter III. Briefly, the intervention involved self-monitoring of diet and exercise behaviors, led by a registered dietitian. Participants were instructed on reducing energy intake by 500 kcal/day to achieve a weight loss of 0.5 kg/week. Energy prescriptions were calculated

using the National Academy of Sciences/Institute of Medicine equation with adjustments made based on lactation status (26). Participants were asked to track their dietary intake using the online USDA SuperTracker program on at least 3 days a week (27). They were also given a pedometer (Omron Healthcare, Inc., Lake Forest, IL) with a daily exercise goal of 10,000 steps. Diet and pedometer records were reviewed biweekly by the registered dietitian, and individualized recommendations were provided to participants. The control group was instructed to continue their current diet and exercise habits.

Measurements

Anthropometrics, body composition, and metabolic and inflammatory biomarkers were measured at baseline and after the 12-week intervention.

Anthropometrics. Height and weight were measured using a digital stadiometer (235 Heightronic Digital Stadiometer, Snoqualmie, WA) and a calibrated digital scale (Tanita BWB-800S). A Gulick tape was used to measure waist circumference at the narrowest point of the torso, and hip circumference was measured at the maximum circumference of the hip (28).

Body Composition. Fat mass, fat mass, and trunk fat mass were measured by dual-energy x-ray absorptiometry (DXA: Lunar Prodigy Advance, GE Healthcare, Madison, WI, Encore 2011 software version 13.60) by a trained DXA technician. Trunk fat was measured as the fat mass in the neck, chest, abdominal, and pelvic regions.

Blood Biomarkers. Fasting blood samples were drawn by a trained phlebotomist. Since anti-inflammatory medications or acute illness may alter concentrations of inflammatory proteins, participants were instructed to not take these medications within

24 hours of the initial laboratory visit. Laboratory measurements were rescheduled if the participant was ill within two weeks of the initial visit. Blood samples were left at room temperature for 20 minutes to allow for clotting, then spun in a centrifuge at 3000 rpm at 4°C for 30 minutes. Serum was partitioned into micro-centrifuge tubes and stored at -80°C. ELISA kits were used to determine concentrations of high sensitivity -CRP (hs-CRP; Genway Biotech, Inc., San Diego, CA) and insulin (Merckodia, Uppsala, Sweden). Colorimetric assay was used to measure glucose concentrations (Cayman Chemical, Ann Arbor, MI), total, HDL, and LDL cholesterol, and triglycerides (Wako Chemical, Richmond, VA). Insulin resistance was calculated using the homeostatic model assessment of insulin resistance (HOMA-IR) using the equation: $HOMA-IR = [Fasting\ glucose\ (mg/dL) \times Insulin\ (\mu U/mL)]/405$ (29).

Blood Pressure. Blood pressure was measured after resting for 5 minutes in a seated position using a digital monitor (LifeSource UA-853, San Jose, CA). Two blood pressure readings were obtained, and the results were averaged.

Cardiovascular Fitness. A submaximal treadmill testing was used to determine predicted maximal oxygen consumption (VO_2 max) using a modified Balke protocol (28). Resting heart rate (RHR) was determined using a heart rate (HR) monitor (Polar, Inc., Woodbury, NY) prior to exercise testing. This was used to determine the maximum HR reserve (HRR) using the formula, $HRR = (220 - age - RHR) \times 0.85 + RHR$. After a three minute warm up, participants selected a brisk, slightly uncomfortable speed at either a walking (< 3.7 mph) or jogging (> 3.7 mph) pace. Every three minutes the incline of the treadmill was increased by 2.5%. HR and perceived exertion were recorded every minute.

The test was concluded when the participant's heart rate reached 85% of their predicted maximum HR or if she asked to stop. Predicted VO₂ max was determined using a linear regression model (28).

Metabolic Syndrome

Metabolic syndrome was determined based on the NCEP III criteria. A participant was considered to have MetSyn if they met at least three of the following criteria: waist circumference greater than 88 cm, triglycerides greater than 150 mg/dL, HDL cholesterol less than 50 mg/dL, blood pressure greater than 130/85 mm Hg, and fasting glucose greater than 100 mg/dL (2).

C-Reactive Protein Risk

CRP risk categories were assigned based on the American Heart Association and Centers for Disease Control and Prevention recommendations based on risk of coronary outcomes as follows: less than 1 mg/L (low risk), 1.0-3.0 mg/L (medium risk), and greater than 3.0 mg/L (high risk) (30).

Lactation

Each participant was assigned a lactation score in order to determine the duration and intensity of lactation. Every two weeks, participants in both groups were asked how they were feeding their infant. For every week since delivery, a participant was given a score of 2 if she was fully breastfeeding, a score of 1 if she was combining breastfeeding and formula feeding, and a score of 0 if she was fully formula feeding. The maximum score was 36 to 52 based on when the participant entered the study. The total score was divided by the maximum score to obtain the lactation score percentage. Women were

considered formula feeding if they had a score less than 25% of the maximum, low intensity, low duration breastfeeding with a score between 25-75% of the maximum, and high intensity, high duration breastfeeding with a score greater than 75% of the maximum.

Statistical Analysis

Data was analyzed using JMP software (v.11.0.0, SAS Institute, Cary, NC). Student's *t*-test and χ^2 analysis were used to compare differences in baseline characteristics between groups for continuous and categorical variables respectively. Repeated measures ANOVA was used to test for time by group interactions, and main effects of time and group for anthropometrics, body composition, hs-CRP, lipids, glucose, insulin, and blood pressure between the intervention and control groups. Repeated measures analysis of covariance was used to test for significant differences in variables with lactation score percentage at endpoint and weeks postpartum at baseline used as covariates. Stepwise regression was used to determine independent predictors of change in biomarkers. Data are reported as mean (SEM), with significance set at $p \leq 0.05$.

Results

Thirty-four women were randomized to the intervention ($n = 16$) or control ($n = 15$) groups. Three women did not complete endpoint measurements due to a new pregnancy ($n = 1$) and lost to follow up ($n = 2$). Three women were excluded from the hs-CRP analysis due to concentrations above 2 SD from the mean (> 13.6 mg/dL, range 22.5 to 43.2 mg/dL) indicating likely acute inflammatory response. Additionally, the hs-CRP

concentrations were not normally distributed so natural log of these values was calculated and used for analysis.

Baseline characteristics are reported in Chapter III (Table 3.1), and they did not differ between the intervention and control groups. Briefly, women at baseline were on average 31.3 ± 0.7 years of age, weighed 75.5 ± 1.6 kg, with a BMI of 27.8 ± 0.5 kg/m². They were predominantly primiparous (65%) and breastfeeding at a high intensity and high duration (90%).

Changes in weight, body composition, and cardiovascular fitness are presented in Chapter III (Table 3.2). Women in the intervention group had significantly greater reductions in weight (-3.8 ± 0.7 vs -1.8 ± 0.7 kg), BMI (-1.4 ± 0.2 vs -0.7 ± 0.3 kg/m²), waist circumference (-4.4 ± 0.6 vs -1.7 ± 0.6 cm), and trunk fat (-1.8 ± 0.4 vs -0.7 ± 0.4 kg) compared to the control group. There was a trend for greater reductions in fat mass in the intervention group ($p = 0.052$). The women in the intervention group also had a significant increase in VO₂ max compared to a decrease in the control group.

Metabolic Syndrome and Cardiometabolic Risk Factors

Changes in metabolic syndrome risk factors are presented in Table 4.1. The intervention group had greater reductions in waist circumference compared to the control group. While there was a trend for reduction in LDL cholesterol ($p = 0.09$) over time, there were no significant differences between groups for lipid profile (total cholesterol, LDL, HDL, triglycerides), insulin, glucose or blood pressure. However, after controlling for lactation duration and intensity at endpoint, there was a trend for significant differences in HOMA-IR between groups ($p = 0.06$), with the control group having a

Table 4.1. Metabolic Syndrome and Cardiovascular Risk Factors

	Baseline	Endpoint	Change
Metabolic Syndrome Criteria			
Waist circumference (cm) ^a			
Intervention	86.5 (1.8)	82.1 (1.9)	-4.4 (0.6)
Control	86.6 (1.9)	84.9 (2.0)	-1.7 (0.6)
Systolic BP (mmHg)			
Intervention	111.1 (1.8)	108.8 (1.8)	-2.3 (1.4)
Control	110.1 (1.8)	111.3 (2.8)	1.1 (2.5)
Diastolic BP (mmHg)			
Intervention	74.7 (1.9)	75.1 (1.7)	0.4 (2.2)
Control	72.6 (2.0)	72.2 (2.0)	-0.4 (2.4)
HDL cholesterol (mg/dL)			
Intervention	54.3 (4.6)	48.1 (5.5)	-6.2 (4.9)
Control	55.1 (4.8)	52.7 (5.6)	-2.4 (3.9)
Triglycerides (mg/dL)			
Intervention	56.9 (5.8)	58.7 (6.5)	-1.7 (6.6)
Control	65.4 (6.0)	77.8 (10.7)	12.4 (12.8)
Fasting glucose (mg/dL)			
Intervention	84.6 (3.9)	85.7 (4.2)	1.1 (3.6)
Control	87.1 (4.0)	93.9 (5.5)	6.8 (6.9)
Other Risk Factors			
Total cholesterol (mg/dL)			
Intervention	257.2 (12.3)	261.5 (14.2)	4.4 (14.5)
Control	264.5 (18.3)	263.0 (16.8)	-1.5 (18.8)
LDL cholesterol (mg/dL)			
Intervention	115.4 (8.2)	108.1 (6.5)	-7.3 (9.7)
Control	118.7 (8.4)	103.7 (9.2)	-15.0 (8.3)
Insulin (μU/mL)			
Intervention	9.95 (1.31)	10.22 (1.16)	0.27 (0.63)
Control	9.75 (1.35)	11.03 (1.20)	1.3 (1.1)
HOMA-IR (units)			
Intervention	2.12 (0.33)	2.20 (0.30)	0.08 (0.20)
Control	2.20 (0.34)	2.62 (0.38)	0.42 (0.36)
hs-CRP (mg/dL)			
Intervention	2.78 (0.43)	3.19 (0.77)	0.41 (0.70)
Control	3.39 (0.82)	4.19 (1.1)	0.80 (0.58)

BP, blood pressure; HDL, high density lipoprotein; LDL, low density lipoprotein; HOMA-IR, homeostasis model assessment of insulin resistance; hs-CRP, high sensitivity C-reactive protein
Data is mean (SEM). ^a $p < 0.05$

greater increase in insulin resistance compared to the intervention group. After controlling for lactation percentage at endpoint and weeks postpartum at baseline, there was a significant difference in triglycerides between groups ($p = 0.04$), with a decrease in the intervention group and an increase in the control group.

Table 4.2. C-Reactive Protein Risk Category at Baseline and Endpoint.

	Baseline	Endpoint
Low risk (< 1.0 mg/dL)		
Intervention	2 (13%)	6 (40%)
Control	4 (31%)	4 (31%)
Medium risk (1.0-2.9 mg/dL)		
Intervention	6 (40%)	4 (27%)
Control	3 (23%)	0 (0%)
High risk (> 3.0 mg/dL)		
Intervention	7 (47%)	5 (33%)
Control	6 (46%)	9 (69%)

Intervention $n = 15$

Control $n = 13$

There were no significant differences in hs-CRP by group or by time (Table 4.1). CRP risk categories are presented in Table 4.2. CRP risk category did not differ significantly at baseline. However, by endpoint, there was a significantly different distribution between groups with women in the control group being more likely to be in the high risk category ($p = 0.04$). Three participants in the intervention group reduced their risk from high to medium risk, while three women reduced their risk from medium to low risk. No intervention participants increased risk category. One participant in the control group reduced from medium to low risk. However, two participants increased from medium to high risk, and one participant increased from low to high risk. At

baseline, one participant from each group had greater than or equal to three criteria for diagnosis of metabolic syndrome (Table 4.3). By the end of the 12 week intervention, three women in the control group compared to one woman in the intervention group met the criteria for metabolic syndrome.

A stepwise regression was conducted to determine predictors of change in cardiometabolic risk factors. The independent variables were change in weight, change in waist circumference, change in fat mass, change in fat free mass, change in VO₂ max, group assignment (intervention or control), and weeks postpartum at baseline. Change in VO₂ max ($\beta = 0.37, p = 0.03$), change in fat free mass ($\beta = -0.43, p = 0.007$), group assignment ($\beta = -0.46, p = 0.0007$), and triglycerides at baseline ($\beta = -0.53, p = 0.002$) were significant predictors of change in triglycerides ($R^2 = 0.44, p = 0.0001$). Change in VO₂ max ($\beta = -0.05, p = 0.02$) was a significant predictor of change in hs-CRP ($R^2 = 0.19, p = 0.03$). While there were no independent predictors of total cholesterol, the model including change in BMI ($\beta = 0.34, p = 0.48$), change in percent fat mass ($\beta = -0.11, p = 0.82$), change in fat free mass ($\beta = -0.04, p = 0.91$), group assignment ($\beta = 0.13, p = 0.37$), and total cholesterol at baseline ($\beta = -0.72, p < 0.0001$), was significant ($R^2 = 0.46, p = 0.007$). Endpoint lactation score percentage ($\beta = -0.42, p = 0.01$) and baseline HOMA-IR ($\beta = -0.35, p = 0.02$) were significant predictors of change in HOMA-IR ($R^2 = 0.58, p = 0.004$). There were no significant predictors of change in, LDL, HDL, systolic or diastolic blood pressure, glucose, and insulin.

Table 4.3. Number of Participants Meeting Metabolic Syndrome Risk Criteria

	Baseline	Endpoint
Waist Circumference (>88 cm)		
Intervention	7 (44%)	3 (19%)
Control	7 (47%)	5 (33%)
Fasting Glucose (>100 mg/dL)		
Intervention	1 (6%)	3 (19%)
Control	4 (27%)	6 (37%)
Blood Pressure (>130/85 mmHg)		
Intervention	2 (13%)	1 (6%)
Control	1 (7%)	0 (0%)
HDL Cholesterol (<50 mg/dL)		
Intervention	8 (50%)	10 (63%)
Control	10 (67%)	11 (73%)
Triglycerides (>150 mg/dL)		
Intervention	0 (0%)	0 (0%)
Control	0 (0%)	1 (7%)
0 MetSyn Criteria		
Intervention	4 (25%)	4 (25%)
Control	3 (20%)	2 (13%)
1 MetSyn Criteria		
Intervention	7 (44%)	9 (56%)
Control	3 (20%)	5 (33%)
2 MetSyn Criteria		
Intervention	4 (25%)	2 (13%)
Control	8 (52%)	5 (33%)
≥ 3 MetSyn Criteria		
Intervention	1 (6%)	1 (6%)
Control	1 (7%)	3 (20%)

Data are number of participants meeting criteria (percentage).

Discussion

This study found that a diet and exercise intervention resulted in significant weight loss and loss of abdominal obesity in postpartum women. After controlling for lactation status and weeks postpartum at the start of the study, the intervention group had

greater reductions in insulin resistance and triglycerides compared to the control group. However, other metabolic risk factors were not impacted by the intervention.

Previous studies have found conflicting results. In two studies examining the impact of exercise only on cardiovascular risk factors, no differences in lipid profile between groups was observed (21, 22). However, while Lovelady et al found no effect of exercise on insulin and glucose response to a test meal, they did find a significant negative association between change in VO_2 max and change in insulin response (21). Women in these groups were normal weight at the start of the intervention and weight loss was modest. Studies that have combined exercise with an energy restriction have found a greater impact on these risk factors. Davenport et al found a significant reduction in waist circumference, fasting glucose, and LDL cholesterol as a result of a diet and exercise intervention (23). Additionally, Brekke et al found a significant effect of diet on waist circumference, total cholesterol, LDL, and insulin after a 12 week intervention (24). Weight loss in these studies was significantly greater than in the present study. The weight loss achieved in this study may not have been adequate to observe significant differences between groups.

We did not observe significant differences in hs-CRP between groups. This is a similar finding to Brekke et al, who found no effect of diet or exercise on hs-CRP, IL-6, or TNF- α (24). Another study by Stendell-Hollis found a significant reduction in TNF- α following either a Mediterranean or MyPyramid diet in postpartum women, but differences were not significant between groups (25). This may reflect a natural reduction in CRP during the postpartum period. Inflammation is heightened during pregnancy (11-

15), and remains elevated in the early postpartum period (31). Furthermore, weight loss of at least 10% may be required to observe changes in inflammation (32). Weight loss in the intervention group for this study was only 5%. Despite lack of change in CRP in the intervention group, we did observe a reduction in cardiovascular risk with more women in the intervention group moving to a lower CRP risk category compared to the control group. We also observed that changes in VO₂ max were negatively associated with changes in CRP, suggesting that improving aerobic fitness may be beneficial for reducing systemic inflammation. Other studies have found similar associations between VO₂ max and CRP in women (33-35).

Overweight and obese, postpartum women are at risk of metabolic syndrome. In this study, two women (6.6%) met the criteria for metabolic syndrome at baseline, while four women met the criteria at endpoint (12.9%). Another 12 women (39%) had two risk factors for metabolic syndrome at baseline. In these participants, high waist circumference and low HDL were the most frequent abnormal values. This is similar to a study of 68 lactating Swedish women, which found that 6.2% of participants were classified as having the metabolic syndrome, meeting the criteria with high waist circumference and blood pressure and low HDL (36). Weight loss interventions are important for reducing the risk factors in this population as childbearing is associated with an increased risk of metabolic syndrome later in life (18).

Strengths of this study include the randomized, controlled design and the low participant attrition rate. Additionally, few studies have examined the impact of a weight loss intervention on metabolic syndrome and inflammation in postpartum women.

Limitations include the relatively small sample size, and weight loss that, while significant, was modest. However, the strategies utilized in the intervention were designed to conform to the time constraints of caring for a new infant. A study of longer duration or a longer follow up may have yielded better results. Additionally, changes in cardiovascular fitness were associated with changes in CRP. Incorporation of a more intense exercise regimen into a weight loss intervention may help reduce cardiometabolic risk factors further. The participants in this study were eligible to participate between 6 and 14 weeks postpartum. Lipid levels typically return to pre-pregnancy levels by around 6 weeks postpartum (8). However, these levels may have still been elevated in women who started the intervention earlier. Finally, most women (90%) were high intensity, high duration breastfeeding at the start of the intervention, but some woman began formula feeding by the end of the study. Since lactation may help women return to pre-pregnancy concentrations of lipids, glucose, and insulin earlier (9, 10, 19), this change in lactation status may have impacted the results of the study.

In conclusion, overweight and obese, postpartum women are at an increased risk of developing chronic disease later in life (18). The postpartum period is an optimal time to intervene to reduce a woman's risk factors. In this study, we found that a 12 week, home-based, diet and exercise intervention was successful in reducing weight and abdominal obesity, as well as improving triglyceride and insulin resistance in postpartum women.

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CHAPTER V

ASSOCIATION BETWEEN AEROBIC FITNESS AND INFLAMMATION WITH BONE MINERAL DENSITY IN LACTATING WOMEN AFTER A WEIGHT LOSS PROGRAM

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Introduction

Obesity increases a person's risk for chronic disease, such as heart disease and diabetes. This is especially an issue among women of childbearing age, with 55.8% of women between the ages of 20 and 39 years being overweight or obese (1). While obesity has been shown to be associated with higher bone mineral density (BMD) (2), weight loss may increase bone turnover and decrease BMD, particularly at trabecular-rich sites (lumbar spine and total hip) (2). Some researchers have reported decreases in BMD with moderate (3) and rapid (4, 5) weight loss in overweight and obese premenopausal women. However, other studies have not observed bone loss with weight loss (6-8).

This loss of BMD is of concern during weight loss in the postpartum period because lactation is also associated with a decrease in BMD, with reported bone losses of 1 to 3% per month (9), up to a total of 9% at trabecular-rich sites (10). This initial rapid bone loss is thought to be due to increased concentrations of prolactin during early lactation (11). Bone loss slows after 3 to 4 months postpartum as prolactin concentrations decrease (11, 12) or after the return of menses (13). After weaning or after the return of

menses, BMD returns to baseline levels within 12 to 18 months postpartum (14).

However, it is unclear if weight loss during this time exacerbates BMD loss.

Exercise has been shown to attenuate this bone loss in postmenopausal women.

Increased maximal oxygen uptake (VO_2 max) has been found to be associated with

increased total body (15), femoral neck (16), and leg BMD (17). Another study by

Silverman et al found a positive relationship between VO_2 max and femoral neck BMD

after a 6 month weight loss program in overweight postmenopausal women (18).

However, in other reports, the addition of aerobic (19, 20) or resistance exercise (21) to a

weight loss program in overweight and obese premenopausal women did not have an

impact on BMD changes.

Exercise may also reduce BMD losses during lactation. Lovelady et al examined

the impact of a resistance and aerobic exercise intervention on BMD in lactating women

(22). Compared to women in the control group, women in the intervention group had less

bone loss at the lumbar spine after the 16 week intervention. While energy restriction was

not a component of the intervention, both groups lost a similar amount of weight.

Colleran et al investigated the effect of a resistance exercise combined with energy

restriction on BMD in overweight and obese fully breastfeeding women (23). The

exercise and control groups had similar reductions in BMD. However, the intervention

group lost more weight, suggesting that resistance exercise may be protective against

reductions in BMD during weight loss in lactating women. Two other studies found

losses of lumbar spine and femoral neck BMD in exercising women were similar to

non-exercising controls (24, 25). However, these studies did not involve a structured, randomized exercise intervention and the women were within a normal BMI range. The effect of aerobic exercise with energy restriction on BMD has not been well studied in postpartum women.

In addition to its impact on BMD, obesity is associated with elevated levels of inflammatory cytokines, such interleukin 6 (IL-6), tumor necrosis factor alpha (TNF- α), and C-reactive protein (CRP) (26), which are also involved in bone remodeling (27, 28). However, it is unknown if inflammation associated with obesity exacerbates bone loss in breastfeeding women or inhibits the gains observed after weaning. Several studies in postmenopausal women found an association between IL-6, CRP, and TNF- α and total body and regional BMD (29-33). However, others report no significant correlations between inflammatory cytokines and BMD (33, 34).

Few studies examining this relationship in premenopausal women have been conducted. Salamone et al found a negative relationship between TNF- α and IL-6 with femoral neck and lumbar spine BMD (35). Others have found a similar relationship with CRP and BMD in premenopausal women (36, 37). However, two studies found no significant relationship between CRP and BMD (31, 38). Few studies have investigated this relationship during weight loss. Silverman et al found that change in TNF receptor 1 was positively associated with change in femoral neck BMD after weight loss in obese postmenopausal women (18). Labouesse et al reported that 20% of the variance in post-weight loss hip BMD was explained by a combination of inflammatory, endocrine, and anthropometric variables (39).

While these studies suggest that exercise may reduce bone loss observed during a weight loss intervention, results from previous studies are inconsistent. However, few studies have looked at the effect of aerobic exercise on BMD in lactating women. Elevated inflammation in overweight lactating women may also exacerbate this bone loss, but this relationship has not been studied in this population. Therefore, the purpose of this study is to examine the relationship between aerobic exercise, CRP, and BMD, and determine if improvements in cardiovascular fitness and reductions in CRP as a result of a weight loss intervention attenuates the loss of BMD in lactating women.

Methods

Study Participants

Women were recruited from the Greensboro, NC community at pre- and postnatal classes. Flyers were also posted in local obstetrician and pediatric offices. Eligibility criteria include, 1) 6 to 14 weeks postpartum with singleton birth, 2) self-reported BMI between 25 and 35 kg/m² or at least 4.5 kg heavier than pre-pregnancy weight, 3) 18 years and older, 4) sedentary (physical activity less than 3 days per week, 5) free of chronic disease, and 6) non-smokers. Women who had a cesarean section were not excluded from the study, but they did not start the intervention until 14 weeks postpartum. All participants returned a medical clearance form from their physician at baseline clearing them to participate in a diet and exercise intervention. The original study was powered to detect a 2.0 kg change in weight (sample size of 12 per group) with 80% power and a 2-sided alpha of 0.05. However, it was not powered to detect change in BMD.

Study Design

The study was designed to examine the effects of a home-based, self-monitoring diet and exercise intervention on changes in weight and body composition. Participants were randomized, stratified based on BMI and time from childbirth into either the diet and exercise intervention or control group. The study was approved by the Institutional Review Board at the University of North Carolina Greensboro.

Study Intervention

The intervention consisted of a 12-week diet and exercise program with participants eligible to begin between 6 to 14 weeks postpartum. The intervention involved self-monitoring of dietary intake and physical activity, with guidance provided by a registered dietitian (RD). Individualized energy prescriptions with sample meal plans were provided to participants at the beginning of the intervention. Energy needs were calculated using the National Academy of Sciences/Institute of Medicine energy expenditure equation (40). An energy reduction of 500 kcal/day was added in order to promote a 0.5 kg/week weight loss. Women who were fully breastfeeding were allowed an additional 330 kcal/day, while women who were mixed feeding (breastfeeding and formula) were allowed an additional 150 kcal/day.

The exercise component of the intervention involved increasing aerobic exercise. Participants were asked to wear a pedometer (Omron Healthcare, Inc., Lake Forest, IL) every day, and record daily steps and aerobic steps. A goal of 10,000 steps daily was set, with instructions to increase amounts by 1,000 steps every week. Participants were given a secondary goal of achieving 3,000 aerobic steps daily, which is the equivalent of 30

minutes of moderate activity (41). Aerobic steps are calculated when a participant walks at least 100 steps per minute for at least 10 minutes.

The control group was instructed to not change diet or exercise habits for the duration of the study. All participants were contacted biweekly by telephone or email.

Laboratory Measurements

Measurements, including anthropometrics, bone density and bone mineral content (BMC), body composition, cardiovascular fitness, and inflammatory proteins, were taken at baseline (6 to 14 weeks postpartum) and after the 12 week intervention (18 to 26 weeks postpartum).

Body Composition. Height and weight were measured using a digital stadiometer (235 Heightronic Digital Stadiometer, Snoqualmie, WA) and a calibrated digital scale (Tanita BWB-800S). Body composition, BMD, and BMC were measured using whole body dual-energy x-ray absorptiometry (DXA: Lunar Prodigy Advance, GE Healthcare, Madison, WI, QDR enCORE 2011 software version 13.60) by a trained DXA technician. Participants lied flat and still in the supine position on the x-ray table. The fan-beam scanner scanned the whole body from head to toe with a series of transverse scans. Body composition measurements included fat mass, lean mass, and trunk fat mass. Lean mass was calculated as fat-free mass, excluding BMC. Trunk fat was calculated as the amount of fat located in the neck, chest, abdominal, and pelvic regions. BMD and BMC were measured for total body, lumbar spine (L1-L4), and the total hip, including the femoral neck. A pregnancy test was conducted prior to DXA scan using an early pregnancy test,

which detects human chorionic gonadotropin at levels of 20 mIU/mL. This was to ensure that the participant was not pregnant at the time of DXA scan.

Inflammatory Markers. Participants were instructed to not take anti-inflammatory medications the day before and morning of the initial visit. Initial assessment was rescheduled if a participant was ill or taking anti-inflammatory medications as these may alter inflammatory protein concentrations. Blood was drawn after an overnight fast by a trained phlebotomist using standard procedures. Vacutainers were left at room temperature for 20 minutes to allow the blood to clot. Samples were spun in a centrifuge at 3000 rpm at 4°C for 30 minutes. Serum was aliquoted into micro-centrifuge tubes and stored at -80°C until analyzed. ELISA kits were used to determine concentrations of high sensitivity CRP (hs-CRP: Genway Biotech, Inc., San Diego, CA).

Cardiovascular Fitness. Cardiovascular fitness was determined by submaximal treadmill testing using a modified Balke protocol test (42). Resting heart rate (RHR) was determined using a heart rate (HR) monitor (Polar, Inc., Woodbury, NY) worn by participants throughout the testing. Participants warmed up on the treadmill for three minutes, then the speed was increased to a brisk, slightly uncomfortable speed, which remained consistent throughout the testing. Participants either walked (< 3.7 mph) or a jogged (> 3.7 mph). The initial incline was 0% and was increased by 2.5% every three minutes. HR and perceived exertion were recorded every minute during the test. The test continued until the participant's HR reached 85% of their predicted maximum HR or if the participant asked to stop. Maximum HR was determined using the heart rate reserve (HRR) formula [$HRR = (220 - \text{age} - RHR) \times 0.85 + RHR$]. A linear regression model was

used to calculate predicted VO₂ max (independent variable = HR, dependent variable = predicted VO₂) (42).

Dietary Intake

Two 24-hour dietary recalls were collected by telephone or in person within the same week as baseline measurement using the Minnesota Nutrition Data System for Research (NDSR, Nutrition Coordinating Center, University of Minnesota, MN) software. Efforts were made to include one weekend day, but this was not always achieved due to participant scheduling.. This program utilizes a multipass method in order to accurately record dietary intake. Information on supplement use in the previous 24 hours was also obtained. Calcium intake was determined using these dietary records. A 4 day average calcium intake was calculated using two recalls at baseline and two recalls at endpoint.

Lactation

Every two weeks, participants in both groups were asked about their infant feeding practices. A lactation score was calculated for all participants in order to quantify the intensity and duration of breastfeeding. A score of 2 was assigned for every week a woman was fully breastfeeding, a score of 1 for mixed feeding (breastfeeding and formula feeding), and a score of 0 for fully formula feeding. A maximum score of 36 to 52 was assigned depending on when the participant entered the study. Percentage of the maximum score was calculated at baseline and endpoint by dividing the lactation score by the maximum possible score for fully breastfeeding. Women were categorized as high duration, high intensity breastfeeding if they had a score greater than 75% of the

maximum score. They were categorized as formula feeding if they had a score less than 25% of the maximum. Women with scores between 25-75% of the maximum score were categorized as low intensity, low duration breastfeeding.

Statistical Analysis

Data was analyzed using JMP software (v.11.0.0, SAS Institute, Cary, NC). Student's *t*-test and χ^2 analysis were used to compare differences in baseline characteristics between the intervention and control groups. Repeated measures analysis of covariance was used to determine differences in total body, lumbar spine, total hip, and femoral neck BMD and BMC between the intervention and control group over time with endpoint lactation score percentage and weeks postpartum at baseline as covariates. Pearson's correlations coefficients were used to determine the relationship between baseline and endpoint values of total body, lumbar spine, total hip, and femoral neck BMD and BMC with baseline and endpoint body weight and composition, VO₂ max, hs-CRP, lactation score percentage, and average calcium intake. Correlations were also used to determine the relationship between changes in BMD and BMC and the above variables. These analyses were used to determine variables included in the multiple regression models. Stepwise regression was used to determine the independent predictors of change in total body, lumbar spine, total hip, and femoral neck BMD and BMC. Data are reported as mean \pm SEM, with significance set at $p \leq 0.05$.

Results

Thirty-four women were randomized to either the intervention group ($n = 17$) or control group ($n = 17$). Three participants dropped out of the study (1 from intervention,

2 from control) due to pregnancy and lost to follow up. Additionally, three women had endpoint CRP levels greater than 17.6 mg/dL (two SD from the mean), indicating a high likelihood of acute inflammatory response. These values were excluded from the analysis. Since hs-CRP concentrations were not normally distributed, the natural log of these values was used for analysis. Baseline criteria are presented in Chapter III (Table 3.1). There were no significant differences between groups at baseline. Women were an average age of 31.3 ± 0.7 years. They weighed a mean of 75.5 ± 1.6 kg and had a mean BMI of 27.8 ± 0.5 kg/m². On average, participants were 11.6 ± 0.5 weeks postpartum.

The intervention group lost significantly more weight and had significantly greater reductions in BMI than the control group. There was a trend for greater reductions in percent body fat ($P = 0.08$) and total fat mass ($P = 0.05$) in the intervention group. There were no changes in lean mass in either group. Predicted VO₂ max improved by $9.3 \pm 3.5\%$ for the intervention group, while decreasing by $5.3 \pm 5.6\%$ in the control group ($P = 0.03$). These data are presented in Table 5.1.

There were significant reductions in lumbar spine hip and femoral neck BMD in both groups over time, and significant reductions in total body, lumbar spine, hip, and femoral neck BMC (Table 5.2). However, there were no significant time by group interactions for total body BMD or BMC. However, after controlling for lactation score percentage at endpoint and weeks postpartum at baseline, there was a significant difference between groups in total body BMD ($P = 0.02$), total hip BMD ($P = 0.01$) and BMC ($P = 0.003$), lumbar spine BMC ($P = 0.01$), and femoral neck BMC ($P = 0.02$). There was a trend for significant differences between groups for femoral neck BMD

Table 5.1. Body Composition and CRP at Baseline and Endpoint after the Intervention.

	Intervention			Control		
	Baseline	Endpoint	Change	Baseline	Endpoint	Change
Weight (kg) ^a	76.7 (2.2)	72.9 (2.4)	-3.8 (0.7)	74.2 (2.3)	72.3 (2.7)	-1.8 (0.7)
BMI (kg/m ²) ^a	28.4 (0.7)	27.0 (0.8)	-1.4 (0.2)	27.1 (0.8)	26.5 (0.9)	-0.7 (0.3)
Fat mass (kg)	32.2 (1.7)	28.6 (1.7)	-3.5 (0.6)	30.3 (1.8)	28.6 (2.1)	-1.8 (0.6)
Lean mass (kg)	41.9 (0.9)	41.7 (1.0)	-0.2 (0.3)	41.2 (1.0)	41.2 (1.1)	0.0 (0.3)
% Body fat (%)	41.7 (1.2)	38.9 (1.3)	-2.8 (0.5)	40.5 (1.3)	39.0 (1.5)	-1.4 (0.6)
Trunk fat (kg) ^a	16.0 (1.0)	14.2 (1.1)	-1.8 (0.4)	15.6 (1.0)	14.9 (1.2)	-0.7 (0.4)
VO2 max (mL/kg/min) ^a	30.6 (1.3)	33.2 (1.4)	2.6 (1.0)	31.1 (1.4)	29.2 (1.9)	-1.9 (1.7)
Calcium intake (mg) [*]	1405 (151)	1273 (146)	-132 (136)	1247 (103)	1350 (110)	103 (140)
hs-CRP (mg/L)	2.78 (0.43)	3.19 (0.77)	0.41 (0.70)	3.39 (0.82)	4.19 (1.1)	0.80 (0.58)

Values are mean (SEM).

BMI, body mass index; VO2 max, maximal oxygen uptake; hs-CRP, high sensitivity C-reactive protein

^{*} Calcium intake includes intake from supplements.

Significant time by group interaction: ^a $P < 0.05$.

Table 5.2. BMD and CRP at Baseline and Endpoint and Change after the Intervention.

	Intervention			Control		
	Baseline	Endpoint	Change	Baseline	Endpoint	Change
Total Body						
BMD (g/cm ²) ^a	1.187 (0.020)	1.179 (0.012)	-0.01 (0.004)	1.198 (0.021)	1.194 (0.027)	-0.004 (0.005)
BMC (g)	2644 (84)	2579 (66)	-65 (15)	2615 (87)	2591 (96)	-24 (15)
LS BMD (g/cm ²)						
BMD (g/cm ²)	1.225 (0.031)	1.198 (0.025)	-0.027 (0.010)	1.229 (0.032)	1.205 (0.040)	-0.024 (0.010)
BMC (g) ^a	66 (3)	64 (2)	-2 (1)	66 (3)	66 (2)	0 (1)
Hip BMD (g/cm ²)						
BMD (g/cm ²) ^a	1.037 (0.027)	1.018 (0.019)	-0.018 (0.006)	1.020 (0.027)	1.003 (0.030)	-0.017 (0.007)
BMC (g) ^a	32 (1)	31 (1)	-1 (0.2)	31 (1)	30 (1)	-1 (0.2)
FN BMD (g/cm ²)						
BMD (g/cm ²)	1.038 (0.024)	1.021 (0.021)	-0.017 (0.006)	1.018 (0.025)	0.994 (0.023)	-0.028 (0.007)
BMC (g) ^a	4.9 (0.2)	4.8 (0.1)	-0.1 (0.04)	4.8 (0.2)	4.7 (0.1)	-0.1 (0.03)

Data are mean (SEM)

BMD, bone mineral density; BMC, bone mineral content; LS, lumbar spine; Hip, total hip; FN, femoral neck

Significant time by group interaction controlling for lactation score percentage at endpoint and weeks postpartum at baseline; ANCOVA: ^a $P < 0.05$.

($P = 0.06$). The intervention attenuated bone loss after controlling for lactation status and weeks postpartum at baseline.

Predictors of Change in Bone Mineral Density

Bivariate correlation data are presented in Appendix A. At baseline, lean body mass was significantly positively correlated with total body BMD and BMC, lumbar spine BMD and BMC, total hip BMC, and femoral neck BMC. VO_2 max at baseline was positively associated with total hip BMC, and tended to be positively correlated with total hip ($P = 0.05$) and femoral neck ($P = 0.06$) BMD and femoral neck BMC ($P = 0.05$). Lactation score percentage at baseline was negatively correlated with lumbar spine BMD. Weight at baseline was positively associated with total body BMC.

At endpoint, lean mass was significantly correlated with total body BMD and lumbar spine, total hip, and femoral neck BMC. VO_2 max was positively correlated with total hip and femoral neck BMC. There was a trend for positive correlation of VO_2 max ($P = 0.07$) and negative correlation between hs-CRP ($P = 0.09$) and fat mass ($P = 0.09$) with femoral neck BMD. Endpoint hs-CRP was negatively correlated with endpoint femoral neck BMC. Endpoint weight was positively correlated with endpoint total body BMC.

Lactation score percentage was negatively associated with change in total body, total hip and lumbar spine BMD. Change in lean mass ($P = 0.09$) tended to be positively associated with change in total body BMD, while change in hs-CRP ($P = 0.06$) and 4 day calcium average ($P = 0.08$) tended to be negatively associated. Change in VO_2 max tended to be positively correlated with changes in femoral neck BMD ($P = 0.09$). Change

in fat mass was positively associated with change in total body BMC, while change in lean mass and endpoint lactation score percentage were negatively associated. Lactation score percentage was negatively associated with total hip BMC, while change in VO₂ max tended to be positively associated with change in femoral neck BMC ($P = 0.09$).

Stepwise regression models were run to determine predictors of change in total body, lumbar spine, total hip, and femoral neck BMD and BMC, controlling for endpoint lactation score percentage, baseline lean mass, and baseline values for total body, lumbar spine, total hip, and femoral neck BMD and BMC. The independent variables entered into the models were change in weight, change in VO₂ max, change in hs-CRP, and 4 day calcium intake average. Since change in weight and change in fat mass were highly correlated ($r = 0.93$, $P < 0.001$), only change in weight was entered into the model.

Results of the multiple regression analysis are presented in Table 5.3 and 5.4. When controlling for lactation score percentage, baseline lean mass, and baseline total body BMD, change in hs-CRP was a significant predictor of change in total body BMD ($R^2 = 0.51$, $P = 0.003$). Reductions in hs-CRP predicted an increase in total body BMD. Change in VO₂ max was a significant predictor of change in total hip ($R^2 = 0.48$, $P = 0.002$) and femoral neck BMD ($R^2 = 0.42$, $P = 0.01$). An increase in VO₂ max predicted an increase in total hip and femoral neck BMD. There were no significant predictors of change in lumbar spine BMD when controlling for lactation score percentage, baseline lean mass, and baseline lumbar spine BMD.

Table 5.3. Stepwise Regression Models for Change in BMD.

	Δ TB BMD (g/cm ²)	Δ LS BMD (g/cm ²)	Δ Hip BMD (g/cm ²)	Δ FN BMD (g/cm ²)
Intercept	0.136 (0.042)^b	0.071 (0.104)	0.099 (0.056)	0.073 (0.063)
Predictors*:				
Change in weight (kg)	-	-	-	-0.004 (0.02)
Change in hs-CRP (mg/L)	-0.012 (0.003)^b	-	-	-
Change in VO ₂ max (L/min)	-	-0.003 (0.002)	-0.003 (0.001)^a	0.003 (0.001)^a
Covariates:				
Lactation score percentage	-0.0002 (0.0001)	-0.0006 (0.0003)	-0.0005 (0.0002)^a	-0.0003 (0.0002)
Baseline lean mass (kg)	-8.85E-7 (7.58E-7)	-2.34E-6 (2.18E-6)	1.05E-6 (1.13E-6)	1.63E-6 (1.37E-6)
Baseline TB BMD (g/cm ²)	-0.073 (0.039)	-	-	-
Baseline LS BMD (g/cm ²)	-	0.045 (0.079)	-	-
Baseline Hip BMD (g/cm ²)	-	-	-0.123 (0.048)^a	-
Baseline FN BMD (g/cm ²)	-	-	-	-0.145 (0.052)^a

BMD = bone mineral density; TB = total body; LS = lumbar spine; FN = femoral neck; hs-CRP = high sensitivity C-reactive protein.

Data are β coefficient (SEM)

Results are shown only for variables with $p < 0.1$ for final model; Significant effects in **bold**: ^a $p < 0.05$, ^b $p < 0.01$

* Predictor reference values are means of total sample ($n = 31$): Change in weight = -2.9 kg; Change in hs-CRP = 0.59 mg/L; Change in VO₂ max = 1.17 L/min; Lactation score percentage = 86.2%; Baseline lean mass = 41.6 kg; Baseline TB BMD = 1.192 g/cm²; Baseline LS BMD = 1.227 g/cm²; Baseline Hip BMD = 1.029 g/cm²; Baseline FN BMD = 1.028 g/cm²

Table 5.4. Stepwise Regression Models for Change in BMC

	Δ TB BMC (g)	Δ LS BMC (g)	Δ Hip BMC (g)	Δ FN BMC (g)
Intercept	230.7 (227.2)	19.52 (7.92)^a	2.12 (1.50)	0.592 (0.301)
Predictors*:				
Change in weight (kg)	-	-	-	-
Change in hs-CRP (mg/L)	-	-	-	-
Change in VO ₂ max (L/min)	-	-	-	0.019 (0.007)^a
Covariates:				
Lactation score percentage	-1.789 (0.715)^a	-0.061 (0.029)^a	-0.014 (0.010)	-0.002 (0.001)
Baseline lean mass (kg)	-0.002 (0.005)	-0.0002 (0.0002)	5.24E-5 (4.26E-5)	5.37E-6 (7.88E-6)
Baseline TB BMC (g/cm ²)	-0.014 (0.064)	-	-	-
Baseline LS BMC (g/cm ²)	-	-0.129 (0.087)	-	-
Baseline Hip BMC (g/cm ²)	-	-	-0.128 (0.042)^b	-
Baseline FN BMC (g/cm ²)	-	-	-	-0.165 (0.051)^b

BMC = bone mineral content; TB = total body; LS = lumbar spine; FN = femoral neck; hs-CRP = high sensitivity C-reactive protein.

Data are β coefficient (SEM)

Results are shown only for variables with $p < 0.1$ for final model; Significant effects in **bold**: ^a $p < 0.05$, ^b $p < 0.01$

* Predictor reference values are means of total sample ($n = 31$): Change in weight = -2.9 kg; Change in hs-CRP = 0.59 mg/L; Change in VO₂ max = 1.17 L/min; Lactation score percentage = 86.2%; Baseline lean mass = 41.6 kg; Baseline TB BMC = 2.63 g/cm²; Baseline LS BMC = 66.12 g/cm²; Baseline Hip BMC = 31.25 g/cm²; Baseline FN BMC = 4.82 g/cm².

When controlling for lactation score percentage, baseline lean mass, and baseline femoral neck BMC, change in VO₂ max was a significant predictor of change in femoral neck BMC ($R^2 = 0.47$, $P = 0.002$). An increase in VO₂ max resulted in an increase in femoral neck BMC. There were no significant predictors of total body, lumbar spine, or total hip BMC when controlling for lactation score percentage, baseline lean mass, and baseline values of total body, lumbar spine, and total hip BMC.

Discussion

Over the 12-week diet and exercise intervention, the intervention group lost significantly more weight than the control group, with a trend for a greater decrease in fat mass. Cardiovascular fitness levels, as measured by VO₂ max, increased significantly in the intervention group, compared to a decrease in the control group. While both groups had significant decreases in lumbar spine, total hip, and femoral neck BMD and total body, total hip, and femoral neck BMC over time, there were no significant differences between groups. However, when controlling for lactation score percentage at endpoint and weeks postpartum at baseline, there were significant differences between groups for total body and total hip BMD, and lumbar spine, total hip, and femoral neck BMC.

We found that an increase in maximal oxygen uptake was associated with an increase in total hip and femoral neck BMD and BMC, suggesting that the improvement in aerobic fitness observed in the intervention group may be responsible for the attenuation of bone loss. Other studies have observed a positive relationship between VO₂ max and BMD at the total body (12), femoral neck (16) and legs (17) in postmenopausal women. Another study by Ryan et al in postmenopausal women found

that the addition of aerobic exercise to a 6 month weight loss intervention prevented bone loss at the femoral neck, Ward's triangle, and greater trochanter (43). A study by Silverman et al found that after this same intervention, there was a positive relationship between VO₂ max and femoral neck BMD (18). However, other studies in premenopausal women failed to detect a difference in BMD during weight loss when walking, running, or cycling was added to the dietary intervention (19, 20).

Since breastfeeding is associated with increased bone loss of 1 to 3% per month (9) with losses up to 9% at trabecular-rich sites, such as the lumbar spine and hip (10), aerobic exercise may be protective against bone loss during weight loss in the postpartum period. In contrast to our findings, a study Clapp and Little found that regular, self-selected exercise during the first three months of the postpartum period had no impact on total body, lumbar spine, or femoral neck BMD in lactating women despite higher preconception VO₂ max compared to a sedentary control group (25). In contrast to this, Lovelady et al found that breastfeeding women randomized to a 16-week aerobic and resistance exercise group had smaller reductions in lumbar spine BMD compared to a control group (-4.8% vs. -7.0%) (12). However, weight loss was not a target in either of these studies. Colleran et al examined the effect of a 16-week energy restriction and resistance exercise program on BMD in overweight and obese, fully breastfeeding women (23). While women in the resistance exercise group had similar BMD losses compared to the control group, they had significantly higher weight loss, suggesting that resistance exercise may protect against additional bone loss during weight loss in lactating women.

In this study, we did not observe significant differences between groups in hs-CRP concentrations. However, change in hs-CRP was found to be a significant predictor of change in BMD in a multivariate regression model. Weight loss has been shown to reduce inflammation in overweight and obese adults (44). However, its relationship to bone loss during weight loss has not been well studied. Silverman et al found that change in TNF- α receptor, another marker of systemic inflammation, after a weight loss intervention was negatively correlated with change in femoral neck BMD in postmenopausal women (18). Labouesse et al found that after weight loss, there was a negative association between markers of bone turnover and inflammatory proteins (TNF- α , IL-1 β , and CRP) (39). Their study also found that 20% of the variance in post-weight loss hip BMD was explained by inflammatory, endocrine, and anthropometric variables.

Interestingly, we did not observe a significant relationship between calcium intake and BMD. Calcium intake tended to be significantly associated with change in total body BMD, but was not found to be a significant predictor of change in total body lumbar spine, total hip, or femoral neck BMD when controlling for lactation status, baseline lean mass, and baseline BMD. However, average calcium intake in both groups met recommendations for calcium intake for lactating women, with an average intake of 1,329 mg daily (range 644 to 2136 mg) with 21 participants (68%) consuming over 900 mg of calcium daily. Previous studies have found that calcium intakes above 1,000 mg daily were protective of BMD during weight loss, but higher intakes did not have additional benefits on BMD (8).

This study was not powered to detect an association between CRP and BMD, and weight loss observed in the intervention group may not have been adequate to induce significant reductions in CRP. Also, there were more women who stopped fully breastfeeding in the control group. While the effect of lactation on CRP concentrations during the postpartum period remains unclear, the lactation status of participants in this study may have impacted changes in CRP as a result of the intervention. Additionally, the exercise intensity may not have been adequate to fully attenuate bone loss. A more intense exercise regime or one that incorporates aerobic and resistance exercise may be more beneficial in improving CRP and attenuating bone loss. However, the exercise regimen in this study was designed to be time-saving and practical considering the time constraints of caring for an infant. Additionally, the duration of the study (12 weeks) may not have been adequate to observe changes in BMD. During lactation, the rate of bone turnover is increased, with a full cycle occurring over 3 to 4 months (10). A longer study of at least 16-weeks may be needed to detect the effects of exercise on BMD.

This study is the first to our knowledge to report on the relationship between CRP, cardiovascular fitness, and BMD in lactating women. Future research should focus on interventions of a longer duration with a more intense aerobic exercise regimen. The combination of aerobic and resistance exercise may have a stronger impact on BMD. Additionally, studies comparing changes in BMD during weight loss with and without exercise in lactating women are needed.

In conclusion, a 12-week weight loss intervention did not result in increased bone loss in overweight and obese postpartum women. While there were no significant

changes in CRP between groups, decreases in CRP predicted an increase in total body BMD, while an increase in cardiovascular fitness predicted an increase in femoral neck BMD, suggesting that the addition of aerobic exercise to a weight loss regimen may attenuate bone loss observed with weight loss and lactation.

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CHAPTER VI

EPILOGUE

The research presented in this dissertation utilized practical, time and labor-saving strategies for reducing weight retention in postpartum women. It used technology-based tools, such as online diet tracking and regular follow up with an RD by email or phone. Additionally, it was one of few studies to examine the impact of weight loss on MetSyn, cardiometabolic risk factors, and inflammation in this population. Finally, it was the first to our knowledge to examine the relationship between systemic inflammation and BMD after weight loss in postpartum women.

The results of the first study suggest that a home-based diet and exercise intervention that utilized self-monitoring of lifestyle behaviors and individualized recommendations from a registered dietitian is an effective strategy for reducing weight and abdominal obesity in postpartum women. It was also successful in promoting improvements in cardiovascular fitness, which may have been responsible for the increased weight loss observed in the intervention group. The results from the second study suggest that a weight loss intervention may reduce some cardiometabolic risk factors, and reduce the prevalence of MetSyn in this population. Finally, the third study suggests that aerobic exercise contributes to an attenuation of bone loss during weight loss in postpartum women.

One of the biggest challenges faced for this research study was participant recruitment. We utilized a variety of strategies to recruit, including posting flyers in local obstetrician and pediatrician offices, churches, infant stores, day care facilities, at local mothers groups, and on Facebook. We also recruited in person at the Women's Hospital prenatal birth and breastfeeding classes, breastfeeding support groups, and pre- and postnatal yoga classes. We attempted to recruit through local lactation consultants, but struggled to maintain contact with them. The most successful method was in-person recruitment at the hospital classes. This is a very specific population with time constraints unique to them. While many women may have liked the concept of an intervention to help them lose the baby weight, the practicality of following a diet and exercise intervention may have been too time consuming while also caring for a new infant. Several women allocated to the control group even mentioned after the study completed that they were happy to have been randomized to the control group, as they did not believe they would have had the time to follow the intervention.

Another problem was that many women who screened were eligible, but declined participation in the study for reasons including lack of time, returning to work, or not wanting to be assigned to the control group. Changing the eligibility to allow women to participate at 6 weeks postpartum seemed to be an effective way to recruit women, as it allowed us to enroll participants before they returned to work. Additionally, several women who were interested in participating were ineligible to participate due to having a BMI greater than 35 kg/m². These are the women who would most benefit from a weight loss intervention. However, the reason they were excluded was because obese

participants tend to drop out of studies more frequently. They also tend to struggle to lose weight during an intervention, which may have impacted the results of the second study. It was difficult to tell a woman that her BMI was too high to participate in a weight loss intervention, and an attempt was made to find other reasoning for ineligibility. Strategies that effectively help obese women lose weight are needed.

Another problem we encountered was that we did not have enough power to detect significant differences in cardiometabolic risk factors and inflammation. This intervention was designed to test practical strategies for weight loss in postpartum women, so actual weight loss that was observed was modest relative to other studies. This may not have been adequate to cause significant change in these variables over the 12-week time frame. A longer duration intervention targeted toward a specific amount of weight loss may have better results.

One outcome that was noted was that it seemed that the women who had the greatest success with the intervention were already highly motivated individuals, who had relatively healthy lifestyles prior to pregnancy. They just required some extra guidance and something to keep them accountable (regular contact with the RD, diet tracking, pedometer) to help them achieve their goals. Other participants who had poorer diet quality and lower physical activity prior to pregnancy struggled more to lose weight. However, those women were the ones that commented the most on how they were unaware of how many calories they were eating or how sedentary their lifestyle was. Habits formed over many years are difficult to change, but I believe that the intervention helped many of these women to become more aware of their habits and start to make

changes they can maintain. For these women, setting lower, more achievable weight loss goals may be beneficial.

There are several areas of future research that I would like to explore. The first is to design a weight loss intervention tailored toward specific, individualized weight loss goals. The National Institute of Health Body Weight Planner is a new tool available that more accurately estimates the energy intake required to lose a desired amount of weight over a specific time period. A research study utilizing this tool will allow for more individualized calorie prescription to be provided to research participants.

The second area of research is to determine the effect of different dietary components on inflammation and MetSyn. I am planning to use the data from this study to examine the relationship between diet quality and anti-inflammatory food components (omega-3 fatty acids, monounsaturated fats, glycemic index) with inflammation and cardiometabolic risk factors. In the future, I would like to conduct a research study to determine the effects of a Mediterranean-style diet on inflammation and cardiometabolic risk factors in postpartum women.

Finally, I would like to further explore the relationship between aerobic fitness and inflammation. This would first involve conducting an observational study comparing weight-matched sedentary individuals to individuals with varying degrees of physical activity. This would be followed up by designing a randomized, intervention of overweight and obese individuals with a more tailored aerobic exercise regimen.

This study was designed to promote weight loss in postpartum women and reduce cardiometabolic risk factors, and was successful in reducing weight and abdominal

obesity, while improving cardiovascular fitness. We were also successful in improving insulin resistance and triglycerides in this population. The process of conducting this study was rewarding, especially hearing positive comments from participants how it helped them achieve their goals to live a healthier life. This research was successful thanks to the women who participated in the study, the research staff who assisted with recruitment and laboratory visits, and the Women's Hospital for being a main source of recruitment. I am excited to further examine the data from this study, and to continue my research working to improve the health of postpartum women

APPENDIX A
BIVARIATE CORRELATIONS TABLES

Table A.1. Baseline Correlations between Body Composition, Cardiovascular Fitness, and Inflammation with BMD.

	TB BMD (g/cm ²)	LS BMD (g/cm ²)	Hip BMD (g/cm ²)	FN BMD (g/cm ²)
Age (yr)	0.025	-0.051	-0.022	-0.159
Weight (kg)	0.292	0.230	-0.001	-0.004
BMI (kg/m ²)	0.243	0.064	0.018	-0.121
Fat mass (kg)	0.090	-0.008	-0.223	-0.221
Lean mass (kg)	0.446 ^a	0.476 ^b	0.328 ^d	0.326 ^d
VO ₂ max (mL/kg/min)	0.224	0.306	0.362 ^d	0.349 ^d
hs-CRP (mg/L)	-0.086	-0.333 ^d	-0.190	-0.201
Calcium intake (mg)	0.234	0.285	0.217	0.162
Lactation score percentage	0.245	0.272	0.433 ^a	0.342 ^d

Pearson's correlation coefficients

BMD, bone mineral density; TB, total body; LS, lumbar spine; Hip, total hip; FN, femoral neck; BMI, body mass index; hs-CRP, high sensitivity C-reactive protein

^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$, ^d $p < 0.09$

Table A.2. Baseline Correlations between Body Composition, Cardiovascular Fitness, and Inflammation with BMC.

	TB BMC (g)	LS BMC (g)	Hip BMC (g)	FN BMC (g)
Age (yr)	-0.001	0.080	0.090	0.092
Weight (kg)	0.469 ^b	0.279	0.155	0.222
BMI (kg/m ²)	0.244	-0.052	-0.041	-0.004
Fat mass (kg)	0.247	-0.044	-0.153	-0.036
Lean mass (kg)	0.595 ^c	0.685 ^c	0.580 ^c	0.542 ^b
VO ₂ max (mL/kg/min)	0.192	0.197	0.449 ^b	0.359 ^d
hs-CRP (mg/L)	-0.020	-0.289	-0.179	-0.204
Calcium intake (mg)	0.254	0.257	0.219	0.224
Lactation score percentage	0.267	0.221	0.309	0.180

Pearson's correlation coefficients

BMC, bone mineral content; TB, total body; LS, lumbar spine; Hip, total hip; FN, femoral neck; BMI, body mass index; hs-CRP, high sensitivity C-reactive protein

^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$, ^d $p < 0.09$

Table A.3. Endpoint Correlations between Body Composition, Cardiovascular Fitness, and Inflammation with BMD.

	TB BMD (g/cm ²)	LS BMD (g/cm ²)	Hip BMD (g/cm ²)	FN BMD (g/cm ²)
Age (yr)	0.039	-0.001	0.074	-0.039
Weight (kg)	0.326 ^d	0.216	0.010	-0.097
BMI (kg/m ²)	0.288	0.132	0.006	-0.215
Fat mass (kg)	0.162	0.071	-0.200	-0.304 ^d
Lean mass (kg)	0.427 ^a	0.333 ^d	0.343 ^d	0.283
VO ₂ max (L/min)	0.108	0.015	0.239	0.331 ^d
hs-CRP (mg/L)	0.0001	-0.158	-0.197	-0.336 ^d
Calcium intake (mg)	0.272	0.193	0.152	-0.038
Lactation score percentage	0.002	0.019	0.264	0.312

Pearson's correlation coefficients

BMD, bone mineral density; TB, total body; LS, lumbar spine; Hip, total hip; FN, femoral neck; BMI, body mass index; hs-CRP, high sensitivity C-reactive protein

^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$, ^d $p < 0.09$

Table A.4. Endpoint Correlations between Body Composition, Cardiovascular Fitness, and Inflammation with BMC

	TB BMC (g)	LS BMC (g)	Hip BMC (g)	FN BMC (g)
Age (yr)	-0.110	0.068	0.122	-0.012
Weight (kg)	0.449 ^b	0.331 ^d	0.162	0.156
BMI (kg/m ²)	0.230	0.079	-0.025	-0.067
Fat mass (kg)	0.247	0.101	-0.150	-0.113
Lean mass (kg)	0.555 ^c	0.550 ^c	0.610 ^c	0.533 ^b
VO ₂ max (L/min)	0.143	0.096	0.377 ^a	0.365 ^a
hs-CRP (mg/L)	-0.116	-0.093	-0.309	-0.396 ^a
Calcium intake (mg)	0.310 ^d	0.282	0.205	0.041
Lactation score percentage	-0.005	-0.006	0.281	0.185

Pearson's correlation coefficients

BMC, bone mineral content; TB, total body; LS, lumbar spine; Hip, total hip; FN, femoral neck; BMI, body mass index; hs-CRP, high sensitivity C-reactive protein

^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$, ^d $p < 0.09$

Table A.5. Correlations between Change in Body Composition, Cardiovascular Fitness, and Inflammation and Change in BMD.

	Δ TB BMD (g/cm ²)	Δ LS BMD (g/cm ²)	Δ Hip BMD (g/cm ²)	Δ FN BMD (g/cm ²)
Δ Weight (kg)	0.167	0.040	0.164	-0.085
Δ BMI (kg/m ²)	0.128	0.076	0.197	-0.045
Δ Fat mass (kg)	0.060	0.152	0.209	0.024
Δ Lean mass (kg)	0.301 ^d	-0.254	-0.121	-0.306 ^d
Δ VO ₂ max (L/min)	-0.044	-0.273	0.224	0.314 ^d
Δ hs-CRP (mg/L)	-0.358 ^d	-0.078	-0.162	-0.172
4 day calcium average (mg)	-0.315 ^d	-0.039	-0.088	-0.061
Endpoint lactation score %	-0.473 ^a	-0.383 ^d	-0.492 ^b	-0.222

Pearson's correlation coefficients

BMD, bone mineral density; TB, total body; LS, lumbar spine; Hip, total hip; FN, femoral neck; BMI, body mass index; hs-CRP, high sensitivity C-reactive protein

^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$, ^d $p < 0.09$

Table A.6. Correlations between Change in Body Composition, Cardiovascular Fitness, and Inflammation and Change in BMC.

	Δ TB BMC (g)	Δ LS BMC (g)	Δ Hip BMC (g)	Δ FN BMC (g)
Δ Weight (kg)	0.139	0.224	0.174	0.046
Δ BMI (kg/m ²)	0.143	0.200	0.209	0.059
Δ Fat mass (kg)	0.356 ^a	0.239	0.229	0.085
Δ Lean mass (kg)	-0.589 ^c	-0.021	-0.132	-0.116
Δ VO ₂ max (L/min)	0.017	0.207	0.181	0.313 ^d
Δ hs-CRP (mg/L)	-0.127	-0.152	-0.201	-0.095
4 day calcium average (mg)	-0.064	0.070	-0.153	-0.040
Endpoint lactation score %	-0.486 ^b	-0.418 ^a	-0.513 ^b	-0.321

Pearson's correlation coefficients

BMC, bone mineral content; TB, total body; LS, lumbar spine; Hip, total hip; FN, femoral neck; BMI, body mass index; hs-CRP, high sensitivity C-reactive protein

^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$, ^d $p < 0.09$

APPENDIX B
STUDY FORMS

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO

Project Title: Get Active and Eat Right: Moms at Work

Project Director: Cheryl Lovelady and Elyse Shearer

Participant's Name: _____

What is the study about?

This is a research project studying the effects of a diet and exercise program on weight loss in postpartum women.

Why are you asking me?

We are recruiting women 18 years and older who are pregnant or up to 14 weeks postpartum. Women must be overweight or are at least 10 pounds heavier than they were before they were pregnant. Participants must be free of chronic disease and nonsmokers. Participants who have had a C-section will be eligible to participate at 14 weeks postpartum.

What will you ask me to do if I agree to be in the study?

This study will begin ten to fourteen weeks after you deliver your baby and will continue for twelve weeks. If you consent to participate, your baseline measurement will be done at 10 to 14 weeks postpartum. Upon completion of the baseline measurement (described below), you will be assigned by chance to one of two groups. The intervention group will participate in the 12 week reduced calorie diet and exercise program. If you are assigned to the control group, you will be asked not to change your diet or exercise habits until the end measurements. Upon completion of the second set of measurement, at 22 to 26 weeks postpartum, the control group will be given all the dietary intervention materials, as well as a consultation with the registered dietitian.

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 diet and exercise program.
2. Participate in two short dietary recall sessions. You will be called two times in one week at your convenience at the beginning (10 to 14 weeks postpartum) and at the end of the intervention (22 to 26 weeks postpartum). This diet record will be used to determine your nutritional intake and develop a reduced calorie diet for the intervention group.
3. Visit the Human Nutrition Laboratory at UNCG for several measurements at the beginning and end of the study. This visit should take approximately 2 hours, including the DXA scan and BOD POD analysis.

- a. You will be asked to provide a total of 2 tablespoons of venous blood per laboratory measurement. The blood will be drawn in the morning at the lab after an overnight fast (no alcohol for 24 hours prior to blood draw). Venipuncture will be performed by a trained phlebotomist. The blood is need to assess your blood sugar, lipids (cholesterol, triglycerides), insulin, and markers of inflammation and metabolism.
- b. Your height and weight will be recorded followed by resting heart rate, blood pressure, and waist and hip circumference.
- c. Your cardiovascular fitness will be measured 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 how hard you think you are working will be measured throughout the test.
- d. Your body composition will be measured BOD POD analysis. You will be asked to wear form-fitting clothes, such as a swim suit, and a swim cap. You may wear your own swim suit or one will be provided to you by the research staff. You will sit quietly in the BOD POD. You may hear clicking sounds or the hum of a fan during the procedure. You will not feel any changes in pressure. The measurement will take about 5 minutes.
- e. 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 minutes depending on your height.
- f. You will be given a pregnancy test to ensure that you are not pregnant before the DXA scan is administered.

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

1. Follow a reduced calorie diet prescribed by the Registered Dietitian (RD) at your initial meeting. You will be asked to track your diet three days per week for 12 weeks using the USDA MyPlate SuperTracker, found online. This record will be accessed by the RD in order to provide you with diet recommendations, as well as to ensure compliance with the reduced calorie diet. Diet recommendations will be sent to you by email.
2. You will be given an exercise prescription, and encouraged to walk briskly with a pedometer (provided to you) or perform other exercises every day. You will be asked to record the number of steps and other physical activity in a log book, which will be provided.
3. You will be required to meet with the research staff at the Human Nutrition Laboratory after 6 weeks, where we will measure your weight, waist and hip circumference. This meeting should take about 15 minutes.

4. You will be asked to measure your weight, waist, and hip circumference weekly and text or email these measurements, as well as daily steps, to the research staff every week.
5. You will be encouraged to breastfeed your baby and provided with support and resources for pumping breast milk at work.

What are the dangers to me?

The Institutional Review Board at the University of North Carolina at Greensboro has determined that participation in this study poses minimal risk to participants. However, there is a risk of injury during exercise for you. Temporary muscle fatigue and/or respiratory discomfort may result from the graded exercise test. Weekly exercise may result in temporary muscle soreness. Insertion of the needle during the blood draw 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. The University has no policy or plan to pay for any injuries you might receive as a result of participating in this research protocol.

If you have any concerns about your rights, how you are being treated or if you have questions, want more information or have suggestions, please contact the Office of Research Compliance at UNCG toll-free at **(855)-251-2351**.

Questions, concerns or complaints about this project or benefits or risks associated with being in this study can be answered by **Dr. Cheryl Lovelady** who may be contacted at **(336-256-0310)**.

Are there any benefits to society as a result of me taking part in this research?

The results of this study may be used to improve weight loss in overweight postpartum women and prevent obesity and chronic disease later in life. Strategies tested in this study may be used to promote weight loss for postpartum mothers across the country in order to reduce healthcare costs.

Are there any benefits to *me* for taking part in this research study?

Results of all the tests conducted will be provided to you at no cost. All mothers participating in the study will undergo two free bone density scans and two BOD POD analyses, which provide valuable bone density and body composition information. Women in the control group will receive a free consultation with the RD at the end of the study. Benefits to the intervention participants include the potential for weight loss and increased cardiovascular fitness.

Will I get paid for being in the study? Will it cost me anything?

There are no costs to you or payments made for participating in this study.

How will you keep my information confidential?

All information obtained in this study is strictly confidential unless disclosure is required by law. All information will be stored in a locked file cabinet in the Human Nutrition Lab; only the researchers will have access to the records. Any report of this research that is made available to the public will not include your name or any other individual information by which you could be identified.

What if I want to leave the study?

You have the right to refuse to participate or to withdraw at any time, without penalty. If you do withdraw, it will not affect you in any way. If you choose to withdraw, you may request that any of your data which has been collected be destroyed unless it is in a de-identifiable state.

What about new information/changes in the study?

If significant new information relating to the study becomes available which may relate to your willingness to continue to participate, this information will be provided to you.

Voluntary Consent by Participant:

By signing this consent form you are agreeing that you read, or it has been read to you, and you fully understand the contents of this document and are openly willing consent to take part in this study. All of your questions concerning this study have been answered. By signing this form, you are agreeing that you are 18 years of age or older and are agreeing to participate, or have the individual specified above as a participant participate, in this study described to you by _____.

Signature: _____ Date: _____

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?

If YES to All Then GIVE US A CALL!

The purpose of this research is to investigate the effects of a diet and exercise program on weight loss in postpartum women.

Who is eligible?

- Women who are pregnant or have a baby less than 14 weeks old
- 18 years or older
- Overweight or are at least 10 pounds heavier than before pregnancy
- Nonsmokers
- Free of chronic disease
- English speaking

All eligible women in the study receive a bone density scan, body composition analysis, exercise testing, and blood analysis 2 times during the study. Some women in the study may be enrolled in a 12-week intervention which includes dietary modifications and exercise instruction under the supervision of a registered dietitian. Women not enrolled in the intervention will receive a free consultation with the registered dietitian at the completion of the study.

The initial and follow up measurements take approximately 2 hours. If enrolled in the intervention, you will meet with the research staff 2 times over 12 weeks for 15 minutes. Participants will be asked to monitor their diet and exercise weekly. Times will vary for each participant.

For More Information, please contact:
Dr. Cheryl Lovelady or Elyse Shearer
at 336.256.1090 or email e_sheare@uncg.edu

University of North Carolina at Greensboro
Human Nutrition Laboratory



Research Study: Get Active, Eat Right, Mom's at Work

First Contact Date: _____

Screening Form

Name _____ Age _____

Phone Number _____ Number of Children _____

Address _____

Are you currently pregnant? _____

Weeks Pregnant _____ Due Date for Infant _____

Plan to breastfeed? _____

If not pregnant, when is baby's birthdate? _____

C-section? _____ Delivery/Pregnancy Complications? _____

Full term infant? _____ Singleton birth? _____

Weight after delivery _____ Weight gain? _____ Breastfeeding? _____

Pre-pregnancy Weight _____ Current Weight _____

Current Height _____ ft _____ in Smoker? _____

Agrees to random assignment? _____ Returning to work/school? _____

Chronic diseases? (DM, HTN, CVD, asthma, bone/joint problems) _____

Medications? _____

BMI (prepregnant): _____

Comments: _____

Physical Activity

How much exercise do I need?

Adults need at least **30 minutes** of moderate aerobic activity **5 or more days a week** and muscle strengthening activities on **2 or more days a week**.

What is moderate aerobic activity?

Aerobic activity or "cardio" gets you breathing harder and your heart beating faster. All types of activities count as long as you're doing them at a moderate or vigorous intensity for **at least 10 minutes at a time**.

Moderate-intensity aerobic activity means you're working hard enough to raise your heart rate and break a sweat. One way to tell is that you'll be able to talk, but not sing the words to your favorite song. Here are some examples of activities that require moderate effort:

- Walking fast
- Doing water aerobics
- Riding a bike on level ground or with few hills
- Playing doubles tennis
- Pushing a lawn mower

What are muscle-strengthening activities?

Muscle-strengthening activities should work all the major muscle groups of your body (legs, hips, back, chest, abdomen, shoulders, and arms). Try to do 8—12 repetitions per activity that count as 1 **set**. Try to do at least 1 set of muscle-strengthening activities, but to gain even more benefits, do 2 or 3 sets.

There are many ways you can strengthen your muscles, whether it's at home or the gym. You may want to try the following:

- Lifting weights at the gym
- Working with resistance bands
- Doing exercises that use your body weight for resistance (i.e., push ups, sit ups)
- Heavy gardening (i.e., digging, shoveling)
- Yoga

How can I fit exercise into my day?

Wearing your pedometer everyday can help you get enough exercise. Aim for **10,000 steps** daily. In addition to increasing steps in routine activities, aim for **30 minutes of aerobic steps** every day. Aerobic steps are counted when you do at least **10 minutes** of brisk walking at a time.

If you can't fit in 30 minutes at a time, you can break it up into smaller chunks of time during the day. As long as you're doing your activity at a moderate or vigorous effort for at least 10 minutes at a time.

- Try going for a 10-minute brisk walk, 3 times a day. You can do 10 minutes before work or school, 10 minutes during lunch, and 10 minutes at the end of the day.

Tips to get 10,000 Steps

Walk Whenever Possible

- Walk instead of drive, whenever you can
- Walk your children to school
- Take the stairs instead of the escalator or elevator
- Take a family walk after dinner
- Replace a Sunday drive with a Sunday walk
- Go for a half-hour walk instead of watching TV
- Get off the bus a stop early, and walk
- Park farther from the store and walk
- Make a Saturday morning walk a family habit
- Walk briskly in the mall
- Take the dog on longer walks
- Go up hills instead of around them

Move More in Your Home

- Garden, or make home repairs
- Do yard work. Get your children to help rake, weed, or plant
- Work around the house. Ask your children to help with active chores
- Wash the car by hand
- Use a snow shovel instead of a snow blower

Live Actively

- Join an exercise group
- Do sit-ups in front of the TV. Have a sit-up competition with your kids
- Pace the sidelines at kids' athletic games
- Choose an activity that fits into your daily life/lives
- Use an exercise video if the weather is bad
- Avoid labor-saving devices, such as a remote control or electric mixers
- Play with your kids at least 30 minutes a day
- Dance to music... with your kids
- Choose activities you enjoy.
- Explore new physical activities
- Give yourself a gold star with non-food related rewards, such as a family day at the park, lake, or zoo
- Swim with your kids
- Buy a set of hand weights and play a round of Simon Says with your kids—you do it with the weights, they do it without

What is a Portion?

Using common items can help you portion food correctly, even when dining

 1 cup = baseball	 ½ cup = lightbulb	 1 oz or 2 tbsp = golf ball	 1 tbsp = poker chip	 1 slice of bread = cassette tape
 3 oz chicken or meat = deck of cards	 3 oz fish = checkbook	 1 oz lunch meat = compact disc	 3 oz muffin or biscuit = hockey puck	 1½ oz cheese = 3 dice

Portions Sizes of Common Foods

Grains

1 cup unsweetened cereal = baseball
 ½ cup sweetened cereal = lightbulb
 ½ cup cooked grains = lightbulb
 3 cups popcorn = 3 baseballs
 1 slice bread
 1 mini bagel

Fruits and Vegetables

1 medium fruit = baseball
 16 grapes
 ½ cup fruit juice
 ½ cup canned fruit = lightbulb
 1 cup fresh, cut fruit = baseball
 1 cup raw vegetables = baseball
 ½ cup cooked vegetables = lightbulb

Meats, Fish, Nuts, Beans

3 oz lean meat/poultry = deck of cards
 3 oz grilled/baked fish = checkbook
 3 oz tofu = deck of cards
 2 tbsp peanut butter = golf ball
 2 tbsp hummus = golf ball
 ¼ cup nuts and seeds = 2 golf balls

Fats and Oils

1 tsp butter/oil = 1 die
 1 tbsp light butter spread = 1 poker chip
 1 tbsp mayonnaise = 1 poker chip
 1 tbsp salad dressing = 1 poker chip
 2 tbsp light mayonnaise = 1 golf ball
 2 tbsp light salad dressing = golf ball

Dairy and Cheese

1½ ounce cheese = 3 stacked dice
 1 cup yogurt = baseball
 ½ cup frozen yogurt
 1/2 cup ice cream = lightbulb
 1 cup milk

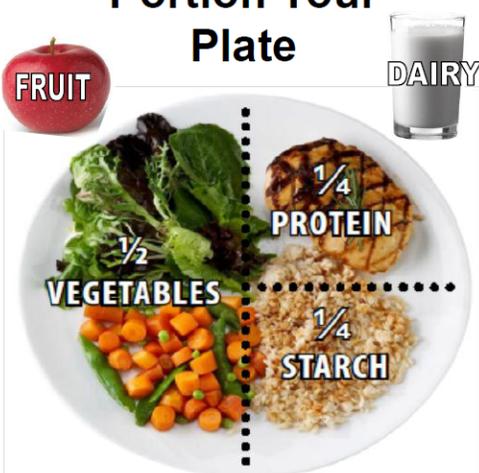
Sweets

1 piece chocolate = dental floss package
 1 brownie = dental floss package
 1 slice cake = deck of cards
 1 cookie = 2 poker chips

Portion Control

When you are trying to eat healthy, the amount of food you eat plays an important role in moving toward and maintaining a healthy weight. It's easy to misjudge portions sizes. Using the Plate Method can help you portion your food correctly while still enjoying meals and feeling satisfied.

Portion Your Plate



FRUIT

DAIRY

1/2 VEGETABLES

1/4 PROTEIN

1/4 STARCH

1/2 Plate Vegetables
Fill half of your plate with a colorful variety of vegetables.

1/4 Plate Proteins
Choose a variety of lean protein foods and keep portions small. Bake or grill meats. Use plant proteins, such as beans, lentils, nuts, and seeds, more often.

1/4 Plate Grain
Whole grain starches are more nutritious and keep you feeling full longer. Make at least half of your grains whole grains.

Fruit
Vary your fruit choices. Choose whole, cut up, canned, or dried fruit more often than fruit juice.

Dairy
Calcium-rich foods help maintain healthy bones. Choose low-fat milk, cheese, and yogurt.

Tips for decreasing portion size

- Figure out how big your portions really are. Measure how much the bowl glasses, cups, and plate you usually use hold. Pour your breakfast cereal into your regular bowl. Then, pour it into a measuring cup. How many cups of cereal do you eat each day?
- Measure a one portion of some foods and drinks to see what they look like in your glasses and plates. For example, measure 1 cup of milk to see what 1 cup of liquid looks like in your favorite glass.
- Use measuring cups and spoons instead of serving spoons to correctly portion your plates.
- Start a meal by portioning out small amounts of food and drinks. Take your time to enjoy the meal, and only go back for more if you are still hungry.
- Use smaller plates, bowls, and glasses to “trick” yourself into thinking you have bigger portions. It is also harder to fit large portions on a small plate.
- Drink a glass of water prior to a meal or start your meal with a cup of broth or tomato-based soup to fill you up prior to the meal. You will be less likely to overeat.

Empty Calories



What are empty calories?

Empty calories come from foods that are high in added sugars and lots of fat. They are called “empty” calories because they contain high amounts of calories and not much else – such as vitamins, minerals, fiber. Most empty calories come from junk food, desserts, and sweetened drinks. You can still enjoy these foods, but reducing the amount of empty calories in your diet can help you lose weight and improve your health.

What foods have empty calories?



- Regular soft drinks
- Fruit drinks
- Sweetened coffee and tea drinks
- Cake
- Candy
- Ice cream
- Pastries
- Donuts
- Cookies
- Sweetened yogurt
- French fries
- Potato chips
- Pretzels
- Crackers (not whole grain)
- Sweetened cereal
- Canned fruit in heavy or light syrup
- Mayonnaise
- BBQ sauce
- Pancake syrup
- Ketchup (in large amounts)

Comparing Calories

Foods <u>with</u> Empty Calories	Calories	Foods <u>without</u> Empty Calories	Calories
Sweetened applesauce (1 cup)	175	Unsweetened applesauce	105
Sugar-sweetened cereal (1 cup)	150	Unsweetened cereal	90-120
Regular soda (20 ounce bottle)	250	Diet soda	0
Fruit drink (20 ounce bottle)	250	Water	0
Regular mayonnaise (1 tbsp)	100	Light mayonnaise	50
Sweetened yogurt (6 ounces)	250	Light yogurt	90-120

Intuitive Eating

Intuitive eating is an approach that teaches you how to create a healthy relationship with your food, mind, and body—where you ultimately become the expert of your own body. The underlying premise of Intuitive Eating is that you will learn to respond to your inner body cues because you were born with all the wisdom you need for eating intuitively.

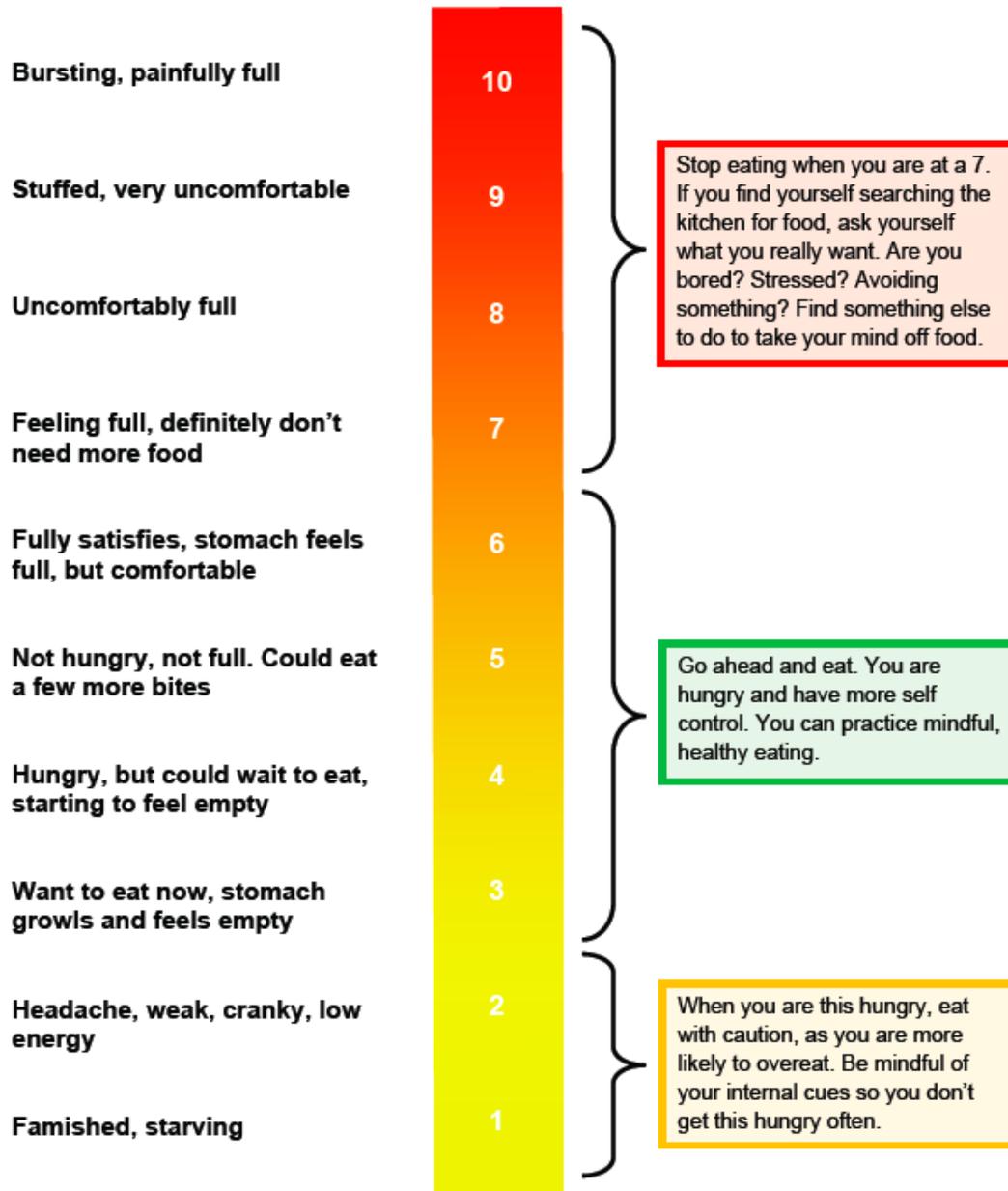
How to Eat Intuitively

- Whenever you feel like eating, rate your hunger on a scale from 1 to 10 with 1 being extremely hungry and 10 being stuffed. Ask yourself if you are really hungry or if you are satisfying an emotion, bored, or just eating out of habit.
- If you rated your hunger a 3 to 5, go ahead and eat. Your body is telling you it needs to fuel up. If you find that you are not really hungry, do something to distract yourself, such as take a walk or play with your children.
- Do not wait until you are too hungry (score of 1 or 2). You are more likely to make poor food choices and overeat. Try to eat every 4 to 5 hours.
- Take your time when eating and enjoy the meal. Stop when you feel satisfied, but not uncomfortably full (score of 5 or 6).
- Be mindful of your internal cues while eating. When you eat in the car or eat in front of the TV, it is impossible to recognize when you are full. Also, be aware of little “tastes” while you are cooking or “small” handfuls from the candy bowl.
- No foods are off limits. If you restrict a favorite food, such as sweets, you are more likely to overeat it later. If you have a craving for a food, see if you can distract yourself first. If the craving continues, it’s ok to indulge in moderation, but continue to be mindful of feeling of your body’s cues.
- Don’t beat yourself up if you let yourself get too hungry, overeat, or let stress get the best of you. This is a lifestyle change and takes practice to get it right. The important thing is that you resume intuitive eating rather than use the slip as an excuse to binge more.

Principles of Intuitive Eating

- **Reject the “diet mentality,”** because diets don’t work.
- **Honor your hunger.** Eat if you are hungry. If you don’t, it will trigger overeating.
- **Make peace with food.** Give yourself permission to enjoy the pleasures of food.
- **Rid yourself of the “food police” mentality** that labels certain foods as “good” or “bad.” Replace it with positive self-talk that recognizes we all need occasional splurges.
- **Get in touch with your body’s signals of comfortable fullness.** We all sometimes eat past the point of fullness, for emotional reasons or just because the food tastes so good.
- **Discover the satisfaction factor.** Savoring every mouthful will help you feel full. Sometimes, the first two bites of a food are the most satisfying.
- **Learn how to cope with your feelings without using food.** Food won’t solve your problems. Find other ways to deal with your feelings.
- **Accept your body,** and make sure your weight loss expectations are realistic.
- **Find pleasure in activity.** Focus on how good it feels simply to move and be active.
- **Choose foods that are good for your health and that you enjoy.** Eating is about pleasure, not denial.

HUNGER SCALE



Meal Planning and Preparation

When life gets hectic, cooking is often one of the first things to get pushed to the side. It may feel like preparing a meal only adds stress to your day. However, cooking at home has countless benefits. It allows you the opportunity to control the nutritional quality of your food, and eating dinner together gives your busy family a time to connect and enjoy each other.

Meal Planning

Before you can dive in to a cooking routine, you should take some time to organize. Planning your dinners can reduce stress, save time, and streamline mealtime for your family.

- Make a collection of quick and healthy recipes that you and your family like. Store these recipes in a special file on your computer, in a notebook, or on note cards in a box. Add to this collection as you find new favorite recipes.
- Set a scheduled weekly time to sit down and plan your meals for the week. Ask family members for meal suggestions. Do this on a day when you have plenty of extra time.
- Make a grocery list. This will ensure you have everything you need for the week and save time in the store.
- Keeping a well stocked pantry will help you throw together a healthy meal in a hurry. See the box to the right for some must-have pantry items.
- Use pre-prepared ingredients to save time in preparation:
 - Rotisserie chicken
 - Pre-made pizza dough/crust
 - Pre-chopped vegetables or fruit
 - Low sodium pasta sauce.

Pantry Staples

- Whole-wheat pastas
- Quick-cooking rice
- Cereals, crackers
- Canned beans
- Canned diced tomato, tomato sauce
- Canned fruits and vegetables
- Low-sodium broth or powdered bouillon
- Oil and vinegar
- Other sauces and condiments (soy sauce, mustard, etc.)
- Herbs & spices (like basil, oregano, rosemary, garlic, cumin, etc.)

Frozen Staples

- Frozen vegetables
- Meat, pre-portioned
- Frozen fruit

Refrigerated Staples

- Fresh vegetables (especially pre-washed salad)
- Fresh fruits
- Milk, yogurt, cheeses

Cooking

When it comes to cooking meals for your family, your experience needs to be enjoyable, and your time needs to be used wisely. Here are some tips to make the most of your time in the kitchen.

- Take advantage of free time. Spend some time doing prep work on weekend or days off. Chop fresh vegetables and fruit or cook a large batch of pasta for later in the week.
- Cook once; eat twice! Cook a larger quantity of a meal on one day, and save it for use later in the week. You can even get creative with your leftovers. For example, have grilled chicken on Monday night, and chicken fajitas on Thursday.



- Cook and freeze. Prepare a double or triple batch of food like baked spaghetti or soup, eat part of it one night, and portion out the rest in freezable containers to freeze for another day. This works great for single-size portions too.
- Use the slow cooker. The slow cooker can be a great tool for easy meals. Simply toss in the ingredients in the morning, and when you come home, dinner had practically cooked itself.
- Take turns in the kitchen. Share the responsibility of cooking with your husband, partner, or even older children. You need to lighten your load once in a while, and this can be a fun opportunity to grow together in the kitchen.

Cooking can be fun, and can easily become something that you look forward to every day. To be successful at cooking, it is important to build a foundation of cooking knowledge gradually. Utilize resources, such as friends and family who cook. Cooking magazines, TV shows, and websites are great resources, and can provide you with recipe ideas.

Cooking Resources

Eatingwell.com
Cookinglight.com



Smart Choices: Healthy Options for Dining Out

Choosing healthy meals while dining out can be a challenge, but you can use these tips and tricks to maneuver your way through the menu and choose delicious, healthy meals. Eating out can be healthy and enjoyable, with these simple tips!



Choosing a dining option:

One of the most challenging things is choosing a restaurant to dine out. When choosing, consider:

- Does the restaurant offer healthy eating options?
 - Salad bar
 - Menu items under 500 calories
 - Healthy sides
- What is the restaurant known for? Steak, Seafood, BBQ, All-you-can-eat buffet?
 - Knowing what type of restaurant will help you plan your strategy

Navigating Restaurant Menus

Restaurants can offer more than 100 options on their menu, so it is important to understand how to “navigate” the menu and find the healthiest choices.

Appetizers:

- Choose salads with low-fat dressings
 - *Did you know?* A restaurant salad can have the same number of calories as other main dishes due to many additions (bacon, cheese, croutons) and salad dressing
- Split appetizers with a group
- Avoid soups that are cream-based; soups with a broth base are usually lighter
- Avoid beverages with high sugar and calories; one glass can have up to 250 calories. Switch to water or other low sugar/low calorie drinks
- Skip the bread basket

Main Course:

- Choose items that are: “grilled”, “broiled”, “steamed”, “roasted”, or “baked” instead of “breaded”, “battered”, or “fried”
- Avoid entrees with heavy or creamed sauces
- For large dinner portions, split with a friend or take half home
 - Some restaurants offer a smaller portion of the meal if you ask
- Choose your sides. Substitute vegetables, fruit, or whole grains for higher calorie sides, such as fries or chips

Dessert:

- Split dessert items
- Limit extra toppings or choose healthier toppings like fruit

Healthy Grocery Store Shopping

The supermarket can be an overwhelming place, especially when one wants to choose healthy choices. This handout is designed to help you maneuver your way through the supermarket and not get deterred from the healthy food options

Grocery Store Tour: Making healthy choices

When grocery shopping, shop the perimeter of the supermarket. This will help you make the healthiest choices.

1. **Produce.** Spend the most time in the produce section. Choose a rainbow of colorful fruits and vegetables. There is little to avoid here.
2. **Breads, Cereals, and Pasta.** Choose the least processed foods that are made from whole grains. When choosing whole-grain cereals, aim for at least 4 grams of fiber per serving, and the less sugar, the better. Choose a variety of whole grains, such as whole-wheat bread and pastas, brown rice, grain mixes, quinoa, bulgur, and barley.
3. **Meat, Fish, and Poultry/Deli.** Choose lean cuts of meat (like round, top sirloin, and tenderloin), opt for skinless poultry, and watch your portion sizes. Aim for 2 servings of fish weekly.
4. **Dairy.** Choose low-fat and nonfat milk and cheese. If you enjoy higher-fat cheeses, keep your portions small. Choose light yogurt and watch the sugar content.
5. **Frozen Foods.** Frozen fruits and vegetables without sauce are a convenient way to help fill in the produce gap. Other healthy options are whole-grain waffles for snacks or meals, portion-controlled bagels, 100% juices for marinades and beverages, and plain cheese pizza that you can add extra veggies to for a quick meal.
6. **Canned and Dried Foods.** Keep a variety of canned vegetables, fruits, and beans on hand to toss into soups, salads, pasta, or rice dishes. Whenever possible, choose vegetables without added salt, and fruit packed in juice. Tuna packed in water, low-fat soups, nut butters, olive and canola oils, and assorted vinegars should be in every healthy pantry.

Other Tips and Tricks

- Plan Ahead: plan your meals before going grocery shopping and make a list. There are online interactive tools that can help you form your menus and make a shopping list
 - Smartphone Apps
 - FREE: Recipe, Menu & Cooking Planner By Pepperplate Inc.
 - Eatingwell.com Menu Planner
- Eat before you go shopping to prevent impulse buys
- Don't have time to grocery shop? Some markets offer pick up service. Order groceries online and pick up on your way home.
 - Harris Teeter Express Lane: \$4.95 fee
 - Lowes Foods To Go: \$4.95 fee

Participant Questionnaire

1. My ethnicity is:

- Asian or Asian American, including Chinese, Japanese, and others
- Black or African American
- Hispanic or Latino, including Mexican American, Central American, and others
- White, Caucasian, Anglo, European American; not Hispanic
- American Indian/Native American
- Other (write in):

2. What is the highest level of education you have completed?

- Graduate degree
- Some graduate school
- College degree
- Some college
- High school
- Some high school

3. My marital status is:

- Single
- Married
- Separated or divorced
- Widowed
- Other

4. What is your total household income?

- Less than \$20,000
- \$20,000 to \$30,000
- \$30,000 to \$39,999
- \$40,000 to \$49,999
- \$50,000 to \$59,999
- More than \$60,000

5. Do you work or plan on returning to work?

- Yes
- No

6. If you answered yes to Question 5, what is your occupation?

7. How many hours do you usually work each week?

- Less than 20 hours/week
- 20-30 hours/week
- 31-40 hours/week
- More than 40 hours/week

8. What is your activity level at work?

- Sitting
- Standing – Light work
- Standing – Moderate work
- Standing – Heavy work
- Walking
- Lifting

Perceived Stress Scale

The questions in this scale ask you about your feelings and thoughts **during the last month**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?..... **0 1 2 3 4**
2. In the last month, how often have you felt that you were unable to control the important things in your life?..... **0 1 2 3 4**
3. In the last month, how often have you felt nervous and “stressed”?..... **0 1 2 3 4**
4. In the last month, how often have you felt confident about your ability to handle your personal problems?..... **0 1 2 3 4**
5. In the last month, how often have you felt that things were going your way?..... **0 1 2 3 4**
6. In the last month, how often have you found that you could not cope with all the things that you had to do? **0 1 2 3 4**
7. In the last month, how often have you been able to control irritations in your life?..... **0 1 2 3 4**
8. In the last month, how often have you felt that you were on top of things?..... **0 1 2 3 4**
9. In the last month, how often have you been angered because of things that were outside of your control? **0 1 2 3 4**
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?..... **0 1 2 3 4**