AN ABSTRACT OF THE THESIS OF

Whitney M. Sweat for the degree of Master of Science
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Title: Low Energy Dense Diet and High-Intensity Exercise: Impact on Weight and Waist Circumference in Abdominally Obese Women

Abstract approved:

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Aging, obesity and increased waist circumference (WC) increases risk for metabolic syndrome (MetS). MetS is a cluster of symptoms (elevated WC, triglycerides, blood pressure, fasting glucose, and decreased high-density lipoprotein cholesterol [HDL-C]) increasing risk for chronic disease. Low-energy dense (LED) diets, emphasizing whole food eating patterns, have not been examined in combination with moderate (mod)/high-intensity physical activity (PA) or dietary protein levels to determine their impact on changes in body weight (BW) and WC in premenopausal, abdominally obese women. PURPOSE: To determine the effect of two 16-wk diet and PA interventions, differing in protein intake, on BW, WC, MetS risk factors, dietary patterns, energy density (ED), and min of Mod-Hi PA. METHODS: Healthy, abdominally obese (WC ≥80cm) women (n=38; 34±10y) were randomly assigned to either a 15 or 25% (+18 g/d whey protein) en from protein diet. Individualized LED diets plans decreased energy intake (EI) by ~300kcal/d; PA 5 d/wk (30-60 min/d) consisted of supervised, high-intensity Zumba classes 3d/wk (≥65%HRmax; ≥6METs) and self-selected mod-intensity PA (≥3METs) 2d/wk. Servings of fruits/vegetables, whole grains, and low-fat/fat-free dairy (LFD), fiber, high calorie beverages (BEV), ED, and PA were monitored before (T1), during (T2) and after (T3) the intervention using repeated measures ANOVA. Bonferroni simultaneous testing procedure was used in analysis of multiple comparisons. RESULTS: At T1, groups did not differ in dietary patterns, PA, BW, WC, or MetS risk. Groups responded similarly to the interventions so data were combined, with BW and WC decreasing ($p<0.0001$) by -4.8±2.7kg and -7.1±3.6cm, respectively. Comparing T1 vs. T2, there were increases ($p<0.0001$) in fruits/vegetables, (Δ=+1.5 ser/d), whole grains (Δ=+1.0 ser/d), LFD (Δ=+0.5 ser/d), fiber (Δ=+5.7g/1000kcal), and decreases in BEV (Δ=-165kcal/d) and ED (Δ=-0.55kcal/g). During the intervention high-intensity Zumba PA was 87min/wk; total min of all mod-intensity PA increased by 75 min/d ($p<0.0001$); VO_2max improved from 29.3±4.7 (T1) to 34.4±5.3 (T3) mL/kg/min ($p<0.0001$). Triglycerides significantly decreased (-24±52mg/dl; $p=0.006$), no other significant changes occurred in MetS risk factors. Exploratory analysis indicated that increases in fruits/vegetables and LFD, and decreases ED were associated with BW loss, while increases in whole grains, fiber, LFD, and min/wk of high-intensity PA (Zumba) were associated with WC reductions. CONCLUSION: For abdominally obese women, an intervention focused on LED foods and high-intensity PA significantly reduced BW and WC and improved dietary patterns regardless of protein intake. Helping clients identify a few key factors that positively promote reductions in BW and WC may improve weight loss success, while reducing MetS risk factors.

Low Energy Dense Diet and High-Intensity Exercise: Impact on Weight and Waist Circumference in Abdominally Obese Women

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Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Whitney M. Sweat, Author

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CONTRIBUTION OF AUTHORS

Kari D. Pilolla, PhDc was directly involved with the study design, participant recruitment, data collection, and data analysis. Dr. Gianni Maddalozzo performed all body composition assessments. Melissa Princehouse served as an undergraduate research assistant since the beginning of the study and participated in recruitment, data collection, and data entry. Dr. Melinda Manore assisted with the study design, finding funding, data analysis and interpretation, and writing.

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DEDICATION

This thesis is dedicated to my mother for always being there as a source of support, understanding, and knowledge. Without her, I would not be where I am today.

Low Energy Dense Diet and High-Intensity Exercise: Impact on Weight and Waist Circumference in Abdominally Obese Women

Chapter 1: Introduction and Literature Review
I. Introduction

A. Background and Significance

Currently, with an estimated 68% of the United States adult population considered overweight or obese (body mass index [BMI] $\geq$25kg/m^2) (Flegal, Carroll, Ogden, & Curtin, 2010), efforts to reduce the prevalence of excess weight are extremely important. Overweight/obesity is a major risk factor for the development of numerous chronic diseases, including the Metabolic Syndrome (MetS) (Lavie, Milani, & Ventura, 2009; Maison, Byrne, Hales, Day, & Wareham, 2001). Interventions emphasizing positive dietary and physical activity (PA) behavior change have been shown to reduce body weight, fat mass, waist circumference (WC), and features of MetS (Larson-Meyer, Redman, Heilbronn, Martin, & Ravussin, 2010). However, the majority of the weight loss research literature has been focused on energy restriction and alterations in macronutrient composition (e.g. increasing % energy intake from protein or reducing fat or carbohydrate), rather that improving habitual dietary patterns and altering energy density of the diet. Identifying which dietary patterns help reduce chronic disease and manage weight may help improve success of interventions designed to improve health outcomes.

Metabolic Syndrome. MetS consists of a group of symptoms that increases an individual's risk for chronic disease. The International Diabetes Federation (IDF) criteria for MetS is given in Table 1.1 (IDF, 2005). Based on the IDF criteria, the prevalence of MetS in adults over age 20y is estimated at 39% (Ford, 2005). Two primary factors that contribute to MetS are age and obesity; however factors that contribute to obesity, such as poor diet and low levels of PA, contribute to MetS risk as well.

Age. Overall, age-adjusted prevalence of MetS is 41% in men and 37% in women (Ford, 2005); however, the prevalence of MetS increases as women age, eventually surpassing men. At ages 50-59y, men and women have an estimated prevalence of 54% and 49%, respectively, but by age 60-69y, prevalence in women

(63%) exceeds that of men (58%) (Ford, 2005). Young individuals who are overweight/obese are also at increased the risk for MetS.

Obesity. Ervin (2009) found that compared to normal weight women, overweight females have a five-fold increase in MetS risk, while obese women have up to 17 times the risk. In men, overweight individuals had six times the risk for MetS, while obese men had 32 times the risk compared with normal weight males. Location of body fat is also important, as abdominal obesity is a primary risk factor in the development of MetS (Grundy et al., 2005). Increases in abdominal obesity, WC, and visceral fat occur as women age (Kuk, Lee, Heymsfield, & Ross, 2005), with 62% of women estimated to have abdominal obesity (Ghandehari, Le, Kamal-Bahl, Bassin, & Wong, 2009). In general, aging is associated with increased subcutaneous fat. However, when women go through menopause, fat storage shifts towards greater visceral adipose deposition (Kuk et al., 2005). This factor was demonstrated in a 4y longitudinal study following 156 premenopausal women (age > 43y); increases in total abdominal fat were correlated with increasing follicle-stimulating hormone (FSH) 4y prior to menopause. FSH levels increased up to the final menstrual period and 1y post-menopause. Decreasing estradiol levels were also associated with increases in total abdominal fat (Sowers et al., 2008).

Table 1.1: International Diabetes Federation (IDF) classification of metabolic syndrome (abdominal obesity plus 2 or more of the following) (IDF, 2005)

Metabolic Syndrome Criteria	Men	Women
Abdominal Obesity	Waist Circumference (WC): ≥ 37 in (94 cm)	Waist Circumference (WC): ≥ 31.5 in (80 cm)
Triglycerides (TG)	≥ 150 mg/dL (8.3mmol/L)	≥ 150 mg/dL (8.3mmol/L)
High Density Lipoprotein-Cholesterol (HDL-C)	≤ 40 mg/dL (2.2mmol/L)	≤ 50 mg/dL (2.8mmol/L)
Fasting Blood Glucose	≥ 100 mg/dL (5.6mmol/L)	≥ 100 mg/dL (5.6mmol/L)
Blood Pressure	Systolic: ≥ 130mmHg, and/or Diastolic: ≥85mmHg	Systolic: ≥ 130mmHg, and/or Diastolic: ≥85mmHg

To summarize, as premenopausal women age, their risk for developing obesity, abdominal obesity, and MetS increase. Thus, a critical need exists to develop approaches to help prevent women from transitioning to overweight/obesity and to the development of MetS.

B. Lifestyle Change to Promote Weight Loss and Reduce MetS Risk

Decreased PA and poor dietary choices play a role in the development of MetS and its risk factors (Grundy et al., 2005). Interventions emphasizing dietary and PA behavior change, both alone and in combination, have been shown to reduce weight, fat mass, and WC (Larson-Meyer et al., 2010) or the prevalence of MetS (Katzmarzyk et al., 2003). Several dietary factors have been shown to reduce the risk of MetS and promote weight loss, including diets high in protein (Muzio, Mondazzi, Harris, Sommariva, & Branchi, 2007), high in whole grains, fruits and vegetables as the primary carbohydrate source, and non-hydrogenated unsaturated fats as the primary fat source (Hu & Willett, 2002). Greater PA is also associated with decreased MetS risk factors in women, regardless of age (Woolf et al., 2008). Thus, appropriate diet and exercise approaches are cost-effective methods to reduce body weight and abdominal obesity, and prevent the development of MetS. Overall, just a moderate level of weight loss (5-10%) has been shown to improve blood lipids (serum triglycerides, total cholesterol, low-density lipoprotein-cholesterol [LDL-C], high density lipoprotein-cholesterol [HDL-C]) and reduce diabetes risk (Hamman et al., 2006; Lavie et al., 2009). Understanding these nutrition and PA behaviors associated with MetS can provide insight into educational approaches that can reduce risk factors for the development of MetS and chronic disease. Since women are at high risk for development of MetS simply due to age, our focus is to reduce the additional risk of developing MetS associated with abdominal obesity, decreased PA, and poor dietary habits in overweight, abdominally obese, premenopausal women.

Impact of Diet Patterns on Weight Loss and MetS Risk. Overall, diets containing more whole fruits and vegetables, unrefined grains, and less total fat and saturated fat have been shown to be beneficial for weight loss and reducing MetS risk (Azadbakht, Mirmiran, Esmaillzadeh, Azizi, & Azizi, 2005; Ello-Martin, Roe, Ledikwe, Beach, & Rolls, 2007). These dietary approaches may lead to decreased energy intake, due to the low energy density of the diet, increased satiety, and better weight management. Energy density refers to the energy (kcal) in a given amount

(g) of food (kcal/g) (Rolls, Drewnowski, & Ledikwe, 2005). When a food is low in energy density, a greater weight of food can be consumed for the same, or lower amount of energy (Table 1.2). Water has the greatest impact on energy density because it adds weight without adding energy (kcal). Fat influences energy density because is contains 9 kcal/g while carbohydrate and protein contribute 4 kcal/g. However, a high-fat food with high water content, such as cheese, can have the same energy density as a food that is fat-free, but low in water content, such as pretzels. Fiber is another component that can lower the energy density of foods (Rolls et al., 2005). Laboratory research on energy density shows that over the course of a few days, the weight of food consumed is more constant than the energy intake, which may be important in weight management. For example, Bell et al. (1998) found that when the weight of foods was held constant, but the energy density lowered 30% by the addition of water-rich vegetables, participants consumed less total energy by -425 kcal/d. Similar levels of hunger and fullness were reported between the control diet and the lower energy density diet, likely because the same weight of food was consumed. Modifying the food energy density of a variety of eating patterns with the addition of water-rich fruits and vegetables and high fiber whole grains can promote a lower energy intake while still maintaining palatability (Rolls et al., 2005). A widely recommended dietary approach to decrease chronic disease risk factors is the Dietary Approaches to Stop Hypertension (DASH) eating plan (NIH, 2003). This diet emphasizes low energy density foods with a daily recommendation of 4-5 servings of both fruits and vegetables (Table 1.7).

Dietary Components Associated with Weight Loss and MetS Risk Reduction. Water and fiber are key components of low-energy dense diets; fruits, vegetables, and minimally processed grains contain ample amounts of these components (Rolls et al., 2005). Other factors associated with altering energy density are reducing added fats and sugar-sweetened beverages while choosing low-fat dairy products and lean protein sources. Fat can substantially alter energy density (Rolls et al., 2005), while low-fat dairy products and protein containing foods may enhance satiety and weight loss (Leidy, Carnell, Mattes, & Campbell, 2007; Major et al., 2008). Finally, sugar-sweetened beverages contribute added kcals with little added satiety

(Malik, Schulze, & Hu, 2006). These food components and how they are hypothesized to affect weight loss and, thus, decrease MetS risk are summarized below.

Table 1.2: Examples of low and high energy density foods (kcal/g food)

Low Energy Dense Foods	High Energy Dense Foods
Apple (1 med, 2 ¾" diameter; 138 g) = 81 kcal Energy Density: 0.59 kcal/g food	Potato Chips (1 serving; 28 g) = 153 kcal Energy Density: 5.46 kcal/g food
Spinach (1 cup chopped, raw; 30 g) = 7 kcal Energy Density: 0.23 kcal/g food	Brownie (2" square; 24 g) = 112 kcal Energy Density: 4.67 kcal/g food
Cauliflower (1 cup chopped, raw; 100 g) = 25 kcal Energy Density: 0.25 kcal/g food	Cheddar cheese (1 slice, 28 g) = 114 kcal Energy Density: 4.07 kcal/ g food

- **Fruits and vegetables.** Fruits and vegetables are high in water and fiber content and are considered low-energy dense foods (Rolls et al, 2005). Adding whole fruits and vegetables to the diet reduces the overall energy density and because of the added bulk, may decrease the amount of food that can be consumed. A review by Rolls et al (2004) reports that some studies find fruits and vegetables to enhance satiety and reduce hunger, especially when added to mixed dishes. When foods are low in energy density, more satisfying portions can be encouraged, producing greater fullness while adding little energy. Low-energy density foods may, thus, promote weight management. For example, in a cross-sectional study of US adults (Ledikwe et al., 2006), women with low energy dense diets (<1.6 kcal/g) were more likely to be of normal weight than women with high energy dense diets (>2.0 kcal/g). For all participants, those that consumed more fruits and vegetables had the lowest dietary energy density values and lower prevalence of obesity. Increased fruit and vegetable consumption alone has been associated with lower anthropometric measures of BMI and WC (Ahmad Esmaillzadeh et al., 2006) and preventing weight gain over the long term in women (He et al., 2004). He et al. (2004) found an inverse relationship between increased fruit and vegetable intake and risk of obesity in a 12y longitudinal study of women aged 30-55y (n=74,063). Taken together, a diet high in fruits and vegetables can assist in maintaining a healthy body weight, lower WC, and prevent weight gain with aging.

- **High fiber and minimally processed carbohydrates.** The high fiber content of fruits and vegetables also contributes to their satiating effect (Rolls et al., 2004). In addition to fruits and vegetables, other high fiber carbohydrates that promote post-meal satiety include minimally processed whole grains, legumes, and peas. These minimally processed, high-fiber, high water carbohydrates are associated with lower BMI (Sahyoun, Jacques, Zhang, Juan, & McKeown, 2006), and decreased prevalence of MetS risk factors (Esmaillzadeh, Mirmiran, & Azizi, 2005). Whole grains contain fiber, lignans, phytosterols, antioxidants, and anti-nutrients that may assist in weight maintenance and protect from MetS risk factors, such as hyperinsulinemia and hypercholesterolemia (Slavin, 2003). A recent cross-sectional study of Framingham Heart Study Participants assessed intakes of whole and refined grains on WC, subcutaneous adipose tissue (SAT), and visceral adipose tissue (VAT). Whole grain intake was inversely associated with SAT and VAT, while refined grain intake was positively associated with these variables (McKeown et al., 2010). An intervention study in which participants were randomized to consume only whole or refined grains found that those consuming primarily whole grains had greater reductions in WC (-4.7 cm [whole grain] vs. -2.5 cm [refined grain]) and abdominal body fat (-2.2% vs. -0.9%) (Katcher et al., 2008). Additionally, increased dietary fiber (Du et al., 2010) and other fiber containing foods, such as legumes (Crujeiras, Parra, Abete, & Martínez, 2007; Papanikolaou & Fulgoni, 2008), have been shown to be inversely associated with positive weight and WC changes. Alterations in gut satiety hormones, energy density, delayed gastric emptying, reduction in blood glucose and cholesterol has been implicated in the benefits of higher fiber diets (Slavin, 2005). Thus, a higher fiber diet may promote lower body weight, WC, abdominal obesity, and MetS risk factors.
- **Fat.** Another characteristic of reduced dietary energy density is decreased total fat intake. Fat contributes a greater amount of energy per gram of food

(9 kcal/g) compared to carbohydrate and protein (4 kcal/g). Lower fat diets consistently promote weight loss (Ello-Martin et al., 2007) and better long-term weight control (Howard et al., 2006; Schulz, Nöthlings, Hoffmann, Bergmann, & Boeing, 2005). For example, Tanumihardjo et al. (2009) compared two dietary interventions: One group was encouraged to consume >8 servings/d of vegetables and 2-3 fruit servings/d while a second group was given only specific targets for fat (≤25% of energy) and energy intake (-500 kcal/d). At 3-mo, both groups experienced weight loss and reduced total fat and energy intake. However, while the high vegetable group lost weight (-1 kg), the reduced fat group lost significantly more weight (-5 kg, treatment effect: $p<0.0001$) at 3-mo. Furthermore, only the reduced fat group maintained their weight loss at 12 and 18-mo. Thus, while it is important to encourage increased fruit and vegetable intake as part of a healthy diet, helping individuals control energy and fat intake is also essential.

- **Low-fat dairy.** Although the literature is equivocal, some research does suggest that low-fat dairy products aid in weight loss and weight maintenance (Zemel et al., 2008; Zemel, Richards, Mathis, et al., 2005; Zemel, Richards, Milstead, & Campbell, 2005; Zemel, Thompson, Milstead, Morris, & Campbell, 2004). Azadbakht et al. (2005) assessed adequacy of dairy intake in Tehranian adults (18-74y) and divided participants into quartiles based on dairy intake. They found those in the lowest quartile (≤1.7 servings/d) had a greater prevalence of MetS (28% versus 21%) and its components compared to those in the highest quartile (≥3.1 servings/d). Highest dairy consumption was also associated with lower BMI (24.9 vs. 26.7 kg/m^2) and WC (83 cm vs. 87 cm).

  Some intervention studies also report that higher calcium intakes and higher consumption of dairy products can enhance weight and trunk fat loss during energy restriction (Zemel, Richards, Mathis, et al., 2005; Zemel et al., 2004). For example, Zemel et al. (2008) found that participants consuming the recommended daily servings of dairy products (3 servings/d) during weight maintenance had a significantly higher energy intake at all time points, yet weight change was similar to the low-dairy group, with lower energy intake. This may be explained by differences in resting metabolic rate (RMR) and respiratory quotient (RQ) between the groups. Although not statistically significant, the average RMR in the recommended dairy group was higher (1851 kcal/d) during the weight maintenance phase than in the low-dairy group (1751 kcal/d) ($p = 0.08$). The recommended dairy group also had a significantly lower RQ than the low-dairy group (0.76 versus 0.77 respectively, $p < 0.001$), indicating greater fat oxidation. Another potential mechanism for how dairy can contribute to weight loss may be related to changes in dietary fat and energy absorption. Jacobsen et al. (2005) compared the effects of 3 isocaloric diets in 10 participants in a randomized crossover study. Moderately overweight (mean BMI=26.5 kg/m^2) men and women (18-50y) consumed one of three diets for a period of one week each: 1) low calcium-normal protein; 2) high calcium-normal protein, and 3) high calcium-high protein. Food was prepared for the participants based on estimated energy needs. No statistically significant differences were found in RMR and RQ between the treatments. However, in the high calcium-normal protein group, fecal fat excretion and fecal energy excretion increased in the (18% and 55% [83.5 kcal/d], respectively) compared to the other two groups. Thus, increases in fecal fat and energy excretion when high calcium-normal protein diets are consumed may also partially explain the role of dairy in weight loss. In summary, calcium and/or dairy products may facilitate weight and fat loss during energy restriction, possibly by increasing RMR, fat oxidation, and fecal fat and energy excretion.

- **Sugar-sweetened beverages.** Over the past decade, the percent of US adults consuming sugar-sweetened beverages has increased from 58% to 63% of the population (adding approximately 46 kcal/d) (Bleich, Wang, Wang, & Gortmaker, 2009). Higher consumption of sugar-sweetened beverages has been associated with increased weight gain and the risk of type 2 diabetes in women (Schulze et al., 2004). Research clearly shows a positive relationship between the intake of sugar-sweetened beverages and overweight and obesity. As reviewed by Malik et al. (2006), multiple studies in children, adolescents, and adults indicate that intake of sugar sweetened beverages promote weight gain and adiposity. Specifically, soft drinks have been show to increase the risk of developing MetS (Dhingra et al., 2007). Chen et al .(2009) found that a reduction of 100 kcal/d of liquid energy intake was associated with 0.3 kg of weight loss, while the same energy reduction from solid food was associated with a loss of 0.06 kg over a 6-mo period. Thus, reducing energy intake from sugar-sweetened beverages had a greater impact on weight loss than reducing energy intake from solid foods alone (p = 0.006). When analyzing individual beverages, reducing sugar-sweetened beverages by one serving/d was associated with a 0.5 kg reduction in weight. To reduce the risk of obesity and MetS, sugar-sweetened beverages should be decreased and replaced with healthy, non-caloric alternatives such as water (Hu & Malik, 2010).

- **Protein.** Energy-restricted diets high in protein or carbohydrate can have beneficial effects on abdominal obesity, weight loss, and metabolic variables (Foster et al., 2010; Muzio et al., 2007; Swain, McCarron, Hamilton, Sacks, & Appel, 2008). However, evidence also suggests that higher protein intakes may be more beneficial at promoting weight and WC loss than more traditional low-fat, higher carbohydrate dietary patterns (Leidy et al., 2007; Meckling & Sherfey, 2007; Vander Wal, Gupta, Khosla, & Dhurandhar, 2008).

  When combined with energy restriction, higher protein intakes are thought to promote greater weight loss by: 1) increased satiety, 2) preservation of fat-free mass (FFM) and 3) increased diet-induced thermogenesis (Leidy et al., 2007; Westerterp-Plantenga, Nieuwenhuizen, Tome, Soenen, & Westerterp, 2009). Increased satiety may reduce subsequent energy intake, as shown by Vander Wal et al. (2008) in a study of 36h energy intake following a higher protein breakfast (20% protein meal vs. 15% protein meal). Leidy et al. (2007) found that when combined with energy restriction, post-prandial satiety levels were more sustained on a diet containing 30% energy (reductions of 10% from the higher protein and 27%

from the lower protein). This diet also and preserved more metabolically active FFM. Preservation of FFM may assist in maintenance of RMR. Lastly, protein ranks the highest for diet-induced energy expenditure, the cost of digesting, absorbing, and storing (storage of absorbed, but no immediately oxidized protein) in comparison to other macronutrients (20-30% vs. 0-3% for fat and 5-10% for carbohydrate) (Westerterp-Plantenga et al., 2009). Taken together, improved satiety, reduced energy intake, and increased energy expenditure may all contribute to the benefits of a greater protein intake (>20-30% of energy) on weight loss. However, altering the macronutrient composition of the diet and reducing the dietary energy density by promoting fruits, vegetables, whole grains, and lean proteins may prove even more beneficial than changing macronutrient contribution alone.

Impact of Macronutrient Composition on Weight Loss and MetS Risk. There is only limited research examining the impact of the combined effects of the above dietary factors for weight loss and reducing MetS risk compared to research examining changes in macronutrient composition. Research does suggest that increasing the protein content of the diet may be beneficial for weight loss (Meckling & Sherfey, 2007; Vander Wal et al., 2008; Westerterp-Plantenga et al., 2009). Research by Meckling & Sherfey (2007) found that a 12-wk intervention with high protein diet (1:1 carbohydrate to protein ratio) promoted greater weight loss (-7.0 kg vs. -4.0 kg, $p<0.05$) and reductions in WC (-8.0 cm vs. -6.5 cm, non-significant) compared to a lower protein diet (3:1 carbohydrate to protein ratio). However, changes in MetS risk factors were similar between groups. Conversely, Noakes et al. (2005) found that a high protein diet (30% energy from protein vs.17% energy from protein) resulted in significantly greater improvements in triglyceride concentration (-0.3 mmol/L vs. -0.1 mmol/L, respectively; $p=0.007$) in obese women, but did not promote greater weight loss (-7.6 kg vs. -6.9 kg, respectively) over a 12-wk time period.

These studies found benefits of a higher protein diet, but results are mixed. Other studies have compared diets of varying macronutrient content and have not found protein to be more beneficial over others (Johnston, Tjonn, & Swan, 2004;

Muzio et al., 2007; Swain et al., 2008). For example, Johnston et al. (2004) found that a 6-wk intervention with two low-fat diets (<30% energy), one high-protein (32% energy from protein, 41% carbohydrate) and the other high-carbohydrate (15% energy from protein, 66% energy from carbohydrate), resulted in similar improvements in weight (-6%), total cholesterol (-9.5%), LDL-C (-12.5%), and fasting insulin (-24%) in overweight men and women (19-54y). Another study, the OmniHeart trial identified three different options for a heart healthy diet (Swain et al., 2008). One diet was rich in carbohydrate and emphasized whole grains, fruits, and vegetables, while another was high in protein, primarily from plant sources, and the third was high in unsaturated fat. All three diets caused comparable reductions in blood pressure, total and LDL-C, and coronary heart disease risk (body weight not assessed). Additionally, Muzio et al. (Muzio et al., 2007) found that two different diets, 1) high carbohydrate, high fiber versus 2) high protein with mostly unsaturated fat, had beneficial effects on risk factors such as central obesity, hypertension, hypertriglyceridemia, and cholesterol levels. Taken together, these studies suggest that the types of foods consumed, such as increased whole grains, fruits, and vegetables may be as important in reducing risk factors as composition of the diet.

Impact of Physical Activity on Weight Loss and MetS Risk. Americans do not meet PA recommendations; less than 50% of adults are meeting the American College of Sports Medicine (ACSM) recommended amounts of PA (Physical Activity Guidelines, 2008; Haskell et al., 2007). The ACSM recommends 150 min/wk of moderate intensity exercise (≥3-6 metabolic equivalents [METs]) or 75 min/wk of high-intensity exercise (> 6 METs) for disease prevention (Garber et al., 2011). This is similar to the 2008 PA Guidelines for Americans that also recommends PA for weight loss, weight maintenance, and reduction in Mets risk factors (Physical Activity Guidelines, 2008). High-intensity exercise protects against MetS risk factors and chronic disease, and requires less time spent in PA than exercise at a more moderate-intensity level (Garber et al., 2011).

C. Rationale for Identifying Food Patterns & Physical Activity Interventions

Currently, the average American food patterns contain few of the foods shown to be beneficial for weight loss and MetS risk reduction and bear little resemblance to the 2010 Dietary Guidelines for Americans (DGA) (Dietary Guidelines for Americans, 2010). The most recent DGA report describes the typical American diet as containing too many calories, solid fats, added sugars, refined grains, and sodium, with too little dairy, fiber, unsaturated fats, and important nutrients found in vegetables, fruits, whole grains, and low-fat milk products. Studying foods and their interactions in combination with one another (e.g food synergy) may provide risk reduction information that is harder to identify in studies of single foods or nutrients (Jacobs & Tapsell, 2007). Thus, since individuals consume combinations of foods, not isolated nutrients, examining dietary patterns that reduce chronic disease risk and manage weight might improve success of intervention programs. A healthful diet does not follow a rigid prescription. One can look at worldwide dietary patterns, such as the Mediterranean diet pattern (wheat, unrefined cereals, vegetables, fruits, nuts, olive oil) for correlations between dietary patterns and reduction in chronic disease risk (Babio, Bulló, & Salas-Salvadó, 2009). It is likely that the combination of reduced saturated fat, higher unsaturated fat, and plant-based foods contribute to its health benefits rather than one single component (Jacobs & Tapsell, 2007). In the United States, the DASH diet (NIH, 2003), which was originally designed to lower blood pressure (Table 1.7), emphasizes vegetables, fruits, low-fat milk products, whole grains, poultry, and seafood. The DASH diet is an example of a low energy density eating plan and can also be a tool to promote weight loss (more information on the DASH diet is provided in literature review). Furthermore, as it is important to study dietary patterns, it is also important to study how this approach interacts with increased PA, since it is also beneficial in improving outcomes related to weight loss and reducing MetS risk.

Below is a summary of the recent research on dietary patterns, PA, weight, and MetS risk factors. The research literature will be more thoroughly reviewed in Chapter 2.

Summary of Cross-sectional Studies: Diet Patterns. Food frequency questionnaires (FFQ) are frequently used in cross-sectional studies to assess dietary intakes at one specific time point. Many studies identified healthy diet patterns from these research tools that consisted of high intakes of fruits, vegetables, whole grains, and low-fat dairy products. Compared to unhealthy diet patterns, which consist of more refined grains, sweets, high fat meats and dairy, and sugar-sweetened beverages, healthier diet patterns are inversely associated with weight and MetS risk factors such as abdominal obesity, triglyceride levels, fasting blood glucose, and blood pressure (Deshmukh-Taskar et al., 2009; Ahmad Esmaillzadeh & Azadbakht, 2008a, 2008b; Rezazadeh & Rashidkhani, 2010). Other studies comparing food intakes to specific dietary guidelines (DGAs) found similar results, specifically that individuals that adhered more closely to the recommendations had lower BMI, WC, abdominal obesity, total cholesterol, fasting blood glucose, and blood pressure (Fogli-Cawley et al., 2007; McNaughton, Dunstan, Ball, Shaw, & Crawford, 2009a). Overall, healthier diet patterns are associated with less MetS risk factors.

Summary of Longitudinal Studies: Diet Patterns. Epidemiological longitudinal studies find similar relationships between dietary patterns and weight and MetS risk factors by identifying risk factors over time (Lutsey, Steffen, & Stevens, 2008; Millen et al., 2006; Newby, Weismayer, Akesson, Tucker, & Wolk, 2006; Schulze, Fung, Manson, Willett, & Hu, 2006). In these studies (8-12 y duration), FFQs were used to assess dietary intakes of large populations with healthy and unhealthy dietary patterns emerging. Overall, those with healthier diet patterns experienced less weight gain and had lower risk for developing MetS during follow-up than those with less healthy dietary habits.

Summary of Intervention Studies: Diet Patterns. Intervention studies have used various methodologies to assess dietary patterns (including FFQs and multiple day food records) and their relationship to body weight and MetS risk factors. Typically, dietary assessments using multiple day food records (≥3-d) result in greater accuracy than FFQs, although requiring more analysis and participant burden (Crawford, Obarzanek, Morrison, Sabry, 1994). Researchers have specifically examined the use of low energy density diets for weight loss. For example, Ledikwe et al. (2007) found that larger reductions in dietary energy density (≥-5.2 kcal/g) were related to greater weight loss in hypertensive adults. Similarly, Ello-Martin et al. (2007) found that reducing energy density and increasing fruit and vegetable intake were primary predictors of weight loss in obese women. Individuals incorporating more fruits and vegetables into their diet, in addition to consuming less energy from fat, lost 33% more weight than those limiting their fat intake alone. Azadbakht et al. (2005) found the DASH eating plan to promote greater improvements in weight and MetS risk factors than a weight reducing diet alone. Similarly, Blumenthal et al. (2010) used the DASH eating plan to promote low energy density foods, but also included moderate-high intensity exercise into the intervention. In obese hypertensive men and women, the DASH eating plan (Table 1.7) alone improved blood pressure and LDL-C, but the addition of exercise and weight loss resulted in greater improvements in insulin sensitivity, total cholesterol, and triglyceride levels compared to the DASH diet group alone and controls. In a weight loss study also emphasizing vegetables and fiber rich foods, Jacobs et al. (2009) assessed the effects of diet and moderate-high intensity exercise in middle-aged, overweight men. Dietary improvements (based on an overall dietary score) were associated with favorable changes in weight, WC, blood pressure, total and LDL-C, glucose, and insulin. Additionally, the combination of exercise and improved dietary patterns resulted in greater weight loss compared to those that only modified diet.

Summary of Physical Activity Interventions. Two studies highlighted above assessed PA, dietary patterns, and their effects on MetS and weight change (Blumenthal et al., 2010; Jacobs et al., 2009). Unfortunately, most studies analyze dietary patterns or PA effects alone. Research on different PA patterns does suggest, however, that PA plays an important role in modifying MetS risk factors (Katzmarzyk et al., 2003; Larson-Meyer et al., 2010) and promoting weight loss (Donnelly et al., 2009). Exercise on its own has been shown to reduce WC and body fat (Ross et al., 2004; Volpe, Kobusingye, Bailur, & Stanek, 2008) with high-intensity PA showing additional reductions in abdominal subcutaneous and visceral fat (Coker, Williams, Kortebein, Sullivan, & Evans, 2009; Irving et al., 2008). When combined with a moderate energy restriction, PA has an additive effect on weight loss compared to diet alone (Donnelly et al., 2009) and together promotes greater reductions in body weight, WC, and percentage of body fat (Foster-Schubert et al., 2011).

Overall, research indicates the benefits of low energy density diets, lower energy from fat, increased fruits, vegetable, and fiber consumption, and increased moderate/high-intensity PA on weight loss. Taken together, intervention studies assist in identifying common dietary and PA patterns that are beneficial for promoting weight loss and reduction in MetS risk factors.

D. Study Purpose and Hypotheses

From the studies summarized above, it is evident that a relationship exits between dietary and PA patterns, weight, and MetS risk factors. Diets rich in fruits, vegetables, whole grains, low-fat dairy, and lean meats are associated with better health outcomes. Cross-sectional studies provide information on the effects of dietary patterns on weight and MetS risk factors at a single point in time (Deshmukh-Taskar et al., 2009; Ahmad Esmaillzadeh & Azadbakht, 2008a, 2008b; Fogli-Cawley et al., 2007; McNaughton et al., 2009a; Nettleton et al., 2008; Rezazadeh & Rashidkhani, 2010; Sonnenberg et al., 2005), while longitudinal studies can identify correlations between changes in diet and risk factors over time (Lutsey et al., 2008; Millen et al., 2006; Newby et al., 2006; Schulze et al., 2006). While the epidemiological studies include very large sample sizes for analysis, they relied on FFQs to examine food patterns, rather than measured food intake. Additionally, these studies do not provide information on the effect specific recommendations. Intervention studies provide more insight into direct approaches to reduce weight and MetS risk factors, such as decreasing the energy density of a diet. However, few interventions studies examining dietary patterns have included PA as part of the intervention. If exercise is included, most research has incorporated moderate intensity exercise (Ello-Martin et al., 2007) and the only studies incorporating high-intensity PA were done in middle-aged men or a combination of men and women (Blumenthal et al., 2010; Jacobs et al., 2009). Higher intensity exercise may have additional benefits in reducing abdominal obesity (Irving et al., 2008). Lastly, many intervention studies focus on macronutrient alterations in the diet, but do not report changes in eating patterns or dietary energy density. Since making improvements in both of these factors, decreasing energy density (Ello-Martin et al., 2007; Ledikwe et al., 2007) or increasing protein intake (Meckling & Sherfey, 2007; Noakes et al., 2005), has shown beneficial effects, it is important to determine if these types of interventions can be combined. Often, higher protein diets contain more animal protein, which may make it difficult to have a lower-fat and lower energy dense diet.

To our knowledge, no intervention study using low energy density diets and high-intensity PA, while examining two levels of dietary protein, has been done in premenopausal, abdominally obese women. Aging, weight gain, and decreased PA may especially put women at greater risk for developing MetS. Thus, research is needed to assess the effects of dietary patterns and PA together on the prevention of obesity and MetS risk factors. To address this need, our study has identified the effects of changes in dietary patterns, energy density, dietary protein level, and high-intensity PA in overweight, abdominally obese, premenopausal females on weight, WC, and MetS risk factors.

Overview of Intervention. As part of a larger study, premenopausal women, categorized as overweight or mildly obese (BMI: 26-32 kg/m^2) with an elevated WC (>80 cm) were randomized into one of two dietary intervention groups that differed in protein content (15% vs. 25% [+18 g/d whey protein] energy from protein). Both groups were placed on a mild energy restricted diet (at least -300 kcal/d) and asked to perform structured interval training exercise that fluctuated between moderate/high-intensity levels 3-d/wk (>6 METs). Participants also performed an additional 2-d/wk of moderate-intensity exercise on their own (≥3 METs). Specifically, our study targets women prior to the onset of menopause and uses more intense forms of exercise in addition to dietary modifications to promote weight and body fat loss and to reduce WC.

Purpose and Hypotheses. The purpose of this study was to determine the effect of two 16-wk diet and PA interventions, differing in protein intakes, on body weight, WC, MetS risk factors, dietary patterns, energy density, and level of PA. We hypothesized that the intervention would improve dietary and PA patterns (Table 1.3) and reduce dietary energy density, regardless of protein intake, resulting in reductions in body weight and risk factors associated with MetS (Table 1.4). We will also examine which dietary and PA variables contributed most significantly to weight and WC reductions.

- **Hypothesis 1:** Compared to baseline, a 16-wk diet and exercise intervention utilizing a low energy dense eating plan and moderate/high-intensity exercise will improve diet and PA behaviors during and post-intervention, regardless of protein intake.
- **Hypothesis 2:** The intervention will lead to a reduction in body weight, WC, and in risk factors for MetS, regardless of protein intake.
    - Secondary research question: What dietary factors (i.e. fruit and vegetable intake) and PA behaviors (i.e. high-intensity PA) are associated with greater improvements in weight and WC?

Table 1.3: Dietary and Physical Activity Patterns Methods of Measurement

Variable	Pre: 4-d food record	During: Two 24-h diet recall; Zumba attendance	Post: 4-d food record
Fruits & vegetables	Servings/d*	Servings/d*	Servings/d*
Whole grains	Servings/d*	Servings/d*	Servings/d*
Fiber	Grams/1,000 kcal/d	Grams/1,000 kcal/d	Grams/1,000 kcal/d
Low-fat or fat-free dairy	Servings/d*	Servings/d*	Servings/d*
High kcal beverage	Kcal/d	Kcal/d	Kcal/d
Energy density	Kcal/g	Kcal/g	Kcal/g
Moderate/high-intensity PA	Min/d	Min/wk	Min/d

*USDA My pyramid serving sizes for various fruits (1 small orange, 1 cup applesauce, ½ cup 100% juice), vegetables (1 cup raw vegetables, 2 cups leafy greens, ½ cup cooked vegetable), whole grains (1 slice bread, ½ English muffin), dairy products (1 cup milk or yogurt)
PA=physical activity; HR=heart rate

Table 1.4: Study Outcome Measures and Methods of Assessment

Outcome	Pre-Intervention	During	Post-intervention
DIETARY VARIABLES			
Servings of fruits, vegetables, low-fat/fat-free dairy, whole grains, fiber (g), beverages (kcal/d), macronutrient content (% energy), energy intake (kcal/d), energy density (kcal/g)	4-d food record	Two 24-h recalls*	4-d food record
PHYSICAL ACTIVITY PATTERNS			
Moderate and high-intensity PA (min/d ≥3 metabolic equivalents)	4-d PA record	Zumba attendance; HR monitors Daily PA tracking logs	4-d PA record
$VO2_{Max}$	Sub-maximal fitness assessment	N/A	Sub-maximal fitness assessment
BODY COMPOSITION AND SIZE			
Weight (kg)	Scale DXA	Scale	Scale DXA
Waist Circumference (cm)	Clinical measure	Clinical measure	Clinical measure
BMI	Body weight and height	Body weight and height	Body weight and height
METABOLIC SYNDROMD RISK FACTORS AND OTHER BLOOD DATA			
Dyslipidemia (total cholesterol, HDL-C, LDL-C, triglycerides)	Fasted Blood Draw	N/A	Fasted Blood Draw
Insulin Dysregulation (fasting insulin and glucose)	Fasted Blood Draw	N/A	Fasted Blood Draw
Hypertension	Resting Blood Pressure	Resting Blood Pressure	Resting Blood Pressure

*Listing of all foods and beverages consumed in the preceding 24-h period
PA=physical activity, DXA=dual x-ray absorptiometry; HDL-C=high-density lipoprotein cholesterol; LDL-C=low-density lipoprotein cholesterol

II. Literature Review

This review of the literature examines dietary patterns and PA interventions that impact weight, WC, and MetS risk factors and also addresses how protein may impact these variables. Multiple cross-sectional, longitudinal, and intervention studies have examined dietary patterns and their impact on health. The variety of methods used can make the literature difficult to synthesize. In addition, PA is often not assessed along with dietary patterns. Thus, this review will address dietary and PA behaviors identified in the 2010 Dietary Guidelines for Americans (such as increasing fruits, vegetables, minimally processed whole grains, and physical activity), used in our research, and that have been identified in association with certain outcome variables of interest, such as weight, WC, and MetS risk factors.

Studies of dietary patterns can be grouped into 3 categories: 1) epidemiological cross-sectional studies, 2) epidemiological longitudinal studies, and 3) short and long-term intervention studies. Epidemiological study designs provide information on large population based studies, while intervention studies identify key strategies that may promote weight loss and improve health outcomes. Cross-sectional and longitudinal studies relied on FFQs to indicate common dietary patterns found in specific populations. However, some of these studies defined criteria to determine healthier diet patterns, such as The Dietary Guidelines for Americans or overall consensus of study authors. The use of these diet scores provides more convincing evidence that healthier diets are related to lower MetS risk factors. Intervention studies provide even more specific information on dietary patterns and their relation to weight, WC, and MetS risk factors. Studies promoting weight loss and reduction in MetS risk factors will be reviewed.

Unfortunately, a common theme throughout dietary patterns research literature is the lack of PA as part of weight loss or weight control strategies. The benefit of moderate and high-intensity PA as a lifestyle behavior on weight loss and reduction in MetS risk factors is also discussed. Overall, this literature review identifies research that has assessed the effects of dietary patterns, protein, and PA level on weight, WC, and MetS.

A. Cross-sectional Studies.

Numerous cross-sectional studies have examined the associations between food intake patterns, weight, and MetS risk factors at a single time point (Table 1.5). In general, healthier diets that are higher in fruits, vegetables, and whole grains promote lower risk of MetS, abdominal obesity, and overweight. For example, Esmaillzadeh & Azadbakht (Ahmad Esmaillzadeh & Azadbakht, 2008a, 2008b) have assessed dietary behaviors of Tehrani women and their risk for obesity and MetS risk factors. Using FFQs from Iranian teachers (n=486) between the ages of 40-60y, they analyzed diet patterns associated with health risk factors and central obesity. From their work, three major dietary patterns emerged: 1) healthy dietary pattern (high in fruits, vegetables, whole grains, poultry, legumes); 2) Western dietary pattern (higher intake of refined grains, fats, red and processed meats, high-fat dairy, sweets, desserts, soft drinks, and hydrogenated fats) and 3) Iranian dietary pattern (high intakes of refined grains, higher intake of whole grains than the Western pattern, hydrogenated fats, legumes). They then divided women into quintiles based on diet score in each of the patterns. A high diet score in the healthy diet pattern was most desirable. Odds ratios were calculated in each group for risk of general and central obesity, hypertension, dyslipidemia, and diabetes. Women in the upper quintile of the healthy diet pattern were less likely to have abdominal obesity, dyslipidemia, and hypertension, to have lower mean BMI and WC, triglycerides, total and LDL-C, fasting glucose, systolic blood pressure (SBP) and diastolic blood pressure (DBP), and have higher HDL-C levels. Conversely, the top quintile of women in the Western diet pattern had a higher prevalence of obesity, central obesity, and greater odds for hypertension and dyslipidemia. The Iranian dietary pattern was also significantly associated with central obesity, dyslipidemia and at least one cardiovascular risk factor. This diet was more similar to the Western dietary pattern. The only pattern associated with reduced health risk was the healthy dietary pattern.

The original research by Esmaillzadeh & Azadbakht focused on women between the ages of 40-60y. More recent research by Rezazadeh and Rashidkhani (2010) examined a wider age group of women between 20-50y (n=460). In this study, two dietary patterns were identified, healthy and unhealthy. They were similar to the healthy and Western pattern described earlier by Esmaillzadeh & Azadbakht. Individuals in the healthy pattern had higher consumption of fruits and vegetables, poultry, legumes, and low-fat dairy products, while those in the unhealthy pattern consumed more processed meats, soft drinks, sweets, refined grains, red meats, high-fat dairy products, and hydrogenated fats. As expected, both BMI and WC were negatively associated with the healthy dietary pattern and positively associated with the unhealthy, even after adjusting for confounders such as PA, age, and energy intake. Those in the upper quartile of the unhealthy pattern were also more likely to be obese and have central obesity.

Dietary patterns and the risk of MetS in younger men and women have also been examined (19-39y). Using FFQs, Deshmukh-Taskar et al. (2009) identified Prudent (whole grains, vegetables, fruits, low-fat dairy) and Western (refined grains, high-fat dairy, sweetened beverages, red and processed meats) dietary patterns. They found that WC, plasma insulin, and the occurrence of MetS (≥3 MetS risk factors) were inversely associated with a Prudent dietary pattern, while there was a positive association with insulin sensitivity. Individuals with a greater score in the Western dietary pattern had higher MetS occurrence.

As part of the larger Framingham Heart Study, which investigated the progression of chronic disease and adverse health outcomes, Sonnenberg et al. (2005) examined the relationship between dietary patterns and MetS in obese (WC >88 cm) and non-obese women between the ages of 18-76y (n=1615). Their goal was to identify targeted dietary patterns that would inform preventative nutrition interventions. Five dietary patterns emerged from FFQ analysis: 1) **Heart Healthier** (lowest nutrition risk score with higher consumption of fiber, vegetables, fruits, and low-fat milk, lower intake of total and saturated fat); 2) **Lighter Eating** (consumed lower levels of most foods and nutrients); 3) **Wine and Moderate Eating** (higher alcohol, cholesterol, high-fat dairy, and snacks intake, but lower sweetened beverages); 4) **Higher Fat** (lowest intakes of fruits, low-fat milk, and highest intakes of refined grains, margarines and oils, sweets, animal and saturated fat), and 5) **Empty Calorie** (highest overall nutrition risk score, higher intakes in total fat, calories, and sweetened beverages, and lowest intakes of dietary fiber and vegetables). The researchers then examined dietary pattern subgroups for MetS prevalence and its associated risk factors.

MetS risk varied by dietary pattern and obesity status, with16.6% of women identified as having MetS. Unfortunately, the occurrence of abdominal obesity (27.8%), low HDL-C (39.6%), and elevated blood pressure (30.8%) were high in all dietary groups and BMI categories. In general, obese women had higher rates of all MetS risk factors (51.8%) compared to non-obese women (3.3%). Those in the Wine and Moderate Eating sub-group had the lowest overall MetS rates (10.1%), while the Empty Calorie pattern had the highest rate (29.6%). Obese women consuming the Empty Calorie Pattern had an especially high rate of MetS (72.7%) and the highest rate of low HDL-C levels (< 50 mg/dL; 52%).

Overall, these results clearly demonstrated the relationship between dietary patterns and risk for obesity and MetS risk. Interventions to reduce weight and improve dietary habits would be beneficial in reducing the risk for MetS.

One limitation of the previously described cross-sectional research is that they cannot define an "ideal" dietary behavior pattern that reduces risk for chronic disease and obesity. Instead, researchers identify common patterns and trends that are found in their study population. Observed patterns may or may not adhere to dietary guidelines. To address this issue, researchers have developed scoring systems where "healthier diets" are assigned higher points values. This approach, used by Fogli-Cawley et al. (2007), can provide stronger evidence for the benefits of healthier diet patterns. Fogli-Cawley et al. used this method to score FFQ based on the 2005 DGAs (Dietary Guidelines for Americans, 2005) for men and women (26-82y) who participated in the Framingham Heart Study (n=3,177). More points were assigned for appropriate intakes in the different food groups highlighted in the DGAs (fruits, vegetables, grains, low-fat dairy, meat and legumes) and for incorporating less energy dense foods (more whole grains and fiber, less sodium, saturated fat, and cholesterol) in the diet. A higher diet score, adjusted for energy intake, indicated closer adherence to the DGAs (range 0 to 20). Those with the highest dietary score had lower average BMIs and lower risk of abdominal adiposity and hyperglycemia.

Using a similar approach, McNaughton et al. (2009a) examined data from the Australian Diabetes, Obesity, and Lifestyle study. They used the 2003 Dietary Guidelines for Australians (McNaughton, Dunstan, Ball, Shaw, & Crawford, 2009b), which are similar to the US guidelines. Dietary patterns of men and women over the age of 25y (n=7,441) were examined independently. In women, a dietary pattern more closely reflecting the Australian Dietary Guidelines was inversely associated with BMI, SBP, total cholesterol, 2-h glucose, fasting plasma glucose and insulin levels. Higher dietary quality in men correlated with lower BMI, SBP, total cholesterol, fasting blood glucose, and lower abdominal obesity risk. Thus, the only difference between men and women appeared to be the decreased abdominal obesity found in the men with higher diet quality.

Another approach used to score diet quality is to define a healthy dietary pattern *a priori* by overall consensus of study authors. Nettleton et al. (2008) used this method to examine dietary intake based on FFQs from baseline visits of men and women aged 45-84y (n=5,089) taking part in the Multi-Ethnic Study of Atherosclerosis. They scored food intake patterns and classified them as having a positive, negative, or neutral effect on health. Those with a higher positive score had lower BMI, WC, and insulin measures, smaller intakes of saturated and trans fat, and higher intakes of fiber, calcium, folate, vitamin C, and beta-carotene. A healthier diet pattern score was also inversely associated with C-reactive protein (CRP) and triglycerides and positively associated with HDL-C. After adjusting for WC the associations between dietary score and triglycerides and HDL-C were no longer significant.

In summary, the cross-sectional studies reviewed here provide insight into dietary behaviors and health outcomes and typically show an inverse relationship between healthier dietary patterns and disease risk factors. Research using defined dietary scoring criteria provides stronger evidence that healthier diets are associated with lower MetS risk factors. Unfortunately, these studies rely on one time point to assess dietary patterns; thus, they cannot quantify what change in dietary intake behaviors will determine a reduction in MetS risk factors over time.

Table 1.5: Overview of cross-sectional studies assessing dietary patterns, weight change, and MetS risk factors

Authors	Study Population	Methods/Intervention	Key findings
Esmaillzadeh & Azadbakht (2008b)	Female Iranian teachers, aged 40-60y, n=486	Analyzed diet patterns that may contribute to obesity and central obesity. Method: FFQ	Three major dietary patterns emerged: **healthy** (fruits, vegetables, whole grains), **Western** (refined grains, fats, red and processed meats, sweets, soft drinks), and **Iranian** (refined grains, some whole grains, hydrogenated fats). Women in healthy dietary pattern were less likely to have abdominal obesity and had lower mean BMI and WC.
Esmaillzadeh & Azadbakht (2008a)	Female, Iranian teachers, aged 40-60y, n=486	Analyzed diet patterns that may contribute to MetS risk factors. Method: FFQ	Three major dietary patterns emerged: **healthy** (fruits, vegetables, whole grains), **Western** (refined grains, fats, red and processed meats, sweets, soft drinks), and **Iranian** (refined grains, some whole grains, hydrogenated fats). Women in healthy dietary pattern had lower total and LDL-C, triglycerides, fasting blood glucose, and blood pressure.
Rezazadeh & Rashidkhani (2010)	Iranian women, aged 20-50y, n=460	Analyzed diet patterns that may contribute to obesity and central obesity. Method: FFQ	Two major dietary patterns emerged: **healthy** (fruits, vegetables, low-fat dairy products) and **unhealthy** (processed meats, soft drinks, sweets, refined grains, high-fat dairy products). BMI and WC were negatively associated with the **healthy** dietary pattern and positively associated with the **unhealthy.**
Deshmukh-Taskar et al. (2009)	Young adults age 19-39y, n=995	Analyzed diet patterns that may contribute to MetS risk factors. Method: FFQ	Two major dietary patterns emerged: **Prudent** (whole grains, vegetables, fruits, low-fat dairy products) and **Western** (refined grains, sweetened beverages, high-fat dairy, red and processed meats). WC, plasma insulin, and occurrence of MetS were inversely associated with Prudent dietary pattern.

Sonnenberg et al. (2005)	Obese (WC > 88 cm) and non-obese women aged 18-76y, n=1,615	Analyzed diet patterns that may contribute to MetS risk factors. Method: FFQ	Five dietary patterns emerged: **heart healthier** (vegetables, fruits, fiber, low-fat milk), **lighter eating** (lower levels of most foods), **wine and moderate eating** (lower sweetened beverages, higher alcohol, high-fat dairy, snacks), **higher fat** (lowest intake of fruits, low-fat milk, highest intakes of refined grains, sweets), **empty calorie** (highest nutrition risk, higher intakes of total fat, calories, sweetened beverages, lowest intakes of fiber and vegetables). Empty calorie pattern had the highest rate of MetS (29.6%). Obese women in empty calorie pattern had especially high risk of MetS (72.7%).
Fogli-Cawley et al. (2007)	Adults aged 26-82y, n=3,177	Scored diet based on DGAs 2005 to assess dietary patterns and risk of MetS. Method: FFQ	Higher dietary score indicated closer adherence to DGAs. Those with the highest dietary score had lower average BMIs, lower risk of abdominal obesity, and hyperglycemia.
McNaughton et al. (2009a)	Adults > 25y, n=7,441	Scored dietary intake based on Dietary Guidelines for Australians to assess dietary patterns and risk of MetS. Intake patterns of men and women were analyzed separately. Method: FFQ	In **women**, dietary pattern more closely reflecting DGAs was inversely associated with BMI, SBP, total cholesterol, 2-h glucose, fasting plasma glucose and insulin. In **men**, more adherent dietary pattern was inversely associated with lower BMI, SBP, total cholesterol, fasting blood glucose, and lower abdominal obesity.
Nettleton et al. (2008)	Adults aged 45-84y, n=5,089	Scored diet (positive, neutral, negative on health) based on a priori consensus of study authors. Method: FFQ	Higher positive score had lower BMI, WC, and insulin measure, lower intakes of saturated fat, and higher intakes of fiber.

*WC=waist circumference; MetS=Metabolic Syndrome; DGAs=Dietary Guidelines for Americans; FFQ=Food Frequency Questionnaire; BMI=body mass index; SBP=systolic blood pressure

B. Epidemiological Longitudinal Studies

Epidemiological, longitudinal studies are especially beneficial in investigating dietary patterns and their relationship to weight and MetS risk factors over time. This approach allows researchers to track food behaviors associated with the development of certain health outcomes. The longitudinal studies reviewed here have tracked diet patterns over 8-12y (Table 1.6). In general, study results show that improvement in diet patterns are associated with lower BMI, WC, and MetS risk factors. For example, Shulze et al. (2006) followed women (n= 51,670; aged 26-46y) for 8y and collected FFQ at baseline, mid-way, and at the end of the study (1991, 1995, and 1999). Weight was self-reported bi-annually. This study was part of the larger Nurse's Health Study II, which is a series of studies following women to investigate factors associated with women's health. From the 3 FFQ measurements, two dietary patterns emerged: 1) Prudent dietary pattern, and 2) Western dietary pattern. The Prudent diet was characterized by higher intakes of fruits, vegetables, whole grains, fish, poultry, and legumes, while the Western diet pattern was higher in processed meats, refined grains, sweets & desserts, potatoes and French fries. Women were then divided into quintiles based on their diet score in each of the patterns, with a higher score indicating greater resemblance to the described dietary pattern. Women with a consistently high Western pattern score had higher body weight and BMI. Average weight gain over the 8y period was greatest among women who decreased their Prudent diet score while weight gain was smallest among those with an increased Prudent score.

Similarly, Lutsey et al. (2008) identified a Prudent and Western diet pattern in a 9y longitudinal study of adults (n=9,514) aged 45-64y taking part in the Atherosclerosis Risk in Communities Study. Those with MetS at baseline, as defined by the American Heart Association (AHA), were excluded from the analysis. Diets were assessed using FFQs at baseline and 6 years later. The Western dietary pattern was associated with the consumption of red and processed meats, fried foods, refined grains, and sweets, whereas the prudent dietary pattern was higher in vegetables, fruits, fish and poultry. After 9 years, 39.8% of the participants met the criteria for MetS, with abdominal obesity the most frequent common risk factor. After adjusting for other behavioral characteristics, the Western pattern was associated with a greater risk of developing MetS. Specifically, greater consumption of meat, fried foods, sweetened beverages, and diet soda were associated with development of MetS.

Another 9y study, by Newby et al. (2006), specifically examined women (average age 50y) in the Swedish Mammography Cohort (n= 33,840). Dietary patterns were assessed using FFQs at the start and end of the study and BMI was calculated based on self-reported height and weight. Women were divided by BMI into normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obese (≥ 30 kg/m^2) categories. Four dietary patterns emerged: 1) **Healthy** (vegetables, fruits, whole grains); 2) **Western/Swedish** (meat, processed meats, refined grains); 3) **Alcohol** (wine, spirits, snacks, beer, chocolate), and 4) **Sweets** (sugary foods, sweet baked goods, chocolate, soda, refined grains, dairy desserts). Women were scored in each dietary pattern. After analyzing the association between change in food pattern score and change in BMI, the researchers found smaller increases in BMI over time in normal weight and overweight women who had an increased healthy pattern score. The largest decrease in BMI was found in obese women with an increased healthy pattern score. Thus, if women adhere to a healthier dietary pattern they can prevent weight gain or even lose weight over time. This is particularly evident in obese women.

Lastly, as part of the Framingham Offspring-Spouse study, Millen et al. (2006) tracked dietary patterns of healthy women (30-69y) for 12y. They found that a healthier dietary intake was related to a lower risk of developing abdominal obesity. Researchers quantified dietary intake with a scoring system as described earlier. Using one initial 3-d diet record and clinical assessments from 4 follow-up exams, each individual was assigned a nutrition risk score from their baseline 3-d diet record. Dietary intake was ranked so that a more desirable intake was associated with a lower nutrition risk score. Fasting lipids, plasma glucose, blood pressure, weight and height, abdominal obesity, and self-reported PA were collected approximately every 4y after the initial assessment. Researchers found that women in the higher nutrition risk category consumed more energy from fat, had lower intakes of carbohydrate, fiber, and micronutrients, and had a higher risk of developing abdominal obesity and MetS during the 12y follow-up. One limitation to this study is that it did not assess dietary patterns at the conclusion of the study; thus, they did not capture changes to intake behaviors relative to MetS risk factors over the 12y period.

Based on the above research, a healthier diet pattern reduces the risk of developing abdominal obesity, MetS, overweight and obesity in women. A common theme emerges: diets high in fruits and vegetables are associated with healthier dietary patterns, while less desirable intakes consist of more refined grains, sweets, and processed meats. In summary, these longitudinal studies provide further insight into the relationships between diet patterns, overall health, and the long-term implications of dietary patterns and MetS risk. While the discoveries associated with these longitudinal studies reflect information from large, representative population samples and offer more insight into the important role of diet patterns, they still do not identify direct cause and effect. Intervention studies give more information on specific dietary patterns and their affects on weight, WC, and MetS risk. Furthermore, while PA level was typically assessed, it was to control for it as a potential confounding factor, rather than identify its impact on MetS risk.

Table 1.6: Overview of longitudinal studies assessing dietary patterns, weight change, and MetS risk factors

Authors	Study Population	Methods/Intervention	Key findings
Schulze et al. (2006)	Women aged 26-46y, n=51,760	8y study assessing dietary patterns and weight change. Method: FFQ	Two major dietary patterns: **Prudent** (whole grains, vegetables, fruits, low-fat dairy products) and **Western** (refined grains, sweets and desserts, red and processed meats). Average weight gain (8y) was greatest among women who decreased Prudent diet score and smallest among those that increased their prudent score.
Lutsey et al. (2008)	Adults aged 45-64, n=9514	9y study assessing dietary patterns and relation to MetS risk factors (assessed every 3y). Method: FFQ	Two major dietary patterns: **Prudent** (vegetables, fruits, fish, poultry) and **Western** (refined grains, sweets and desserts, red and processed meats). The Western pattern was associated with greater risk of developing MetS.
Newby et al. (2006)	Women born between 1914-1948 (average age 50y), n=33,840	9y study assessing dietary patterns and weight change. Method: FFQ	Four dietary patterns: **healthy** (vegetables, fruits, whole grains), **Western/Swedish** (meat, processed meats, refined grains), **alcohol,** (wine, spirits, snacks, beer, chocolate), and **sweets** (sugary foods, sweet baked goods, soda, refined grains). Normal weight (BMI 18.5-24.9 kg/m^2) and overweight (BMI 25-29.9 kg/m^2) women in the healthy pattern score had smallest increases in BMI. Obese women (BMI > 30 kg/m^2) with increase in healthy pattern score had the largest decrease in BMI.
Millen et al. (2006)	Women aged 30-69y, n=300	1-y study assessed dietary patterns, anthropometrics, and blood data to identify relationship between nutrition intake and MetS. Method: FFQ	A less desirable intake based on nutrition risk score (higher energy intake from fat and less intake of fiber and micronutrients) was associated with higher risk of developing abdominal obesity and MetS during the 12y follow-up.

*FFQ=Food Frequency Questionnaire; MetS=Metabolic Syndrome; BMI=body mass index

C. Intervention Studies

Intervention studies allow the researcher to examine the impact of specific dietary pattern interventions in individuals at risk for MetS and determine resultant changes in risk factors (see Table 1.9). Information on dietary patterns can be extrapolated from studies that have clearly defined their dietary interventions. In the following section, two dietary approaches are discussed that link dietary patterns to weight and MetS risk reduction. First, research using the DASH Dietary Pattern (Table 1.7) is discussed followed by studies promoting low energy density diets. Initially, the DASH diet was used to identify the impact of diet on reducing blood pressure in hypertensive individuals. This diet approach emphasizes a daily intake of 6-8 servings of primarily whole grains, 4-5 servings of vegetables, and 4-5 servings of fruits (NIH, 2003). Since the completion of the early research, this diet pattern has been used to help modify dietary intake in other populations. It closely resembles a low energy density (low kcal/g of food) eating pattern that will be reviewed later in this section. A low energy density diet describes an eating pattern high in fruits, vegetables, and fiber containing foods (Table 1.2). This allows for a greater amount or weight of food to be consumed at a relatively low energy intake (Rolls et al., 2005).

Table 1.7: DASH (Dietary Approaches to Stop Hypertension) eating plan

Food Group	Servings per day
Grains (emphasis on whole grains)	6-8
Vegetables	4-5
Fruits	4-5
Low-fat/Fat-free dairy	2-3
Lean meats and poultry	≤ 6
Fats (emphasis on unsaturated fats)	2-3
Nuts, seeds, legumes	Moderation
Sweets	≤ 5 a week

DASH Dietary Pattern. Azadbakht et al. (2005) incorporated the DASH diet into a dietary intervention for adults with MetS (n=116) to promote weight loss. Participants were encouraged to reduce their energy intake by 500 kcal while following the principles of the DASH eating plan (no change to PA level). Two other dietary groups were used in the study: 1) control group maintaining their habitual eating plan, 2) weight-reducing group with an energy deficit of 500 kcal/d, but with lower intakes of fruits, vegetables, whole grains, legumes, and higher intakes of red meat, saturated fat, and sweets. The DASH eating plan improved the mean of all components of MetS (Table 1.8).

Table 1.8: improvement in MetS risk factors: DASH eating plan versus weight reducing diet alone (Azadbakht et al., 2005)

MetS Risk Factor	DASH Eating Plan	Weight-Reducing Diet
WC	**Men: -**7 cm **Women:** -5 cm	**Men: -**5 cm **Women:** -4 cm
HDL-C	**Men:** +7 mg/dL **Women:** +10 mg/dL	**Men:** +1 mg/dL **Women:** +2 mg/dL
Triglycerides	**Men:** -18 mg/dL **Women:** -14mg/dL	**Men:** -13 mg/dl **Women:** -10 mg/dL
SBP	**Men:** -12 mmHg **Women:** -11 mmHg	**Men:** -6 mmHg **Women:** -6 mmHg
DBP	**Men:** -6 mmHg **Women:** -7 mmHg	**Men:** -1 mmHg **Women:** -2 mmHg
Fasting Blood Glucose	**Men:** -15 mg/dL **Women:** -8 mg/dL	**Men:** -4 mg/dl **Women:** -5 mg/dL
Body Weight	**Men:** -16 kg **Women:** -15 kg	**Men:** -13 kg **Women:** -12 kg

*WC= waist circumference; HDL-C= high density lipoprotein cholesterol; SBP=systolic blood pressure; DBP=diastolic blood pressure

Blumenthal et al. (2010) used PA in conjunction with the DASH diet in overweight/obese (BMI 25-40 kg/m^2) hypertensive individuals. The original design of the DASH diet did not incorporate PA so the full effect of the diet could be assessed (Svetkey et al., 1999). The purpose of the study was to ascertain benefits of the DASH diet on insulin sensitivity and blood lipids. In a 4-mo randomized controlled trial of men (n=47) and women (n=97), participants were assigned to one of three diets: 1) DASH diet alone (no energy restriction); 2) DASH diet + energy restriction and exercise (DASH diet servings adjusted for weight loss; and 3) Control group consuming their usual diet. In the DASH diet + energy restriction and exercise, the exercise component consisted of 30 min supervised sessions 3 times/wk at 70-85% of their baseline heart rate reserve ([HRR] mod/high-intensity). As expected with the dietary intervention, after 4-mo of treatment, both of the DASH diet groups saw improvements in blood pressure. However, a combination of the DASH diet with exercise and weight loss significantly improved insulin sensitivity, glucose tolerance, total cholesterol, and triglyceride levels compared to the DASH diet only group and the control group. They also significantly reduced LDL-C levels compared to the control group, but not the DASH diet alone. Dieting and exercising participants also lost an average of 8.7 kg, while the DASH diet alone group lost 0.3 kg. The control group increased their weight by 0.9 kg. In summary, these results show that the DASH dietary pattern alone provides health benefits; however, its effects can be enhanced with weight loss through energy restriction and exercise. Unfortunately, without an exercise only weight maintenance group, it is difficult to assess if these added benefits were the result of weight loss or the high-intensity exercise. The specific benefits of PA will be reviewed later in this section.

Low Energy Density Dietary Pattern. As previously mentioned, the DASH diet is one method of promoting low energy density foods. Ledikwe et al. (2007) examined the DASH eating plan and its effects on dietary energy density, weight, and WC in a large cohort (n=658) of healthy men and women over the age of 25y with pre-hypertension or stage 1 hypertension (SBP of 120-159 mmHg and/or DBP of 80-95 mmHg). Participants were randomized into one of 3 groups (2 intervention groups [standard diet, DASH diet], 1 control group) for the 6-mo study. The DASH diet group received education on the DASH eating plan, but both intervention groups (standard diet and DASH diet) received information on weight loss, reducing sodium intake, and increasing PA. The control group had just a single advice session. All participants were encouraged to engage in PA, but a specific, targeted exercise program was not included. The DASH diet group decreased weight by -6.1 kg, while the other standard diet intervention group lost an average of -5.1 kg. Weight loss was not significantly different between intervention groups, but both intervention groups lost significantly more weight than the control group (-1.1 kg). However, the DASH group significantly reduced their energy density compared to the other two groups. Reductions in energy density for the DASH intervention group, standard diet intervention group, and the control were -0.56 kcal/g food, -0.26 kcal/g food, and -0.17 kcal/g food, respectively. The DASH group also significantly increased the weight of food they ate by > 50 g. This was accompanied by the largest increase in fruit, vegetables, and low-fat dairy products.

An overall decline in energy density and weight was observed for all groups, but individual variability in actual weight and energy density reduction was present within each of the groups. Thus, results from all participants were combined to further assess the relationship between changes in dietary energy density and body weight. Participants were classified into tertiles based on change in dietary energy density. Tertile 1 included those with a small decrease of ≤0.1 kcal/g in energy density (mean change: +0.22 kcal/g food), tertile 2 included those with a moderate decrease in energy density between 0.11 to 0.51 kcal/g (mean decrease: -0.31 kcal/g food), and tertile 3 included those with the largest decrease, ≥ 0.52 kcal/g (mean decrease: -0.90 kcal/g food). Individuals with the largest decrease in energy density had significantly greater weight loss than those with low or moderate reductions in energy density (tertile 3: -5.9 kg, tertile 2: -4.0 kg, tertile 1: -2.4 kg). Tertile 3 also reduced WC significantly more (-5.7 cm) compared to tertile 2 (-3.7 cm) and tertile 1 (-2.3 cm). Overall, larger reductions in energy density were related to increases in fruits, vegetables, and fiber, and decreases in fat and saturated fat intake. Regression analysis also indicated that a decrease in food energy density was the strongest predictor of weight loss and even modest decreases in energy density resulted in weight and WC reductions.

Generally, the dietary changes described above will lower the energy density (kcal/g) and the total energy intake (kcal/d) of the diet (Rolls et al., 2005). Ello-Martin et al. (2007) also used a low energy density diet while conducting a year-long intervention study in obese (BMI 30-40 kg/m^2) women (20-60y). Participants (n=71) were asked to adhere to a reduced fat diet (RF) or a reduced fat diet plus added fruits and vegetables (RF+FV). Participants were educated to make food choices appropriate for their assigned diets. Both groups lost significant amounts of weight after 1y (RF+FV= -7.9 kg; RF= -6.4 kg), but the weight loss pattern during the study was significantly different between groups (p=0.002). After the first 6-mo of the intervention, during which subjects had more frequent contact with staff members, the RF+FV group had lost 33% more weight than the RF group (RF+FV= -8.9 kg; RF= -6.7 kg; p=0.034). During the second 6-mo, weight change was similar in between groups, but the RF+FV group maintained greater overall weight loss than the RF group. At the conclusion of the intervention, 49% of participants in the RF+FV group and 28% of subjects in the RF group were no longer considered obese. Additionally, the RF+FV group consumed significantly lower dietary energy density than the RF group (1.23 kcal/g vs. 1.46 kcal/g, respectively; p=0.019). Energy density, fruit, and vegetable intake were the primary predictors of weight loss during the study. In addition to modifying dietary patterns, PA was also used as part of the intervention. Women were asked to walk as a form of exercise, but participants were not given a specific PA requirement.

More recently, a year-long intervention was conducted in a large group (n=187) of middle-aged men (mean age 45y), with risk factors for MetS (~ 50% of the population met the criteria) that included a specific exercise component in addition to changing dietary patterns (Jacobs et al., 2009). The men were randomized into one of 4 groups: 1) diet only; 2) exercise only; 3) diet + exercise; or 4) control group. Dietary interventions were tailored to each participant's preferences and risk factor profile; however, overall recommendations were made to increase consumption of fish, vegetables, and fiber rich products while reducing sugar and saturated fat. The exercise program included supervised workout sessions for 60 minutes 3 d/wk, and included aerobics, circuit training, fast walking, and jogging (intensity not specified). A diet score was assessed from baseline and after 1y with a FFQ using an *a priori* defined scoring index. A higher score indicated that an individual generally met the recommended dietary changes. An increase of 10 points from baseline to post-intervention in the diet score was associated with favorable changes in weight (-3.5 kg/10 points), WC (-3 cm/10 points,) SBP (-3 mmHg/10 points), total and LDL-C (-0.34 and -0.28 mmol/L/10 points), glucose (-0.18 mmol/L/10 points), and insulin (-22 pmol/L/10 points). At the conclusion of the study, the following combined data for the diet only and diet plus exercise groups were identified: weight decreased by -5-7 kg, WC by -5-7 cm, and blood pressure by -5-6 mmHg. The exercise only group saw a -2 kg weight reduction, a decrease in WC of -3 cm, and a decrease of -3 mmHg in SBP. All intervention groups saw similar reductions in body fat percentage (-1-2%), total and LDL-C, and fasting insulin levels (-25 pmol/L). In analyzing the effect of diet score and intervention group together on weight loss, researchers found that for every 10-point increase in diet score, weight decreased by 2.7 kg in the diet only group, 3 kg in the exercise group, and 4.5 kg in the diet plus exercise group. In summary, an improved diet score resulted in improvements in weight, WC, SBP, total and LDL-C, and fasting glucose and insulin. However, the diet only and diet plus exercise groups saw greater reductions in weight, WC, and SBP than the exercise only group, although PA alone appeared to yield similar results on reducing body fat percentage, total and LDL-C, and fasting insulin and glucose as the dietary intervention. The effects of exercise, energy restriction, and an improved diet score also promoted the greatest weight loss in this study when diet score and intervention group were analyzed together.

Low energy density diets have not only been used to promote initial weight loss, but also to improve weight maintenance. Greene et al. (2006) re-assessed participants (n=74) 2y after they completed the EatRight weight loss program. This initial research promoted low energy dense foods. Dietary intake at follow-up was assessed using 4-d food records. Initially, subjects averaged 94.1 kg and lost an average of -4 kg during the intervention. Thirty-eight percent of participants lost greater than 5% of their starting body weight. The majority of those returning for follow-up were women (64%; ~51.5y). At follow-up, the average weight was 90.7 kg; average weight gain was 0.59 kg. Weight maintenance was defined as gaining < 5% of body weight since the completion of the EatRight program. Almost 80% of the participants maintained or lost additional weight, with 45.9% losing additional weight after completing the program. Average weight change for maintainers was -1.3 kg at follow-up. The remaining subjects, however, gained significantly more weight at follow-up (mean weight gain: of 7.9 kg; p<0.001). The authors reported that the food intake of weight maintainers compared to weight gainers was lower in total energy (1776 kcal vs. 2020 kcal/d; p=0.058), and significantly lower in energy density (1.67 kcal/g vs. 1.98 kcal/g; p=0.016). After adjustment, there was a trend for lower percent calories from fat (33% versus 36%; p=0.153) and saturated fat (10.5% versus 12.1%; p =0.065) in the weight maintainers. A lower intake of total calories, energy density, and calories from fat and saturated were all significantly correlated with maintaining weight loss. Additionally, based on mean percentages of recommended United States Department of Agriculture (USDA) serving sizes, those that maintained their weight loss had a non-significant greater intake of vegetables (96% vs. 85% of recommendation). Conversely, those that gained weight, had significantly larger portions of meat and dairy (120% vs. 103% of recommendation), fats (144% vs. 83% of recommendation), and caloric beverages (185% vs. 138% of recommendation). Unfortunately, exercise was not mentioned as part of the initial intervention, nor was it discussed at follow-up.

A second study of eating patterns and weight management by Howard et al. (2006), examined post-menopausal women (n=48,835) participating in the large, randomized intervention study, the Women's Health Initiative Dietary Modification Trial. Average follow-up time was 7.5y. Women were randomly assigned to a reduced dietary fat diet or the control group. A series of educational sessions led by dietitians were provided to the women in the intervention group. They were instructed to reduce their fat intake to less than 20% of their energy intake, to aim for 6+ servings of preferably whole grains/d, and to increase fruit and vegetable intake to 5 or more servings/d. These participants were informed that the diet was not intended to promote weight loss, and were encouraged to maintain their usual energy intake by replacing fat calories with calories from other sources, mainly carbohydrate. The control group received a copy of the Dietary Guidelines for Americans (1990 and 1995) and other diet and health related education materials, but otherwise had no contact with the study dietitians. Women were scheduled annually for weight, height, WC, and hip circumference measurements. Diet was monitored with FFQs completed at baseline, 1y, and then every three years. After 1y, the reduced dietary fat group had a mean weight loss of -2.2 kg, while the control showed no significant change. The reduced fat group also maintained significantly lower weights than the control group at 1y (-1.9 kg; $p < 0.001$) and at 7.5y (-0.4 kg; $p=0.01$). Women were then divided in quintiles based on changes in energy intake from fat; significant linear trends were found between fat intake and weight change ($p<0.001$). Women in the first quintile, with a more substantial decrease in fat intake (decrease > -11.1%), had the largest weight loss (intervention group: -1.5 kg, control: -1.25 kg). Conversely, those in the fifth quintile increased their fat intake the most (>

3.2%), and showed an average weight gain (intervention: +0.75 kg, control: +0.25 kg). Similar analysis in the intervention and control groups indicated significant linear trends for weight loss and increasing servings of fruits, vegetables (p for trend intervention: p=0.005; control: p=0.02), and carbohydrates (both groups p for trend<0.001). In the intervention group only, a significant linear trend between increased fiber intake and weight loss (p=0.002, p=0.24 for control) was found. In summary, this study indicates positive benefits of reducing fat intake and replacing it with fruits, vegetables, and high fiber carbohydrates on weight over time, but again, PA was not used as part of the intervention.

Collectively, the intervention studies indicate direct, beneficial effects of dietary intake patterns on weight and MetS risk factors. Diets rich in fruits, vegetables, and whole grains, and low in added fat, were inversely related to weight, WC, and MetS risk factors. Unfortunately, PA was not often an integral part of the intervention. Only one study, conducted by Jacobs et al. (2009), detailed specific, supervised, mod/high-intensity exercise in one of their intervention groups. However, this study only assessed the combined effects of dietary patterns and exercise in men. Blumenthal et al. (2010) also included mod/high-intensity exercise, but mode was not specified and it was done in a combination of hypertensive men and women. In these studies, intervention groups participating in PA lost greater weight and body fat (Jacobs et al., 2009) and had more improvements in insulin sensitivity and blood lipids (Blumenthal et al., 2010), indicating the added benefits of PA.

Table 1.9: Overview of intervention studies assessing dietary patterns, weight change, and MetS risk factors

Authors	Study Population	Methods/Intervention	Key findings
Azadbakht et al. (2005)	Overweight or obese adults (BMI 25-40 kg/m^2) with MetS, n=116	6-mo randomized controlled trial with 3 dietary interventions: 1) DASH + Weight Reducing, 2) Weight Reducing alone and, 3) Control usual diet. Main outcomes assessed as a result of the intervention were components of MetS. Method: 3-d food record	The DASH diet group had higher intakes of fruits, vegetables, whole grains, and low-fat dairy. The DASH diet resulted in more significant differences in HDL-C, triglycerides, SBP and DBP, WC, fasting blood glucose, and weight than the weight-reducing group alone.
Blumenthal et al. (2010)	Overweight or obese adults (BMI 25-40 kg/m^2) with hypertension, n=144	4-mo randomized controlled trial to assess benefits of DASH diet alone or DASH diet with exercise and weight loss on insulin sensitivity and blood lipids. Exercise consisted of three 30 minute sessions/wk at moderate-high intensity (70-85% HRR). Method: 4-d food record & FFQ	Both dietary intervention groups saw improvements in blood pressure and LDL-C. However, a combination of the DASH diet with exercise and weight loss also had improvements in insulin sensitivity, total cholesterol, and triglyceride levels. Unfortunately, an exercising weight maintenance group was not included to identify added benefits of exercise alone to DASH diet.
Ledikwe et al. (2007)	Adults >25y with pre or stage 1 hypertension, n=658	6-mo trial, participants randomized into one of two intervention groups or a control. The intervention groups both received information on weight loss, reducing sodium intake, and physical activity, but one group followed information from DASH diet. Method: 24-h recalls	Both intervention groups lost significant amounts of weight and more than the control group. When analyzing all participants together, overall weight loss was significantly correlated with lower food energy density. When divided into tertiles of decrease in energy density, individuals with the largest decrease in energy density had significantly greater weight loss than those with low or moderate reductions.

Ello-Martin et al. (2007)	Obese women (BMI 30-40 kg/m^2) aged 20-60y, n=72	1-y trial; participants were asked to adhere to a reduced fat (RF) diet pattern or reduced fat plus added fruits and vegetables (RF+FV) diet pattern. Walking was the primary form of recommended physical activity (no target recommendation for duration, frequency, or intensity). Method: 3-d diet records	After the first 6-months, the RF+FV group lost 33% more weight than the RF group and the RF+FV group maintained greater weight loss for the second 6 months. At the conclusion of the study, 49% of the RF+FV and 28% of the RF subjects were no longer considered obese. Energy density, fruit, and vegetable intake were the primary predictors of weight loss.
Jacobs et al. (2009)	Middle aged-men (average age 45y) with risk factors for MetS, n=187	1-y trial; Men were randomized into 1 of 4 groups: 1) energy restriction alone, 2) exercise alone, 3) exercise and energy restriction, or 4) control group. Individualized diet plan for each participant, but encouraged increased consumption of fish, vegetables, and fiber rich foods. Exercise included three 60-min sessions a week of aerobic type exercise (jogging, circuits, brisk walking; intensity not specified). Method: FFQ	An increase in diet score was associated with favorable changes in weight, WC, SBP, total and LDL-C, glucose, and insulin. Individuals in the energy restriction plus exercise group with an increase in diet score had the greatest decrease in weight.
Greene et al. (2006)	Adults (average age 51.5y) 2y after completing weight loss intervention study	Follow-up study to assess the effects of dietary energy density on weight maintenance. Low energy density foods were promoted during initial intervention study. Weight maintenance defined as gaining <5% of body weight since the completion of the program and staying below initial weight. Method: 4-d food records	The food intake of weight maintainers compared to weight gainers was significantly lower in total energy intake and energy density, and lower in percent calories from fat, and saturated fat (non-significant). Weight maintainers consumed more vegetables (non-significant), and significantly less meat and dairy, fats, and caloric beverages.

Howard et al. (2006)	Post-menopausal women, n=48,835	Women were either provided with formal education on reducing their fat intake while increasing their servings of whole grains, fruits, and vegetables or a handout on the DGAs. Weight, height, WC and hip circumference were measured annually with an average follow-up time of 7.5 years. Method: Series of FFQ	The reduced fat group had a mean weight loss of 2.2 kg in the first year (no change in the control group) and they maintained significantly lower weights than the control group throughout the study period. Reduction in fat intake was associated with greater weight loss, as was increased intake of fruits and vegetables, carbohydrates, and fiber.

*DASH=Dietary Approaches to Stop Hypertension; MetS=Metabolic Syndrome; HDL-C=high density lipoprotein cholesterol; SBP=systolic blood pressure; DBP=diastolic blood pressure; WC=waist circumference; LDL-C=low density lipoprotein cholesterol; HRR=heart rate reserve; FFQ=Food Frequency Questionnaire; DGAs=Dietary Guidelines for Americans

D. Protein intake and Metabolic Syndrome Risk

Both diets high in protein or high in carbohydrate (e.g. low in fat) can have beneficial effects on abdominal obesity, weight loss, and metabolic variables (Foster et al., 2010; Johnston et al., 2004; Muzio et al., 2007; Swain et al., 2008). For example, Johnston et al. (2004) found that a 6-wk intervention with two low-fat diets (<30% energy), one high-protein (32% energy from protein, 41% carbohydrate) and the other high-carbohydrate (15% energy from protein, 66% energy from carbohydrate), resulted in similar improvements in weight (-6%), total cholesterol (-9.5%), LDL-C (-12.5%), and insulin sensitivity (-24%) in overweight men and women (19-54y). However, some evidence suggests that higher protein intakes may be more beneficial at promoting weight and WC loss than more traditional low-fat higher carbohydrate dietary patterns. For example, Vander Wal et al. (2008) reported significantly greater losses in body weight (-2.63 kg vs. -1.59 kg; $p<0.05$) and a trend toward greater WC reductions (-2.5 cm vs. -1 cm [results estimated from graph]; $p<0.06$) in obese individuals after 8 wks on an isocaloric energy-restricted high protein breakfast diet (12.6 g protein, 1.2 g carbohydrate, 14 g fat) compared to a high carbohydrate breakfast diet (7.5 g protein, 37.9 g carbohydrate, 1.1 g fat). In a different study of overweight and obese women, Meckling and Sherfey (2007) compared the effects of a control (3:1 ratio carbohydrate to protein intake) vs. high protein diet (1:1 ratio carbohydrate to protein intake); both combined with moderate intensity circuit training exercise on features of MetS. Compared to the control group, the high protein group lost significantly more weight (-7.0 kg vs. -4.0 kg; $p<0.05$) and had non-significantly greater decreases in WC (-8.0 cm vs. -6.5 cm). Te Morenga et al. (2011) also found that in overweight/obese women, those following a high protein (HP) diet for 8-wk (30% protein, 40% carbohydrate) lost significantly more weight (-4.5 kg vs. -3.3 kg; $p=0.039$) and body fat (-4.0 kg vs. -3.4 kg; $p=0.029$) than those on a high fiber (HF) diet (50% carbohydrate, >35 g fiber, 20% protein). However, reductions in WC were similar (HP: -5.4 cm, HC: -4.7 cm).

Higher protein diets have also been studied in features of MetS. In the previous study by Meckling and Sherfey (2007), changes in MetS risk factors were similar between groups even though differences in weight loss were observed.

Conversely, Noakes et al. did not find that a HP diet (HP diet: 30% energy from protein vs. HC diet: 17% energy from protein) resulted in greater weight loss (HP: -7.6 kg; control: -6.9 kg) in obese women (BMI ~32 kg/m^2). A HP diet did, however, result in greater improvements in triglyceride concentrations (-0.3 mmol/L vs. -0.1 mmol/L, p=0.007). Furthermore, when participants were subdivided by triglyceride status, those in the HP group with values >1.5 mmol/L lost significantly more weight (-7.9 kg; p<0.05) than individuals in the HC diet with triglyceride levels >1.5 mmol/L (-5.8 kg). Lastly, Te Morenga et al. (2011), found that although all participants reduced triglycerides, fasting plasma glucose, and blood pressure, DBP decreased more in those with the HP diet than the HC diet (-4.7 mmHg vs. -0.9 mmHg).

Overall, improved satiety, reduced energy intake, and increased energy expenditure may all contribute to the benefits of a greater protein intake on weight loss (Leidy et al., 2007; Westerterp-Plantenga et al., 2009). A higher protein diet may also benefit features of MetS in certain individuals. However, since results from changes in dietary macronutrient contribution are mixed, as studies of HP diets have not found additional benefits over more traditional low-fat diets, (Johnston et al., 2004; Muzio et al., 2007; Swain et al., 2008) it is also important to study the impact of alterations of macronutrients in the context of the total diet and PA behaviors.

E. Impact of Physical Activity on Metabolic Syndrome Risk

The following section reviews the impact of PA on weight, adiposity, and MetS risk. Exercise on its own has been shown to reduce WC and body fat (Ross et al., 2004), with high-intensity PA showing additional reductions in abdominal subcutaneous and visceral fat (Irving et al., 2008). Unfortunately, high-intensity PA is not clearly defined in the literature. However, the definition of vigorous intensity exercise, or >6 metabolic equivalents (METs), described by the ACSM and AHA can be considered high- intensity PA (Haskell et al., 2007). Other studies have used a range of ratings of perceived exertion (RPE) (Borg, 1982) between 15-17 on a 6-20 point scale (Irving et al., 2008), VO2peak (70-85%) (Coker et al., 2009), or target heart rates between 75-90% of maximal heart rate (HR) to define high-intensity PA (Coker et al., 2009; DiPietro, Dziura, Yeckel, & Neufer, 2006; Talanian, Galloway, Heigenhauser, Bonen, & Spriet, 2007). Gibala and McGee (2008) describe high-intensity exercise as intermittent exercise performed at an all out effort, or intensity close to $VO2_{peak}$ (i.e. >90% $VO2_{peak}$). Depending on the training intensity, this may last from a few seconds up to several minutes.

This variety of methods for classifying high-intensity PA makes it difficult to compare studies. Examples of moderate and high-intensity activities, based on those listed by Ainsworth et al in the 2000 updated Compendium of Physical Activities (Ainsworth et al., 2000) and the ACSM description of vigorous activities (Thompson, Gordon, & Pescatello, 2009), are listed in Table 1.10.

Table 1.10: Examples of moderate and high-Intensity activities

Moderate Intensity Exercise (3-6 METs)	Vigorous/High Intensity Exercise (> 6.5 METs)
Walking 3.0 mph = 3 METs	Aerobic Dance = 6.5 METs
Mopping = 3.5 METs	Jogging at 5 mph = 8.0 METs
Golf-walking pulling club = 4.3 METs	Tennis singles = 8.0 METs
Bicycling on flat-light effort (10-12 mph) = 6 METs	Bicycling on flat-fast pace (14-16 mph) = 10 METs

When combined with a moderate energy restriction, PA has an additive effect on weight loss compared to diet alone (Donnelly et al., 2009). However, PA, specifically high-intensity exercise, is used infrequently in combination with dietary patterns (Blumenthal et al., 2010; Jacobs et al., 2009) and has not been conducted in women. Thus, the following research reviewed does not have explicit dietary patterns as part of the interventions. Moderate/high intensity forms of PA will be reviewed first, followed by comparisons of the effects of high-intensity exercise to moderate-intensity exercise (Table 1.11).

Moderate/High-Intensity Physical Activity for Weight Loss and MetS Risk Reduction. Ross et al. (2004) found that including PA at ~80% HR_{max} as part of a 14-wk weight loss study of overweight (BMI >27 kg/m^2), premenopausal women (n=54) produced greater reductions in total body and abdominal fat. Exercise-induced weight loss (daily brisk walking or light jogging) resulted in a significant decrease in total body fat of -6.7 kg compared to -4.1 kg in the diet-induced weight loss group (p<0.001), the exercise without weight loss group (-0.5 kg; p<0.05), and the control group (+0.5 kg; p<0.05). Total abdominal fat also decreased significantly more (-1.7 kg) in the exercise group compared to the diet group (-0.9 kg; p<0.008), exercise without weight loss group (-0.3 kg; $p<0.05$), and the control group (+0.1 kg; $p<0.05$).

Similarly, Volpe et al. (2008) examined the effect of 150 min/wk of PA (intensity not specified) in overweight (BMI=27-35 kg/m^2), midlife (24-62y) women (n=90) during a 6-mo supervised intervention comparing diet only, exercise only, and diet + exercise. Participants in the exercise groups gradually increased to five 30-min aerobic exercise sessions/wk. At the conclusion of the study, the diet plus exercise group had a significantly lower body weight (~80 kg, results estimated from graph) than the diet only (~82.5 kg; p=0.03) or exercise only groups (~83 kg; p=0.02). However, WC still significantly decreased in the exercise group (-4.1 cm; p=0.02) despite remaining weight stable, compared to the diet only group (+2 cm).

Based on research by Katzmarzyk et al. (2003), exercise alone can reduce MetS risk. Healthy, sedentary adults (n=621; 17-65y) participated in supervised exercise training sessions on a cycle ergometer 3 times/wk without altering their diet or other PA levels. Exercise intensity was increased from 30-min sessions at 55% of VO2max to 50-min sessions at 75% of VO2max. At the end of 20-wk, reductions occurred in triglycerides, BP, blood glucose, WC, and overall prevalence of MetS.

Other research also demonstrates benefits of additional PA for weight loss and reduction of MetS risk factors. Larson-Meyer et al. (2010) found that incorporation of PA into a dietary intervention elicited greater reductions in several MetS risk factors. An exercise program designed to increase energy expenditure by 12.5% from baseline, using individualized programs of aerobic exercise, such as walking, jogging, or stationary cycling at desired intensity level (65-90% HR_{max}) in combination with a 12.5% reduction in energy intake was compared to an intervention reducing energy intake by 25% alone. The combined diet + exercise intervention resulted in improvements in triglycerides (-15%; $p<0.001$), body weight (-10%; $p<0.001$), total and visceral abdominal fat (~ -25% for both; $p<0.005$), DBP (-5%, $p<0.02$), total cholesterol (-9%, $p<0.02$), LDL-C (-13%, $p<0.02$), VO_2peak (+22%; $p<0.0001$) and insulin sensitivity (+66%, $p<0.02$). Those reducing energy intake by 25% also saw significant decreases in triglycerides (-21%, $p< 0.001$) and body weight (-10%, $p< 0.001$), and abdominal fat (-25%; $p<0.005$), but did not have significant improvements in DBP (-2%), insulin sensitivity (+40%), total cholesterol (-5%), and LDL-C (-6%). Although both intervention groups experienced weight loss, only the diet and exercise group saw significant improvements in DBP, insulin sensitivity, and blood lipids. Unfortunately, results were not stratified according to exercise intensity levels reached during the study, so comparisons cannot be made between individuals choosing high intensity exercise and those engaging in more moderate levels.

Most recently, Foster-Schubert et al. (2011) demonstrated that a combined diet and exercise intervention improved body weight and adiposity in overweight/obese post-menopausal women (n=439). Participants were randomized to either the: 1) calorie reduced diet group (diet), 2) aerobic exercise group (exercise), 3) aerobic exercise + calorie reduced diet group (diet + exercise), or 4) control group for the 12-mo intervention. Personalized dietary interventions goals were provided to those in the diet and diet + exercise groups; those in the exercise and diet + exercise groups participated in five 45 min moderate-to-high-intensity exercise sessions/wk (60-85% HRmax; 3 supervised by study staff). After 12-mo, the diet group lost -7.2 kg, the exercise group -2.0 kg, the diet + exercise group -8.9 kg, and the control group -0.7 kg. Weight loss differences between the diet and diet + exercise groups did not reach the adjusted level of statistical difference. However, decreases in WC were significantly greater in the combined intervention group (diet + exercise: -7.0 cm,) than the diet (-4.5 cm, $p<0.004$) or exercise alone groups (-2.0 cm, $p<0.0001$), highlighting the combined benefits of diet and moderate/high-intensity exercise during weight loss for reductions in abdominal body fat.

<u>High-Intensity Physical Activity for Weight Loss and MetS Risk Reduction.</u> Recently, research has compared moderate forms of exercise to high-intensity exercise. For example, Irving et al. (2008) compared isocaloric exercise programs of differing intensities in obese women (n=27, mean age 51y, BMI =34 kg/m^2) meeting the IDF criteria for MetS. Women participated in high-intensity exercise (RPE =15-17 3-d/wk, RPE 10-12 2-d/wk) or moderate-intensity (RPE =10-12 5-d/wk) exercise programs without making dietary changes. After 16-wk of exercise, those in the high-intensity group had significant reductions in WC (-5.6 cm; $p = 0.001$) and total

abdominal fat (TAF) (-58 cm^2; $p<0.001$) compared to the decreases observed in the moderate-intensity group (WC: -1.2 cm; TAF: -11 cm^2) and the control group (WC: -0.7 cm; TAF: -28 cm^2). Reductions in visceral fat were also significantly decreased in the high-intensity exercise group (-24 cm^2; $p<0.01$), but did not reach statistical significance across conditions compared to the losses in the moderate-intensity (-7 cm^2; p=0.153) and control group (-2 cm^2; p=0.098).

Trapp et al. (2008) studied a younger group of inactive women (n=45) with a mean BMI of 23.2 kg/m^2. Participants followed an exercise training protocol of either high-intensity intermittent exercise training (HIIE; 8 sec sprints 12 sec recovery for 20 min session) or steady-state exercise training (60% VO_{2peak}) 3 times/wk for 15-wk. Energy expenditure over the 15-wk training period was matched between protocols. Only the HIIE protocol resulted in significant decreases in total body mass (-1.5 kg), total body fat (-2.5 kg), and central abdominal fat (-0.15 kg), but this population included mostly normal weight women. These results cannot be extrapolated to overweight/obese women, but do indicate a potential benefit of HIIE on adiposity. Furthermore, the HIIE group also reduced fasting insulin (-33%) significantly more than controls (no change), but not significantly more than the steady-state group (-9%). This latter finding is contrary to results found by DiPietro et al. (2006) in a study of older women (73±10y) on high-intensity exercise and insulin sensitivity. Compared to moderate exercise (65% VO_{2peak}) equivalent in energy expenditure/session, high-intensity exercise (80% VO_{2peak}) improved insulin stimulated glucose utilization without any changes or differences in body composition or fitness.

Coker et al. (2009) also found significant effects of exercise intensity on abdominal fat in older adults (65-90y). Eighteen overweight and obese (BMI 26-37 kg/m^2) sedentary adults completed the study and were randomized into one of three groups: 1) moderate-intensity exercise (50% VO_{2peak}), 2) high-intensity exercise (75% VO_{2peak}) or 3) control (no activity). Participants in the intervention groups exercised 4-5 d/wk for 12 wk; energy expenditure was matched to 1000 kcal/wk for each group. Results showed abdominal visceral fat decreased significantly (-34 cm^2)

in the high-intensity exercise group, but there was no change in abdominal visceral fat in the moderate-intensity or control group.

From these studies, it is evident that PA, especially high-intensity exercise, has beneficial effects on weight, adiposity, and MetS risk factors (i.e. WC, insulin sensitivity, triglycerides). A joint recommendation by ACSM and AHA suggested that high-risk groups, such as overweight, obese, and diabetic populations, could incorporate shorter bouts of high-intensity exercise training in place of low-to-moderate intensity exercise for health benefits (Haskell et al., 2007). The mechanism related to the benefits of high-intensity exercise are still unclear, but Gibala and McGee (Gibala & McGee, 2008) have suggested that rapid improvements in glucose and lipid metabolism in response to high-intensity exercise training may play a role. In part, these metabolic improvements are likely related to increases in skeletal muscle glucose transporter 4 (GLUT4), oxidative enzymes such as citrate synthase and cytochrome oxidase, and fatty acid binding and transport proteins. Another possible mechanism is that the release of catecholamines in response to exercise binds to the large number of adrenergic receptors on visceral fat adipocytes (Lönnqvist, Thöme, Nilsell, Hoffstedt, & Arner, 1995), increasing lipolysis, mobilization, and oxidation of free-fatty acids. Thus, studying the combined benefits of exercise, especially of high-intensity exercise, and dietary patterns would provide further insight on dietary and PA recommendations for the general public.

Table 1.11: Overview of intervention studies assessing physical activity, weight change, and MetS risk factors

Authors	Study Population	Methods/Intervention	Key findings
Ross et al. (2004)	Overweight (BMI>27kg/m^2), premenopausal women; (n=54)	14-wk intervention comparing 1) diet induced weight loss, 2) exercise induced loss (i.e. brisk walking, jogging, ~80% HR_{max}), 3) exercise w/out weight loss, or 4) control.	Exercise induced weight loss resulted in significant decreases in total body (-6.7 kg) and abdominal fat (-1.7 kg) compared to other intervention groups.
Volpe et al. (2008)	Overweight (BMI 27-35 kg/m^2), mid-life women (24-62y); (n=90)	6-mo supervised intervention comparing 1) diet only, 2) exercise only, 3) diet + exercise.	The diet + exercise intervention resulted in lowest mean body weight at the conclusion of the study (~80 kg). Exercise only resulted in greater reductions in WC than the diet only group.
Katzmarzyk et al. (2003)	Healthy, sedentary adults (17-65y); (n=621)	20-wk of supervised moderate intensity (55-75% $VO2_{max}$) exercise training sessions on a cycle ergometer 3 times/wk without alteration in diet or other PA levels.	Reductions in triglycerides, blood pressure, blood glucose, WC, and the overall prevalence of MetS occurred as a result of the intervention.
Larson-Meyer et al. (2010)	Overweight men and women (~BMI: 27.8 kg/m^2; ~age 39y); (n=36)	6-mo intervention comparing 1) caloric restriction, 2) caloric restriction+ exercise (65-90% HR_{max}), or 3) control.	Diet + exercise significantly reduced triglycerides, body weight, DBP, total cholesterol, abdominal fat, and improved insulin sensitivity while energy restriction only significantly improved triglycerides, body weight, and abdominal fat.
Foster-Schubert et al. (2011)	Overweight (~BMI=30.9 kg/m^2), post-menopausal women (~58y); (n=439)	12-mo interventions comparing1) energy restriction, 2) moderate-high intensity (65-80% HR_{max}) exercise intervention, 3) combined diet + exercise, or 4) control.	Average weight loss, reduction in BMI, WC, and % body fat were the greatest in diet + exercise intervention (-10.8%).

Irving et al. (2008)	Obese women (~BMI: 34 kg/m^2, ~age: 51y) with MetS; (n=27)	16-wk trial: Randomized into 1) high intensity exercise protocol (RPE: 15-17) or 2) low intensity exercise protocol (RPE: 10-12) without changing dietary behaviors.	The high-intensity exercise group had significant reductions in WC and total abdominal fat, and greater non-significant reductions in visceral fat, compared to decreases observed in the control group.
Trapp et al. (2008)	Young (~age 20.2y), mostly normal weight women (BMI: 23.2 kg/m^2); (n=45)	15-wk trial: randomized into 1) high intensity intermittent exercise protocol, 2) steady-state exercise (60% $VO2_{peak}$), or 3) control.	Only the high-intensity exercise group had a significant reduction in total body mas, fat mass, trunk fat, and fasting plasma insulin levels.
DiPietro et al. (2006)	Older women (73±10y), inactive (BMI <30 kg/m^2) (n=27)	9-mo intervention: randomized into 1) moderate exercise (65% VO_{2peak}) protocol of 2) high-intensity exercise protocol equivalent in energy expenditure/session (80% VO_{2peak})	The high-intensity exercise group had improved insulin stimulated glucose utilization without any changes or differences in body composition or fitness.
Coker et al. (2009)	Overweight & obese (BMI 26-37), sedentary, older adults (65-90y); (n=18)	12-wk trial randomized into: 1) moderate intensity exercise (50% $VO2_{peak}$), 2) high intensity exercise (75% $VO2_{peak}$), 3) control.	Abdominal visceral fat decreased significantly in the high-intensity exercise group, but there was not change in the moderate-intensity or control group.

*BMI=body mass index; WC=waist circumference; MetS=Metabolic Syndrome; HR=heart rate; DBP=diastolic blood pressure; RPE=rate of perceived exertion

F. Limitations in the Literature

The studies reviewed here have examined body weight, WC, and MetS risk factors and their relationship to dietary patterns and PA. Cross-sectional and longitudinal studies can provide information on dietary patterns and disease risk in large populations. Longitudinal studies offer an additional benefit in that dietary patterns and their effects on disease risk are assessed over an extended length of time. Although limitations exist in the methodology, such as relying on FFQs that may not accurately capture day-to-day variations in food intake, this type of research is extremely useful in generating hypotheses and identifying areas for future research. However, these studies do not imply direct cause and effect, nor do they assist in identifying the mechanism of action. Intervention studies are necessary to identify if specific behavior modifications in dietary and PA patterns can produce positive outcomes in relation to body size and MetS risk. Weighed, multiple day food records will produce more valid food intake measurements and PA patterns can be better-controlled and accurately assessed in intervention studies.

Large, cross-sectional and longitudinal studies also captured a wide range of ages and genders, but results cannot be extrapolated to specific, at-risk populations. As women age they are at an increased risk for abdominal obesity, a primary factor in development of MetS; identifying behavior patterns that can attenuate this risk is important. Although some studies examined pre-menopausal women (Rezazadeh & Rashidkhani, 2010; Schulze et al., 2006), they were cross-sectional or longitudinal in nature; thus, the direct effect of dietary patterns could not be identified.

The reviewed intervention studies come with limitations as well. Rather than focusing on preventing certain risk factors, many of the populations examined already had diagnosed hypertension (Blumenthal et al., 2010; Ledikwe et al., 2007), MetS (Azadbakht, Mirmiran, Esmaillzadeh, Azizi, et al., 2005; Jacobs et al., 2009), or obesity (Ello-Martin et al., 2007). Many intervention studies also focus on macronutrient alterations in the diet, but do not report changes in eating patterns or dietary energy density. Since both increasing protein in the diet and improving dietary patterns while reducing energy density are all beneficial, it is important to determine if these interventions can be combined.

Additionally, defined PA was not included in most intervention studies of dietary patterns. Research that did include PA encouraged more moderate activities, such as walking (Ello-Martin et al., 2007). Only two studies incorporated high-intensity forms of PA in addition to assessing dietary patterns, but one study was done exclusively in men with MetS risk factors (Jacobs et al., 2009) and the other was done in a combination of hypertensive, obese men and women (Blumenthal et al., 2010). Studying PA in combination with dietary patterns is important because exercise can influence weight change, fat distribution, and MetS risk factors (Foster-Schubert et al., 2011; Larson-Meyer et al., 2010; Ross et al., 2004). As women age they are at increased risk of weight gain, specifically in the abdominal area (Kuk et al., 2005). Prevention with improved diet and PA behaviors may lessen the amount of deposition or reverse the development of abdominal obesity, reducing the risk for MetS. In particular, high-intensity PA may have an impact on visceral fat deposition (Irving et al., 2008). In conclusion, no study has examined the effects of improving dietary patterns, reducing energy density of the diet, and increasing high-intensity PA, while assessing two levels of protein in abdominally obese, premenopausal women.

LOW ENERGY DENSE DIET AND HIGH-INTENSITY EXERCISE: IMPACT ON WEIGHT AND WAIST CIRCUMFERENCE IN ABDOMINALLY OBESE WOMEN

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Chapter 2: Manuscript

I. Introduction

It is now estimated that 68% of the adults in the United States are overweight or obese (Flegal et al., 2010). This excess weight increases the risk for metabolic syndrome (MetS) and associated chronic diseases (e.g. hypertension, diabetes and cardiovascular disease) (Lavie et al., 2009). MetS is characterized by higher waist circumference (WC), increased blood triglycerides, and glucose, elevated blood pressure, and lower high-density lipoprotein-cholesterol (HDL-C) (Grundy et al., 2005). For women, MetS risk also raises with age, increasing from an estimated prevalence of 41% in women aged 50-59 to 63% at age 60-69y (Ford, 2005). This increase with age is partially explained due to menopause associated increases in abdominal fat (Grundy et al., 2005; Kuk et al., 2005). Overall, obese women have a 17 times greater risk of developing MetS than normal weight women (Ervin, 2009).

Improved dietary patterns and increased high-intensity physical activity (PA) may be lifestyle behaviors that are effective at reducing abdominal obesity and decreasing metabolic risk factors. On the dietary side, cross-sectional and epidemiological longitudinal research has identified dietary patterns associated with lower body weight (BW), WC, and MetS risk factors (Deshmukh-Taskar et al., 2009; Ahmad Esmaillzadeh & Azadbakht, 2008a, 2008b; Fogli-Cawley et al., 2007; Lutsey et al., 2008; McNaughton et al., 2009a; Millen et al., 2006; Newby et al., 2006; Rezazadeh & Rashidkhani, 2010; Schulze et al., 2006). From this research, two dietary patterns have emerged: 1) healthy diet patterns, associated with lower BW, WC, and MetS, that consist of high intakes of fruits, vegetables, whole grains, and low-fat dairy products, and 2) unhealthy diet patterns, associated with higher BW, WC, and MetS, containing more refined grains, sweets, high-fat meats and dairy, and sugar-sweetened beverages.

Limited research using intervention methodology has been conducted in dietary patterns, but studies using a low energy dense (LED) eating pattern supports findings from epidemiological research. A LED diet contains high amounts of fruits, vegetables, and whole grains, while reducing fat intake. Energy density (ED) is determined by measuring the (kcal) in a given amount (g) of food. Incorporation of satiating, high-fiber, high water, low-fat foods results in the ability to consume a greater volume of food for a lower energy intake, which may enhance weight loss. Weight loss research has indicated that individuals with greater decreases in dietary ED, while increasing fruits and vegetables, experience greater losses in BW and WC than those who do not make such behavior changes (Ello-Martin et al., 2007; Ledikwe et al., 2007).

Another dietary approach that improves dietary patterns and is the Dietary Approaches to Stop Hypertension (DASH) eating plan, which is a LED diet that encourages whole grains, vegetables, low-fat/fat-free dairy, lean meats and poultry, and unsaturated fats (NIH, 2003). While originally designed to reduce blood pressure, the DASH eating plan is an effective way to reduce BW, WC, blood pressure, and other MetS risk factors (Azadbakht, Mirmiran, Esmaillzadeh, Azizi, et al., 2005; Blumenthal et al., 2010).

Recent research also suggests that increasing dietary protein intakes will improve BW loss and changes in abdominal fat by 1) increased satiety, 2) preservation of fat-free mass and 3) increased diet-induced thermogenesis (Leidy et al., 2007; Westerterp-Plantenga et al., 2009). However, higher protein diets, especially those from animal proteins, are typically higher in fat and more energy dense. Thus, we do not know if a high protein, LED diet will produce similar outcomes to a LED diets with more moderate protein intake.

Currently, little research exists examining high-intensity PA in combination with changing dietary patterns and ED, another limitation in the literature. Inclusion of PA into these types of studies is important because PA alone has proven beneficial in reducing BW, WC, and MetS symptoms (Katzmarzyk et al., 2003; Ross et al., 2004; Volpe et al., 2008). Although increased PA alone is not as effective at reducing BW compared to diet alone, it can have an additive effect when combined with dietary interventions aimed at reducing energy intake (Donnelly et al., 2009). For example, Larson-Meyer et al. (2010) found that an intervention reducing energy intake and increasing energy expenditure resulted in greater reductions in triglycerides, BW, blood pressure, and cholesterol than energy restriction alone. Additionally, recent research has specifically examined the benefits of high-intensity PA on abdominal obesity. For example, Irving et al. (Irving et al., 2008) compared isocaloric exercise programs of differing intensity in obese women (n=27, mean age 51y, BMI =34 kg/m^2) with MetS.

Women participated in high-intensity PA (rate of perceived exertion [RPE] =15-17) or moderate (mod)-intensity (RPE =10-12) PA programs without making dietary changes. After 16-wk of exercise, those in the high-intensity group had significant reductions in WC, total abdominal fat, and visceral fat, while the mod-intensity group did not. High-intensity exercise has also been found to be more effective in targeting abdominal fat in healthy women and older adults (Coker et al., 2009; Trapp et al., 2008).

Unfortunately, definitions of high-intensity PA are inconsistent in the literature. Some use RPE between 15-17 (Irving et al., 2008), >90% maximum heart rate (HR) (Talanian et al., 2007), or $VO2_{max}$ >75% (Coker et al., 2009). Gibala and McGee (2008) describe high-intensity exercise as intermittent exercise performed at an all out effort, or intensity close to $VO2_{peak}$ (i.e. >90% $VO2_{peak}$). Depending on the training intensity, this may last from a few seconds up to several minutes. Additionally, the definition of vigorous intensity exercise, or >6 metabolic equivalents (METs), as described by the American College of Sports Medicine (ACSM) can be considered high-intensity PA (Haskell et al., 2007). The ACSM has also suggested that high-risk groups, such as overweight, obese, and diabetic populations, could incorporate shorter bouts of high-intensity PA training in place of low-to-moderate intensity PA for health benefits (Haskell et al., 2007). The mechanism related to the benefits of high-intensity PA remain unclear, but Gibala and McGee (Gibala & McGee, 2008) have hypothesized that rapid improvements in glucose and lipid metabolism in response to high-intensity PA training may play a role.

Only two studies have incorporated planned, supervised, high-intensity PA (>6 METs) along with improved dietary patterns in their protocol. Jacobs et al. (2009) found that modifying both dietary intake patterns and increasing PA from aerobics, circuit training, brisk walking and jogging promoted favorable changes in MetS risk factors and produced greater BW loss compared to diet or exercise alone. Unfortunately, this study was only done in men with risk factors for MetS. Blumenthal et al. (2010) found that the DASH diet combined with high-intensity PA (70-85% initial HR reserve, ~80-90% HR_{max}) and weight loss, resulted in greater improvements in insulin sensitivity, total cholesterol, and triglycerides than the DASH-weight maintenance diet alone. However, this study was conducted in a combination of hypertensive men and women and results were not reported based on gender. Also, due to the lack of an exercising weight-maintenance group, the added benefits of exercise cannot be extrapolated from the benefits of weight loss.

Overall, research indicates the benefits of LED diets, with increased fruits, vegetables, whole grains, fiber, low-fat dairy and less energy dense beverages, combined with increased high-intensity PA (>6 METs) on weight and WC loss and reduction in MetS risk factors. To date no study has examined the effect of a LED diet and high-intensity PA on changes in BW, WC, and MetS risk factors in abdominally obese women, while consuming different dietary protein intakes. Thus, the purpose of this study was to determine the effect of two 16-wk diet and high-intensity PA intervention (>6 METs), differing in protein intakes, on BW, WC, dietary patterns, and ED. We hypothesized that the intervention would improve dietary patterns and PA levels and reduce dietary ED, regardless of protein intake, resulting in reductions BW, WC, and risk factors for MetS. The effect of protein intake on changes in body fat, abdominal obesity, and lean tissue are discussed elsewhere (K. Pilolla abstract).

II. Methods

A. Experimental Approach

This study was part of a larger research project comparing the effects of 2 different protein intakes and high-intensity PA on abdominal obesity and body composition in pre-menopausal, overweight women age 18-50y (WC≥80cm; body mass index [BMI] 25-32kg/m^2). Participants were randomized to one of two groups, 15% (15%Pro, n=18) or 25% (25%Pro, n=20) energy from protein. Both groups were encouraged to follow a LED diet pattern. The intervention was divided into two phases. Phase I (wk 1-4) consisted of nutrition education and exercise training to improve fitness while, phase II (wk 5-16) included adherence to a specific diet and PA protocol.

B. Participants

The Oregon State University Institutional Review Board approved the study protocol and all participants were provided written informed consent. A medical clearance was required from all participants' primary care physicians to participate in high-intensity PA (>6 METs). Initial eligibility was determined through a screening questionnaire for age, gender, BMI, and medical history. Inclusion criteria included: premenopausal females, age18-50y, WC≥80cm (31.5 in), BMI ≥25 but ≤32kg/m^2, stable weight for 4-6mo (<2.5kg body weight change), no use of weight loss supplements, and "moderate risk" for coronary artery disease (CAD) based on the ASCM Guidelines for Exercise Testing and Prescription (Thompson et al., 2009). Exclusion criteria included: pregnancy or lactation, WC<80cm, BMI <25>32 kg/m^2, history of diagnosed CAD, pulmonary disease, or metabolic disease, current diagnosis and treatment for cancer, unmanaged clinical diagnosis of an eating disorder, and inability to participate in the PA component of the intervention (i.e. weight bearing, aerobic activities). Eligibility was confirmed based on measured height, BW, and WC and review of questionnaire responses.

Women were recruited from the local and surrounding areas through flyers, newspaper, and email advertisements. A small compensation was offered upon completion with 80% adherence to study protocol (exercise class attendance, compliance with diet and PA requirements, documentation of compliance). Overall, 262 participants were screened, 61 participants were eligible, and 52 participants underwent baseline testing after randomization. Thirteen did not complete the study due to other commitments (i.e. jobs, school, family). No participant withdrew due to any adverse side effects, but one was excluded due to non-compliance with dietary protocol. Overall 38 completed the study (15%Pro, n=18; 25%Pro, n=20).

C. Baseline, During, & Post-Intervention Assessments.

Baseline (T1) assessments occurred 2-3-wk prior to the start of the intervention. During the intervention (T2), participants met with study staff every 2-4 wk to adjust diet, assess adherence, and measure BW, WC, and blood pressure. More frequent interactions occurred if necessary to keep participants on track. Post-intervention (T3) assessments took place 16-wk after the start of the study. Assessment measures included height (T1 only), BW, WC, BMI, resting blood pressure, 4-d weighed food and PA records, fasted blood draws, sub-maximal exercise testing, and body composition analysis.

D. Dietary Intervention

All participants met with the study Registered Dietitian (RD) to develop an individualized diet plan. Initial energy intake was at least -300 kcals/d less than estimated energy requirements, which were estimated using the Dietary Reference Intake (DRI) equation (IOM, 2005): 354-(6.9 x age in y) + PA x [(9.36 x weight in kg) + (726x height in m)]. A PA factor of 1.0 (sedentary) was used at baseline. Alterations were made to the diet plan throughout the study to maintain an energy deficit (range -300 to -700 kcal/d) and promote continued weight loss. The compositions of the diets were as follows: 15%Pro (60% CHO; 25% fat) and 25%Pro (50% CHO; 25% fat, +18 g/d whey protein).

Individual diet plans were created using The Exchange Method for Diabetes (Exchange Lists for Diabetes, 2008). Participants were asked to increase fruits, vegetables, whole grains, low-fat or fat-free dairy, products, and lean meats, and reduce or eliminate high-calorie and sugar-sweetened beverages (BEV). Tracking booklets were used to record daily intake from each exchange group to monitor adherence. During phase I, participants began mod-intensity PA (≥3 MetS) and attended nutrition education classes covering the exchange method and dietary modifications for weight loss.

E. Physical Activity

Participants attended high-intensity PA (>6 METs) Zumba exercise classes (Latin-inspired dance fitness course; www.zumba.com) 3-d/wk for 60 min taught by a certified fitness instructor. The class provided interval exercise training varying between low (50-65% HR_{max}, warm-up; cool-down), mod (65-85% HR_{max}), and high-intensity (>85% HR_{max}) HR training zones. All classes were supervised and HR monitors (©Polar Electro, USA) worn during exercise sessions monitored target HR zones. During phase I, participants attended supervised Zumba 2-d/wk for 30-45 min and exercised 2-d/wk on their own at mod-intensity (≥3 METs, i.e. brisk walking). During phase 2, participants attended supervised Zumba 3-d/wk for 60 min and continued 2-d/wk of mod-intensity self-selected PA.

F. Assessment Measurements

Diet Assessment. Using a food scale (Cuisinart ® WeightMate Food Scale™, Stanford, CT), 4-d food records (3 weekdays, 1 weekend day) of all food and beverages consumed were recorded at T1 and T3. Two 24-h recalls were collected during T2 using the multi-pass method. Tracking booklets recording daily adherence to exchange points were cross-referenced with 24-h recalls to monitor compliance. Food records were analyzed with ESHA Food Processor Nutritional Analysis Software (version 10.4, 2008, ESHA Research Inc, Salem, OR).

Dietary patterns (servings/d of fruits, vegetables, whole grains, low-fat/fat-free dairy, g/1,000 kcal/d fiber, and kcal/d from BEV) were monitored at each time period. Low-fat/fat-free dairy consisted of fat-free and low-fat dairy only (dairy alternative, 2% and whole milk excluded). BEV consisted of energy containing beverages except 100% fruit juice or low-fat and fat-free dairy beverages. The 2005 USDA MyPyramid definitions of servings were used for each food group (i.e. 1c raw/cooked carrots, 1c grapes, ½c cooked oatmeal, 1c fat-free milk [www.MyPyramid.gov]). The Whole Grain Council Database (www.wholegrainscouncil.org) was used to assess whole grain content of processed whole grain products (i.e. ready-to-eat cereal); 16 g whole grain was determined to be 1 serving. ED was calculated from food records; all beverages were excluded in assessment of ED, except for whey protein smoothies used as part of study protocol or recipes/foods prepared with milk (i.e. oatmeal).

Physical Activity. Concurrent with 4-d food records, 24-h PA was recorded at T1 and T3. During the study, daily PA logs monitored compliance to volitional PA based on rate of perceived exertion (RPE) (Borg, 1982). Average min/wk spent in mod (65-85% HR_{max}) and high-intensity exercise (>85% HR_{max}) was calculated from HR monitors worn during high-intensity Zumba exercise classes (>6 METs).

Fitness Assessment. Fitness was assessed (T1 and T3) using the modified Balke protocol, a standard submaximal VO_2 graded treadmill test (Thompson et al., 2009). After a warm-up, exercise testing began at 2-3 mph with a 0% grade for 3 min each. Treadmill grade was increased every 3 min by 2.5% until the participant reach 85% HR_{max} (HR_{max}=220-age [y]) or exhaustion, followed by a cool down phase. Blood pressure, HR, and RPE (Borg, 1982) were recorded every 3 min.

Anthropometric and Body Composition Data. Height (cm) was measured using a standard stadiometer (T1). BW was measured (T1, T2, T3) to the nearest 0.5 lb (0.25 kg) on a mechanical scale (Seca, Chino, CA). Two WC measurements were taken and averaged (T1, T2, T3), measured to the nearest 0.1 cm using a flexible, inelastic tape measure placed directly on the skin: 1) immediately above the iliac crest (National Institutes of Health) (Pi-Sunyer et al., 1998) and 2) at the narrowest point between the lowest right and the iliac crest (Anthropometric Standardization Reference Manual) (Lohman, 1988). Body composition was measured (T1 and T3) by the same trained technician using dual X-ray absorptiometry ([DXA] QDR 4500 A, Hologic, Waltham MA, USA).

Metabolic Data. Resting systolic and diastolic blood pressure (SBP, DBP; mmHg) was measured with a digital blood pressure machine (Welch Allyn ®, Skaneateles Falls, NY). Blood draws were collected after an 8-h fast. 40 ml samples were immediately centrifuged, aliquoted, and placed on ice for analysis of total cholesterol (TC), HDL-C, low-density lipoprotein cholesterol (LDL-C), triglycerides, fasting insulin, and glucose (Good Samaritan Regional Medical Center Laboratory Corvallis, OR)

G. Statistical Analysis

Power analysis indicated that a sample size of 16 subjects per group was needed to provide 80% power to detect a WC difference of >3cm. Repeated measures analysis of variance (ANOVA) was used to analyze the following diet response variables: fruits + vegetables, whole grains, low-fat/fat-free dairy [serving/d], fiber [g/1,000 kcal], BEV [kcal/d] and ED (kcal/d). In each of these analyses there were two groups (15%Pro; 25%Pro) and three times periods (T1, T2, and T3), and the overall experiment-wise statistical significance level was set at $\alpha=0.05$. We controlled the experiment-wise significance level using the Bonferroni simultaneous testing procedure.

To analyze the MetS risk factors, we again used repeated measures ANOVA. In these analyses, the same two groups (15%Pro; 25%Pro) were examined at two time periods (T1 and T3). The MetS response variables of interest were WC, BMI, BW, blood lipids, blood glucose, and SBP/DBP. The two PA response variables (mod/high-intensity PA [min/d] and VO_2max) were analyzed using the same 2 x 2 repeated measures ANOVA. For these analyses, we set the overall experiment-wise statistical significance level at $\alpha=0.05$ and controlled the experiment-wise significance level in each analysis using the Bonferroni simultaneous testing procedure.

Regression models were used to explore the dietary and PA variables contributing the most to explaining the variability in weight and WC. All statistical analysis were done using SAS statistical package (SAS Institute Inc., Ver. 9.2, Cary, NC). Data are summarized using means and standard deviations (SD).

III. Results

Thirty-eight healthy, pre-menopausal women completed the intervention (15%Pro n=18; 25%Pro n=20). At baseline (T1), there were no significant differences between groups for dietary intake, PA level, body composition, and metabolic variables, with the exception of DBP (Tables 2.1 and 2.2).

A. Dietary Patterns

One primary aim for this study was to assess changes in dietary patterns over the intervention and their association with change BW, WC, and MetS risk factors and weight. Overall, the intervention was successful in improving dietary patterns (Table 2.1) and reducing BW, WC, and MetS risk factors (Table 2.2). There were no significant differences for any of these variables between the protein groups; thus groups were combined for further analysis. By design, total energy intake (kcal/d) significantly decreased during the intervention by -550±356 kcal/d ($p<0.0001$). Correspondingly, BW and WC significantly decreased by -4.8±2.7 kg and -7.1±3.6 cm ($p<0.0001$), respectively. After adjustment for multiple comparisons, significant effects of time were found for all dietary pattern variables examined ($p<0.0071$). Compared to baseline (T1), the intervention (T2) significantly increased servings/d of fruits + vegetables by 1.5±1.4, whole grains by 1.0±1.4, low-fat/fat-free dairy by 0.5±0.7, g fiber/1,000 kcal by 5.7±5.8, and reduced BEV kcals/d by -157±189 ($p<0.0002$; Table 2.1). Overall, ED (kcal/g) decreased by -0.55±0.4 kcal/g ($p<0.0001$).

To determine if dietary changes were maintained, we examined changes in dietary patterns before, during, and after (T3) the intervention. Comparing T1 vs. T3 (Table 2.1), participants significantly increased servings/d of fruits + vegetables, whole grains, low-fat/fat-free dairy, grams/1,000 kcal fiber, and significantly decreased BEV kcals/d ($p<0.002$). ED (kcal/g) also decreased from T1 to T3 by -0.4±0.4 kcal/g ($p<0.0001$). Changes in dietary patterns and ED were observed regardless of protein intake. When comparing T2 to T3, all dietary variables trended downward and BEV kcal/d and ED trended up, but differences between the 2 time points were not significant (Table 2.1), suggesting that dietary changes were being maintained.

Table 2.1. Changes in energy, protein intake, dietary patterns and physical activity (PA) before (pre; T1), during (T2) and after (post; T3) a 16-week diet (15% or 25% en protein groups) and high-intensity PA intervention.

Variable	Group	Pre	During	Post	P-value
ENERGY AND MACRONUTRIENT CONTENT					
Total energy intake (kcal/d)	15%	2154±380	1521±361	1558±337	G: 0.58
	25%	1991±335	1513±187	1577±486	T: <0.0001
	Time Main Effect Means	2073±362	1517±279 [b]	1566±415 [a]	I: 0.23
Protein (g/kg)	15%	0.93±0.3	0.84±0.2 [d]	0.97±0.2	G: 0.001
	25%	0.95±0.15	1.24±0.2 [b]	1.1±0.3 [a]	T: 0.0143
					I: 0.0007
DIETARY VARIABLES ASSOCIATED WITH ENERGY DENSITY					
Fruits + vegetables (cups/d)	15%	1.2±0.7	3.1±1.5	2.7±1.4	G: 0.70
	25%	1.5±0.8	2.8±1.4	2.4±1.3	T: <0.0001
	Time Main Effect Means	1.4±0.8	2.9±1.5 [b]	2.6±1.3 [a]	I: 0.36
Whole grains (servings/d)	15%	1.0±0.9	2.5±1.6	1.8±1.2	G: 0.57
	25%	1.25±0.9	1.8±1.25	1.7±1.2	T: 0.0002
	Time Main Effect Means	1.1±0.9	2.1±1.4 [b]	1.8±1.0 [a]	I: 0.20
Low-fat/fat-free dairy (cups/d)	15%	0.3±0.4	0.6±0.5	0.6±0.5	G: 0.03
	25%	0.45±0.5	1.24±0.9	0.96±0.6	T: <0.0001
	Time Main Effect Means	0.4±0.4	0.9±0.8 [b]	0.8±0.6 [a]	I: 0.07
Fiber (g/1,000kcal)	15%	8.7±4.4	15.2±5.1	14.3±6.1	G: 0.7
	25%	9.0±2.5	14.1±6.9	13.8±5.0	T: <0.0001
	Time Main Effect Means	8.9±3.4	14.6±6.0 [b]	14.1±5.2 [a]	I: 0.75
Beverage energy intake (kcal/d)	15%	284.4±160	68±68	82±58	G: 0.09
	25%	173±179	69±63	75±59	T: <0.0001
	Time Main Effect Means	229±177	68±64 [b]	79±58 [a]	I: 0.19
Energy density (kcal/g)	15%	1.67±0.3	1.24±0.2	1.31±0.3	G: 0.08
	25%	1.86±0.4	1.21±0.4	1.50±0.3	T: <0.0001

	Time Main Effect Means	1.77±0.4	1.22±0.4 [b]	1.41±0.3 [a]	I: 0.29
PHYSICAL ACTIVITY VARIABLES					
Total physical activity (≥3 METs) (min/d)	15%	50±34	NA	126±58	G: 0.11
	25%	87±69	NA	161±119	T: <0.0001
	Time Main Effect Means	69±57	NA	144±95 [a]	I: 0.94
$VO2_{Max}$ (mL/kg/min)	15%	29.7±5.5	NA	34.7±5.9	G: 0.64
	25%	28.9±4.0	NA	34.1±4.9	T: <0.0001
	Time Main Effect Means	29.3±4.7	NA	34.4±5.3 [a]	I: 0.85

G=group; T= time, I =Group x Time interaction; Time Main Effect Means = data combined over groups at each time period. $p<0.0071$ indicated significant differences.
[a]T3 vs. T1; [b]T2 vs. T1; [c] T3 vs. T2; [d]15% vs. 25% en Pro

B. Physical Activity

At baseline, groups did not differ for any PA variables (Table 2.1). During the intervention minutes of high-intensity Zumba exercise (>65% HR_{max}) was 87 min/wk. Within Zumba, overall intensity was >6 METs, which is considered high-intensity PA according to the ACSM (Haskell et al., 2007). When we looked at time spent in intensity levels >85% HR_{max} (~9 METs), minutes/wk of high-intensity interval exercise was 34.9±26.93. When high-intensity PA was combined with the self-selected minutes of mod-intensity PA 2-d/wk, participants reached recommended levels of PA (>150 min/wk) during the intervention. As a result of intervention, $VO2_{max}$, a measure of fitness assessment, participants significantly increased by 17.8±12.0% (p<0.0001).

C. Body Weight and MetS risk factors.

Changes in BW and body composition variables were also assessed as part of the intervention (Table 2.2). In addition to the decreases in BW and WC mentioned earlier, body fat % decreased by -3.1±1.7% (p<0.0001), while lean body mass (LBM; [g]) did not change (p=0.02). There were no between group differences for change in % body fat and LBM (p=0.60; p=0.67, respectively).

MetS risk factors are given in Table 2.2. Triglycerides significantly decreased by -24±52 mg/dL (p=0.006). Although SBP decreased, changes did not reach adjusted statistical significant (p=0.0098). DBP decreased significantly in the 15%Pro group only (p=0.0009), but they began the study with a significantly higher value compared to the 25%Pro group. No significant changes occurred in HDL-C or fasting plasma glucose. Although not considered features of MetS, TC and LDL-C significantly decreased (p-value for both=0.0003) by -18±19 mg/dL, and -11±33 mg/dL, respectively.

Table 2.2. Changes in body composition and metabolic variables before (pre; T1) and after (post; T3) a 16-week diet (15% or 25% en protein groups) and high-intensity PA intervention.

Variable	Group	Pre	Post	P-value
BODY SIZE AND COMPOSITION DATA				
Body weight (kg)	15% 25% Time Main Effect Means	80.3±8.3 79.9±8.4 80.1±8.2	74.8±8.2 75.7±8.3 75.3±8.1[a]	G: 0.94 T: <0.0001 I: 0.13
Body mass index (kg/m^2)	15% 25% Time Main Effect Means	29.9±1.9 29.8±2.8 29.9±2.4	27.9±2.2 28.3±2.9 28.1±2.6a	G: 0.8 T: 0.002 I: 0.68
Total body fat (%)	15% 25% Time Main Effect Means	40.5±3.3 39.0±3.2 39.7±3.2	35.8±3.9 35.8±39 35.8±3.9 [a]	G: 0.60 T: <0.0001 I: 0.044 (NS)
Lean body mass (g)	15% 25%	44715±4362 45281±4589	44098±4179 44744±4191	G: 0.67 T: 0.02 (NS) I: 0.87
METABOLIC SYNDROME RISK FACTORS				
NIH Waist circumference (cm)*	15% 25% Time Main Effect Means	101.1±6.7 101.2±6.0 101.2±6.3	93.3±5.4 94.8±6.1 94.1±5.8 [a]	G: 0.69 T: <0.0001 I: 0.23
Triglycerides (mg/dL)*	15% 25% Time Main Effect Means	133.8±58.1 111.7±53.9 122.7±56.3	97.1±40.1 100.7±41.4 98.9±40.3[a]	G: 0.50 T: 0.006 I: 0.13

Systolic blood pressure (mmHg)*	15% 25%	119±12 111±11	114±14 109±9	G: 0.09 T: 0.0098 (NS) I: 0.2171
Diastolic blood pressure (mmHg)*	15% 25%	78±7[b] 70±8	71±8[a] 71±7	G: 0.095 T: 0.421 I: 0.0034
High density lipoprotein-cholesterol (mg/dL)*	15% 25%	53.9±13.0 57.9±14.7	54.8±12.0 54.3±11.4	G: 0.67 T: 0.28 I: 0.075
Fasting plasma glucose (mg/dL)*	15% 25%	89.5±5.5 90.4±9.6	86.2±5.6 89.1±8.5	G: 0.40 T: 0.07 I: 0.42
ADDITIONAL BLOOD LIPID DATA				
Total cholesterol (mg/dL)	15% 25% Time Main Effect Means	210.9±39.2 196.6±40.0 203.75±39.8	187.7±39.9 184.5±34.5 186.1±36.7 [a]	G: 0.47 T: 0.0003 I: 0.09
Low density lipoprotein-cholesterol (mg/dL)	15% 25% Time Main Effect Means	130.3±34.3 116.3±35.5 123.0±35.2	113.8±35.7 109.8±32.2 111.7±33.5 [a]	G: 0.41 T: 0.0003 I: 0.09

*Denotes MetS risk factor; G= group; T= time; I= Group x time interaction; Time Main Effect Means = data combined over groups at each time period. p<0.0083 indicated significant differences.

[a]T3 vs. T1

[b]15% vs. 25% en Pro

D. Promoters of Weight and WC Change

Besides total energy intake and energy expenditure, we wanted to further examine if any particular dietary and PA patterns contributed more to decreases in BW and WC by using regression analysis. This would allow us to explore these variables in more depth to support future research. Two response variables, BW change (kg) and WC change (cm) were regressed against changes in the following predictor variables: energy density (kcal/g), fruits + vegetables (serving/d), whole grains (servings/d), low-fat/fat-free dairy (serving/d), BEV (kcal/d), fiber (g/1000 kcal/d), protein (g/kg/d), Zumba high-intensity PA (min/wk >65% HR_{max}; >6 METs). From the above list, the predictors variables that appeared to contribute more in decreasing BW were improvements in fruit + vegetable intake (servings/d) and low-fat/fat-free dairy intake (servings/d), and decreases in ED (kcal/g) ($p \leq 0.0008$). For decreases in WC (cm), the predictor variables appeared to contribute more were increases in whole grain intake (serving/d), fiber (g/1,000 kcal/d), low-fat/fat-free dairy intake (serving/d), and Zumba high-intensity PA (min/wk >65% HR_{max}) ($p \leq 0.00072$). To examine these variables further, participants were then divided into tertiles based on reductions in BW and WC. Mean values and overall change from baseline to during the intervention for each of these variables are given in Table 2.3.

Table 2.3. Mean dietary and PA data at T2 and overall mean change (T1 to T2) in these variables for tertiles based on change in body weight (kg). Treatment groups are combined (n=38).

Outcome Variable	Tertile 1 (-1.9±1.1 kg) N=12	Tertile 2 (-4.4±0.9 kg) N=12	Tertile 3 (-7.7±1.4 kg) N=14
ENERGY INTAKE AND ENERGY EXPENDITURE VARIABLES			
Energy intake (kcal/d)			
Mean (T2)	1570±400	1532±263	1460±146
Mean Δ (T1 vs. T2)	-510±345	-411±336	-706±345
Mod/high-intensity PA (min/d)			
Mean (T2)	175±150	136±63	130±64
Mean Δ (T1 vs. T2)	93±85	66±73	67±79
Protein (g/kg)			
Mean (T2)	1.05±0.2	1.10±0.4	1.01±0.3
Mean Δ (T1 vs. T2)	0.05±0.3	0.20±0.4	0.13±0.4
Fat (g/d)			
Mean (T2)	41±18	38±14	40±10
Mean Δ (T1 vs. T2)	-38.0±25	-36.5±23	-39.5±19
DIETARY PATTERN VARIABLES			
Fruit + Veg (serv/d)			
Mean (T2)	2.8±1.7	2.7±1.2	3.2±1.5
Mean Δ (T1 vs. T2)	1.0±1.8	1.5±1.0	2.1±1.4
LF/FF dairy (serv/d)			
Mean (T2)	0.8±0.9	0.9±0.9	1.0±0.7
Mean Δ (T1 vs. T2)	0.4±0.7	0.6±0.7	0.7±0.7
Energy density (kcal/g)			
Mean (T2)	1.1±0.3	1.2±0.3	1.4±0.5
Mean Δ (T1 vs. T2)	-0.7±0.7	-0.5±0.3	-0.5±0.4

*PA=Physical activity; Veg=vegetable, LF/FF=includes low-fat/fat-free (i.e. only skim and 1% milk-fat); mod/high-intensity PA ≥3 metabolic equivalents (METs); T1=Pre-intervention; T2=During the intervention

Table 2.4. Mean dietary and PA data at T2 and overall mean change in these variables (T1 to T2) for tertiles based on change in WC. Treatment groups are combined (n=38).

Outcome Variable	Tertile 1 (-3.1±1.5 cm) N=12	Tertile 2 (-6.8±1.1 cm) N=12	Tertile 3 (-11.1±1.7 cm) N=14
ENERGY INTAKE AND ENERGY EXPENDITURE VARIABLES			
Energy intake (kcal/d)			
Mean (T2)	1612±428	1438±106	1509±212
Mean Δ (T1 vs. T2)	-495±423	-558±349	-597±315
Mod/high-intensity PA (min/d)			
Mean (T2)	133±74	154±144	150±62
Mean Δ (T1 vs. T3)	68±67	75±87	80±84
Protein (g/kg)			
Mean (T2)	1.1±0.2	1.0±0.2	1.05±0.4
Mean Δ (T1 vs. T2)	0.07±0.3	0.10±0.2	0.15±0.5
Fat (g/d)			
Mean (T2)	43±20	37±5	41±10
Mean Δ (T1 vs. T2)	-42±19	34±18	-38±22
DIETARY AND PHYSICAL ACTIVITY PATTERN VARIABLES			
Fiber (g/1,000 kcal)			
Mean (T2)	12.7±6.0	13.3±4.6	17.6±6.5
Mean Δ (T1 vs. T2)	4.2±5.2	3.5±4.1	9.5±6.4
Whole grain (serv/d)			
Mean (T2)	1.7±1.5	2.0±1.4	2.6±1.4
Mean Δ (T1 vs. T2)	0.4±1.1	0.7±1.3	1.8±1.6
LF/FF dairy (serv/d)			
Mean (T2)	0.7±0.9	1.1±0.8	1.0±0.8
Mean Δ (T1 vs. T2)	0.3±0.7	0.6±0.8	0.7±0.7
Zumba (min/wk)			
Mean (T2)	89±26	86±25	85±24

*PA=Physical activity; WC=Waist circumference; LF/FF=Low-fat/fat-free (i.e. skim and 1% milk-fat, 2%); mod/high-intensity PA ≥3 metabolic equivalents (METs); Zumba > 6 METs; T1=Pre-intervention; T2=During the intervention

IV. Discussion

This study is the first to examine the effect of change in dietary patterns and high intensity exercise on BW, WC, and other MetS risk factors in abdominally obese, premenopausal women consuming two different levels of dietary protein. Most dietary and PA interventions report changes in macronutrient content of the diet (e.g. level of carbohydrate and/or fat), but few discuss improvements in dietary patterns and PA level together, especially high-intensity PA. Our intervention, focused on changing food patterns to reduce energy intake, while increasing high-intensity PA, was effective in promoting losses in BW, reductions in WC, and decreases in MetS risk factors, regardless of dietary protein intake. Examination of post-intervention food intake showed that ED and dietary patterns remained similar to that consumed during the intervention. Thus, both dietary interventions, regardless of protein intake, were effective at improving diet patterns and PA level after the conclusion of the study, which has implications for long-term success with weight loss maintenance.

Recent research has encouraged an increase in protein intake to enhance weight loss and to manage chronic disease (Johnston et al., 2004; Meckling & Sherfey, 2007; Noakes et al., 2005). However, increasing protein intake may also result in increased fat intake, primarily from animal fat (Johnston et al., 2004). This study demonstrated that if individuals are encouraged to choose low-fat protein foods and supplements, they can maintain a high protein (25% of en) LED diet pattern that includes fruits, vegetables, and whole grains. However, the high protein intake did not improve outcomes over the more moderate protein intake.

Our research also indicates that multiple factors may play a role in reducing BW and WC, rather than a single factor, such as protein intake. In addition to changes in energy intake and expenditure, other factors associated with reductions in BW were increased intakes of whole fruits and vegetables, low-fat/fat-free dairy, and reductions ED. Factors related to reducing WC were increases in whole grains, fiber, low-fat/fat-free dairy, and high-intensity Zumba PA (>6 METs).

A. Changes in Dietary Patterns

As a result of our intervention, all participants, regardless of protein group, reduced their total energy intake (-551±356 kcal/d) and improved intakes of fruits, vegetables, whole grains, low-fat/fat-free dairy, and fiber, and reduced BEV. Dietary ED also significantly decreased (-0.55±0.4 kcal/g), likely due to the increased intakes of whole fruits, vegetables, and fiber, and decreases in dietary fat intake (-10% of energy from fat). These dietary changes were key contributing factors to change in BW (-4.8±27 kg) and WC (-7.1±3.6 cm).

These results are similar to other studies emphasizing LED dietary patterns for weight loss. Ello-Martin et al. (2007) found that dietary ED was significantly lower (ED=1.23 kcal/g) in participants increasing whole fruits and vegetables and decreasing dietary fat intake compared to those reducing fat intake alone (ED=1.46 kcal/g). This difference was primarily due to eating more fruits and vegetables, while fat intake was similar between groups. Our participants (n=38) achieved a similar ED level by increasing whole fruits and vegetables and reducing fat intake (1.22±0.4 kcal/g). Similarly, Ledikwe et al. (2007) found that the DASH eating plan reduced dietary ED by -0.56 kcal/g in a large cohort (n=658) of healthy, pre-hypertensive or mildly hypertensive men and women. Our participants achieved a similar reduction in dietary ED of -0.55 kcal/g. When dividing participants into tertiles based on ED of the diet, Ledikwe et al. (2007) found that the largest reductions in ED were related to increases in whole fruits, vegetables, and fiber, and decreases in fat intake. Changes in ED and dietary patterns (intake of fruits, vegetables, fiber, and fat) may have important implications in weight management. LED diets promote satiety due to the high water content and bulk (Rolls et al., 2005). Thus, for the same amount of energy, a greater weight of food can be consumed, which may increase adherence to changes in dietary patterns and assist with long-term weight maintenance. Our participants maintained the changes made during the intervention at the post-intervention assessment period (T3; ED=1.41±03), indicating that focusing on alterations in total dietary patterns may be a feasible method to promote changes in habitual food intake.

B. Changes in Physical Activity

Overall, this study focused on increasing minutes of high-intensity PA (≥6 METs, HR ≥65%) and well as more mod-intensity PA (≥3 METs). During the study, Zumba exercise classes provided an average of 87 min/wk of high-intensity PA. High-intensity PA was emphasized in this study because of its hypothesized effect on reducing abdominal obesity and WC, a primary risk factor in MetS. Unfortunately, it is difficult to compare our changes in PA to studies reporting the use of high-intensity PA due to different methods of classifying exercise intensity. Some use measure of RPE (Irving et al., 2008), while others use a target HR training zone (Coker et al., 2009; DiPietro et al., 2006; Gibala & McGee, 2008). However, the ACSM defines mod-intensity PA as 3-6 METs and high-intensity PA as >6 METs (Haskell et al., 2007).

In addition to high-intensity PA Zumba classes, participants were asked to exercise an additional 1-2 h/wk on their own doing mod PA, which together with Zumba classes, would meet the current recommended PA guidelines of 150 min/wk of mod-intensity PA (Physical Activity Guidelines, 2008; Haskell et al., 2007). Compared to baseline, participants increased all PA (≥3 METs) by 75 min/d. This number includes all mod/high-intensity activity, including high-intensity household chores (i.e. moving boxes, mopping), brisk walking, and transportation (i.e. bicycle riding). PA ≥4METs increased by 40 min/d, which may capture more volitional PA, rather than all activity of daily living. PA ≥6METs increased by 12 min/d. Overall, the level of PA in this study was sufficient for significantly improving fitness level in our cohort of women ($VO2_{max}$ increased by 5.1±3.1 ml/kg/min).

C. Changes in Body Composition and MetS Risk Factors

Regardless of treatment goup, risk factors for MetS also improved as a result of our intervention, while no differences existed between protein groups. Of the five MetS criteria, our participants significantly reduced WC and triglycerides, with non-significant reductions in SBP. Other chronic disease risk factors for chronic disease, although not included in MetS criteria, also improved. Weight, BMI, total body fat %, TC, and LDL-C all decreased significantly. These results are similar to other findings from research examining changes in MetS risk factors. Azadbakht et al. (2005)

incorporated the DASH diet into a dietary intervention for adults (n=116) with MetS. The DASH diet improved all components of MetS (WC, HDL-C, triglycerides, SBP, DBP, fasting blood glucose) and reduced BW significantly more than an energy restricted weight loss group only.

Increases in PA alone have also been shown to improve features of MetS. In a study of healthy, sedentary adults (17-65y, n=621), Katmarzyk et al. (2003) found that a supervised mod-intensity (50-75% of $VO2_{max}$) exercise training intervention improved triglycerides, blood pressure, blood glucose, WC, and prevalence of MetS. Other research has suggested that high-intensity PA (>6 METs, RPE 15-17) may more specifically target abdominal fat in women (Irving et al., 2008). However, research combining diet and PA interventions elicit greater improvements in features of MetS than either intervention alone. For example, Larson-Meyer et al. (2010) tested 2 different approaches to imposing a negative energy balance in overweight men and women. One approach used a 25% energy restriction, while the other used a combination of a 12.5% energy restriction with a 12.5% increase in exercise energy expenditure. Details of dietary changes were not clearly outlined. The exercise intervention included individualized exercise prescriptions that allowed participants to select their mode and intensity of activity, as long as it resulted target HR of 65-90% HR_{max} and promoted the required amount of energy expenditure. The latter approach resulted in improvements in more risk factors of MetS (triglycerides, DBP, insulin sensitivity), LDL-C, and TC than diet alone (triglycerides and abdominal obesity only). However, to our knowledge, no studies have examined the combined effects of changes in overall dietary patterns, rather than energy or macronutrient intake, and high-intensity PA level in women only. Blumenthal et al. (2010) found that after a 4-mo intervention, the DASH diet combined with high-intensity exercise (70-85% HR reserve) and weight loss, resulted in greater improvements in insulin sensitivity, total cholesterol, and triglycerides than the DASH diet alone. However, this study was conducted in a combination of hypertensive men and women and results were not reported based on gender. Similarly, Jacobs et al. (2009) conducted a year-long intervention study of both dietary pattern improvements and PA (intensity not defined). Unfortunately it was done only in middle-aged men (~45y) with risk factors for MetS. A supervised, exercise component, consisting of aerobics, circuit training, fast walking, and jogging, was included as part of the intervention, as were changes in dietary patterns. Overall recommendations were made to increase consumption of vegetables, fiber rich products, and lean protein such as fish while reducing sugar and saturated fat. An improved dietary pattern (based on an *a priori* defined scoring index) resulted in improvements in BW, WC, SBP, fasting glucose, TC, and LDL-C. However, in this study of middle-aged men, an improved dietary pattern score and increased PA appeared to be most effective in promoting weight loss. This is similar to findings in our study; increased PA and improved dietary patterns also appears to be an effective method to reduce BW.

D. Dietary and Physical Activity Variables Associated with Weight Loss

Decreases in energy intake and increases in energy expenditure would be expected to drive weight change, but increasing fruits and vegetables and decreasing ED may be important ways to reduce energy consumed. Our participants with the greatest BW loss decreased their energy intake more, but made greater changes in their intake of of fruits and vegetables more than those who lost less weight; however mean intakes during the study were similar (Table 2.3). Ello-Martin et al. (2007) found that in the first 6-mo of a year-long intervention promoting a LED dietary pattern either reduced in fat (RF) or RF plus added fruits and vegetables (RF+FV) in 71 obese women, the RF+FV group lost 33% more weight than the RF group and maintained overall greater weight loss than the RF group during the second 6-mo. Similar to our study, ED, fruit, and vegetable intake were primary factors in weight loss. A LED dietary pattern also reduced weight in a study by Ledikwe et al. (2007). When participants were divided into tertiles based on change in ED they found that those with the greatest decrease of ED (-0.90 kcal/g) had significantly greater BW loss and the greatest increase in fruits, vegetables, and fiber.

In the present study, regression analysis indicated that reducing ED was associated with greater reductions in BW; however, ED was similar across BW tertiles (Table 2.3). In addition, the change in ED was similar across BW tertiles. Dietary fat intake (both the average intake and mean change), which strongly contributes to decreases in ED, was also similar across BW tertiles. These contradictory findings may due to the fact that our calculations for ED do not include changes in liquid energy intake, since ED was calculated without the inclusion of energy containing beverages. Some of our participants that lost large amounts of weight started the study with high intakes of BEV kcals; elimination of these items substantially lower energy intake, and promote weight loss, without changing ED. Thus, this may be another area to explore for BW loss.

Dairy intake has also been associated with increased BW loss when participants follow an energy-restricted diet. Research by Zemel et al. (2005; 2005; 2004) found that when combined with energy restriction, three servings/d of low-fat/fat-free dairy reduce weight more significantly than energy restriction alone. Cross-sectional research has also linked greater low-fat/fat-free dairy consumption (≥3.1 servings/d) to lower BW (Azadbakht, Mirmiran, Esmaillzadeh, Azizi, et al., 2005). However, our results should be interpreted with caution in comparison to these other studies. Participants in our study averaged ~1 serving/d, far from the recommend 3 servings/d or what has been shown to be beneficial for weight loss. Furthermore, mean intakes across tertiles of weight loss (Table 2.3) were not different (0.8-1.0 serving/d). We did encourage our participants to consume only low-fat and fat-free dairy, thus the role of dairy may be related to change in overall energy intake.

E. Dietary and Physical Activity Variables and Waist Circumference Loss

Diet and PA variables have also been associated with decreases in WC. For example, high-fiber diets containing fruits, vegetables, whole grains, and legumes contribute to LED diets (Rolls et al., 2005), and greater decreases in ED have resulted in greater reductions in WC (Ledikwe et al., 2007). Epidemiological research has also found an association between fiber intake and WC. In a epidemiological longitudinal study, Lindstrom et al. (Lindström et al., 2006) found that diets containing >15.55 g fiber/1,000 kcal resulted in a decrease in WC of -2.9 cm over 4 y while diets with <10.88 g/1,000 kcal resulted in decreases of only -0.7 cm. Similarly, Du et al. (2010) found that an increase of 10 g fiber/d was associated with a decrease in WC of 0.8 cm/y over a 6.5y period. Cereal fibers were more associated with a decrease in WC than fruit and vegetable fiber. Other work shows a role for whole grains in WC and abdominal obesity. Mckweon et al. (2010) found that whole grain intake was inversely associated with subcutaneous and visceral adipose tissue, while refined grain was positively associated with these variables. Consistent with this finding, an intervention study by Katcher et al. (2008) emphasizing either all whole grains or only refined grains during energy restriction and weight loss, found that whole grain intake elicited greater decreases in WC compared to refined grain intake (-4.7 cm vs. -2.5 cm, respectively). In our study, those with greater reductions in WC (Table 2.4) consumed approximately one additional whole grain serving/d and 5 g/1,000 kcal more fiber/d, indicating that these variables are indeed areas to further explore as factors that reduce WC.

Dairy servings/d has also been hypothesized to decrease WC. Higher dairy intake has been associated with lower WC measurements in epidemiological studies (Azadbakht, Mirmiran, Esmaillzadeh, & Azizi, 2005). Additionally, consumption of at least 3 servings/d has been shown to be more effective in reducing central abdominal fat than energy restriction alone in intervention research (Zemel, Richards, Mathis, et al., 2005; Zemel, Richards, Milstead, et al., 2005; Zemel et al., 2004). Dairy intake ranged from 0-3 servings/d in our participants during the study. Tertiles showed that those with greater reductions in WC increased their low-fat/fat-free dairy servings/d by 0.7 servings/d, while those with less reductions in WC only increased by 0.3 servings/d (Table 2.4). Again, these results should be interpreted cautiously, as intakes between tertiles were similar during the study (0.7 to 1.0 servings/d). Additionally, our participants were encouraged to switch from regular dairy to low-fat or fat-free, thus the reduction in energy and fat intake may be driving these results.

High-intensity PA (>6 METs) has also been shown to promote decreases in WC. For example, Irving et al. (Irving et al., 2008) found that 16-wk of mod and high-intensity PA (15-17 RPE 3-d/wk; 10-12 RPE 2-d/wk) reduced WC (-5.6 cm vs. -1.2 cm; $p=0.001$) and total abdominal fat (-58 cm^2 vs. -11 cm^2; $p<0.001$) in overweight/obese women significantly more than the mod-intensity group (10-12

RPE 5-d/wk). Trapp et al. (2008) also found that high-intensity interval training (intervals 8sec sprint, 12 sec rest for 20 min) significantly reduced trunk fat in young women, while training at 60% $VO2_{peak}$ did not. A study of overweight older adults by Coker et al (2009) also found that high-intensity exercise reduced abdominal visceral fat (-34 cm^2), while mod-intensity exercise (50% $VO2_{peak}$) did not elicit any changes in abdominal fat. Although regression analysis indicated min/wk in high-intensity Zumba PA was associated with WC, we found similar min/wk of Zumba between those in the highest tertile of WC reduction compared to those in the lowest. However, this is expected because study staff monitored adherence to attendance and HR intensity during Zumba exercise. Thus, all individuals completing the study were compliant with the protocol. Further exploration showed though, that total min/wk of all PA (≥3 METs) increased more and was higher after the study in those with greater reductions in WC compared to those in the lowest tertile (Table 2.4). However, this same finding was not discovered when examining tertiles of BW loss; those that lost more weight did not have greater amounts of total PA (≥3 METs), although energy intake was lower (Table 2.3). This indicates that overall PA level may be particularly important for targeted reductions in WC.

F. Limitations

Although these results indicate that this intervention was effective in reducing BW, WC, and MetS risk factors, it is not without limitations. The outcomes rely on 4-d food records before and after the intervention and 24-h recalls collected during the study, which can contain errors in documenting and reporting food intake. Individuals often underestimate energy intake, which may confound the results. They may also over-report “desirable” food choices (i.e. fruits and vegetables) while under-reporting “undesirable” foods (i.e. added oils and fats). Strategies to reduce errors in reporting were implemented, such as providing food scales to all participants, training study staff to conduct 24-h recalls, and educating participants on weighing, measuring, and estimating portion sizes. Additionally, detailed tracking logs of food intake were completed throughout the study to verify accuracy of 24-h food records.

Other limitations involve PA assessment. At baseline and post-intervention, we had 4-d PA records that captured 24-h activity level. Similarly to reporting energy intake, 4-d PA records can also contain errors due to inaccurate reporting. Additionally, during the study tracking booklets identified only volitional PA. They did not capture other types of PA that were documented in 4-d food records before and after the intervention, such as heavy cleaning, commuting via bicycle, or occupational PA.

Another weakness in the study design is that we only had two groups to analyze, with the original intent of the larger research project to identify the impact of protein only. We did not have a non-exercising control group to identify the additional effect of high-intensity PA alone.

Lastly, our intervention lasted only 16-wk in duration. A longer intervention may be needed to see long-term effects of altering dietary patterns on features of MetS and maintaining weight loss.

G. Future Research

The results of this study provide many opportunities for future research. We did not find protein intake to effect reductions in BW, WC, and MetS risk factors as has been shown in previous work. Future research with longer interventions should examine the impact of adhering to a higher protein diet while also altering habitual dietary patterns and increasing PA (6-12-mo) on weight loss and maintenance. We also did not address differences in satiety between the two groups, and further study in this area may have important implications in long-term weight maintenance.

Identifying beneficial dietary patterns from intervention research is also extremely important. Since the majority of studies reporting dietary patterns are epidemiological, data from intervention studies that determine ED and dietary patterns would add valuable information to the weight loss literature. Inclusion of PA, especially high-intensity PA, into dietary pattern modifications to identify the combined effects of both is also an important area for future work. This also requires that high-intensity exercise be more clearly defined in the literature so that better comparisons can be drawn between studies using this method of exercise.

H. Conclusion

The results of this study show that an intervention focused on LED foods and high-intensity PA significantly reduced BW and WC and improved dietary patterns regardless of protein intake. Rather than focusing on altering macronutrient content alone, weight loss interventions should encourage reductions in dietary ED while incorporating high-intensity PA in those that are able. Helping clients identify a few key factors associated with LED diets that positively change BW and WC may improve weight loss success, while reducing MetS risk factors. For those attempting to lose weight, striving to increase these food groups, rather than focusing on food groups to restrict or eliminate, may promote greater adherence to a weight loss regimen and eating plan.

From this research it is also evident that examination of baseline eating habits is important when making recommendations for weight loss. Based on tertiles of BW and WC reductions, participants that made the greatest increases in fruits, vegetables, whole grains, fiber, and low-fat/fat-free dairy intake started with the lowest intakes. Thus, in individuals with poor baseline dietary patterns, increasing fruits and vegetables and decreasing BEV energy intake may be two simple methods for individuals to reduce energy intake and improve ED. However, if participants start with high intakes of in fruits and vegetables and low intakes of high-energy beverages, they may have to focus on other types of dietary and PA changes and strategies, such as reducing portion size, incorporating more PA, and more closely monitoring energy intake to be successful at weight loss.

Overall, focusing on dietary patterns and high-intensity PA is an effective approach to reduce BW and MetS risk factors in abdominally obese sedentary women. However, future research into improving dietary patterns and increasing high-intensity PA are needed to extend the current findings and identify how nutrition and exercise may interact together to promote health. Long-term intervention studies will identify the best strategies to sustain these changes in dietary patterns and PA to maintain weight loss and reduction in MetS risk factors.

Chapter 3: General Conclusion

The purpose of this study was to determine the effect of two 16-wk diet and PA interventions, differing in protein intakes, on BW, WC, MetS risk factors, dietary patterns, energy density, and level of PA. We hypothesized that the intervention would improve dietary and PA patterns and reduce dietary ED, regardless of protein intake, resulting in reductions in BW and risk factors for MetS.

- **Hypothesis 1:** Compared to baseline, a 16-wk diet and exercise intervention utilizing a low energy dense eating plan and mod-high-intensity exercise will improve diet and PA behaviors during and post-intervention, regardless of protein intake.
- **Outcome 1:** A 16-wk diet and exercise intervention with a low energy dense eating plan and mod-high intensity exercise improved diet (increased fruits and vegetables, whole grains, low-fat/fat-free dairy, and fiber, reduced BEV kcal) and PA behaviors (increased mod [≥3 METs] and high-intensity PA [>6 METs) during and post-intervention. Protein intake did not appear to affect ability to consume a low energy dense diet high in fruits, vegetables, whole grains, low-fat/fat-free dairy, and fiber.
- **Hypothesis 2:** The intervention will lead to a reduction BW, WC, and in risk factors for MetS, regardless of protein intake.
- **Outcome 2:** BW (-4.8±2.7 kg), WC (-7.1±3.6 cm), and triglycerides (-24±52 mg/dL) significantly decreased as a result of the intervention in both protein groups.
    - Secondary research question: What dietary and PA behaviors lead to greater improvements in weight and WC?
    - Other factors that may lead to greater improvements in BW loss and WC reductions include increased fruit and vegetable intake, low-fat/fat-free dairy, whole grains, high-intensity PA, and reduced ED. Further exploration into each of these, is warranted to determine their long-term impact

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APPENDICES

Attachment A: Health History Questionnaire

Age:__________ Date of Birth:________________________(mm/dd/yyyy)

Menstrual History

1. Do you have regular menstrual bleeding? YES NO

If YES:

a. How many cycles per year do you have? ______________

b. When was the start date of your last cycle? ______________

If NO:

a. When was the last time you had any menstrual bleeding or spotting?

- Within the last 6 months
- 7-12 months ago
- Over 12 months ago

b. Have you completed menopause? YES NO

c. Have you had a hysterectomy? YES NO

2. Are you on an effective form of pregnancy prevention? YES NO

If YES, please list form(s)____

3. Have you given birth to any children? YES NO

If YES, please list the year(s):____

Health Assessment

1. How would you rate your overall health at the present time? (Circle One)

Excellent Good Fair Poor

Please complete the following health history table based on diagnoses by a physician:

		Circle YES or NO		Year of Diagnosis	Comments (Resolved, On-going)
I.	**Cardiovascular**				
a	Heart attack	YES	NO		
b	Hypertension (high blood pressure)	YES	NO		
c	Hypotension (low blood pressure)	YES	NO		
d	Angina (chest pain)	YES	NO		
e	Heart murmur	YES	NO		
f	Mitral Valve Prolapsed	YES	NO		
g	Congestive Heart Failure	YES	NO		
h	Rheumatic Fever	YES	NO		
i	Other heart problems:	YES	NO		
II.	**Respiratory**				
a	Shortness of breath	YES	NO		
b	Valley Fever	YES	NO		
c	Pneumonia	YES	NO		
d	Collapsed lung	YES	NO		
e	Emphysema	YES	NO		
f	Tuberculosis	YES	NO		
g	Chronic bronchitis	YES	NO		

h	Asthma	YES NO		
i	Allergies	YES NO		
j	Other respiratory problems:	YES NO		
III.	**Endocrine/Metabolic**			
a	Type I Diabetes Mellitus	YES NO		
b	Type II Diabetes Mellitus	YES NO		
c	High cholesterol	YES NO		
d	Hyperthyroid (overactive thyroid)	YES NO		
e	Hypothryoid (underactive thyroid)	YES NO		
f	Gout	YES NO		
g	Other endocrine/metabolic problems:	YES NO		
IV.	**Musculoskeletal**			
a	Rheumatoid arthritis	YES NO		
b	Osteoarthritis	YES NO		
c	Osteoporosis	YES NO		
d	Fibromyalgia	YES NO		
e	Fractures/dislocations of bones/joints Please list:	YES NO		
f	Bursitis	YES NO		
g	Other musculoskeletal problems:	YES NO		
V.	**Neurological**			
a	Paralysis	YES NO		
b	Multiple Sclerosis	YES NO		
c	Seizures	YES NO		
d	Epilepsy	YES NO		
e	Stroke	YES NO		
f	Parkinson's Disease	YES NO		
g	Transient Ischemic Attack	YES NO		
h	Other neurological problems:	YES NO		
VI.	**Cancers**			
a	Breast	YES NO		
b	Ovary/Uterus	YES NO		
c	Melanoma (Skin Cancer)	YES NO		
d	Lung	YES NO		
e	Leukemia/Lymphoma	YES NO		
f	Colorectal	YES NO		
g	Other Gastrointestinal Cancer:	YES NO		
h	Other Cancer: (Please specify)	YES NO		

Do you have a family history of any of the following health problems? (Circle YES or NO)

Cardiovascular disease	YES	NO
High Blood Pressure	YES	NO
Diabetes	YES	NO
High Blood Lipids	YES	NO
Obesity	YES	NO

Attachment B: Weight, Physical Activity, and Diet History Questionnaire

Weight History

1. Current weight:_____________lbs   Current height:___inches
2. How long have you been at your current weight?_
3. Have you had any weight fluctuations (up or down) of more than 5 pounds in the past 6 months?
   YES   NO
4. What is your highest non-pregnant weight since age 18?__
5. What is your lowest weight since age 18?_______
6. Please check the category which best describes you during:

	Underweight	Normal	Overweight
a) Childhood	________	________	________
b) Teens	________	________	________
c) 20's	________	________	________
d) 30's	________	________	________
e) 40's	________	________	________

Physical Activity History

1. Do you engage in any regular physical activity?   YES   NO

If YES, please complete the following information:

Activity	Time Per Occasion	Times/Week	Intensity
Ex: Walking	30 min	3	Moderate
______________	________	________	________
______________	________	________	________
______________	________	________	________
______________	________	________	________
______________	________	________	________

2. Is the total activity you have recorded your USUAL level of activity?   YES   NO

If NO, why not:
________ a. Illness/injury of self or close relative
________ b. Out of town
________ c. Extra time commitments
________ d. Other: ____________________________

3. Are you unable participate in physical activity for any reason?   YES   NO

If YES, please explain:____

4. Are you unable to participate in strenuous physical activity for any reason?   YES   NO

If YES, please explain:____

5. How active were you 5 years ago compared with today?
________ a. Much more active
________ b. More active
________ c. Same level of activity
________ d. Less active
________ e. Much less active

Diet History

7. Are you on a special diet? (Check all that apply)
   - NO
   - YES, weight loss
   - YES, weight gain
   - YES, diabetic

- YES, vegetarian. If yes, please specify type:______________________
- YES, low salt/sodium
- YES, low fat
- YES, low cholesterol
- YES, for a medical condition. If yes, please specify:________________________
- YES, for other reasons. If yes, please specify:____________________________

Have any of the above diets been recommended to you by a health care professional?
YES NO
If YES, which diets and who recommended them?___________________________________
____

8. Do you consciously limit food choices (e.g. no "bad" foods) to control your weight?
YES NO
9. Do you consciously restrict food intake (calories) in order to control your weight?
YES NO IF YES, do you:
(please check the one that best applies) _______Continuously or chronically diet OR __Go on and off diets regularly
10. How often do you choose the reduced-fat or non-fat versions of a particular food? (Circle one)
NEVER RARELY SOMETIMES OFTEN ALWAYS
11. Are there any foods that you do not eat or eat very frequently?
____
12. What 2 beverages do you currently drink most often? Give amount and frequency for each.
1.____

2.____
13. Do you drink beverages containing alcohol? YES NO
If YES, how many times per week? _______
If YES, please check the types of drinks and list how many you consume each time.
Beer _______ fluid ounces (12 fl oz is 1 can of beer)
Wine _______fluid ounces (5 fl oz is 1 glass of wine)
Liquor _______fluid ounces (1.5 fl oz is 1 shot)
Other ___________________________________

14. Do you drink beverages containing caffeine? YES NO
If YES, please check the types of drinks and list how many you consume each time:
(8 oz = 1 cup; 12 oz = 1.5 cups; 16 oz = 16 oz, etc)
Coffee _______cups/day
Tea _______cups/day
Soda _______cups/day (12 oz = 1 can of soda)
15. Are you taking a vitamin or mineral supplement?
YES NO

If YES, please specify type(s), brand(s), amount(s), and frequency with which you use these supplements:____
If NO, have you used them within the past month?__________ past year?____________
16. Are you currently taking any other type of nutritional or weight loss supplement?
YES NO

If YES, please specify type(s), brand(s), amount(s), and frequency with which you use these supplements:____
____
If NO, have you used them within the past month?__________ past year?____________
17. Who is the primary food preparer and shopper in your household?
Food Shopper: Self Spouse/Significant Other Other________________
Food Preparer: Self Spouse/Significant Other Other________________

Attachment C: Stage of Change Questionnaire

Physical Activity
For each question below, please circle YES or NO regarding your participation in **planned physical activity.** Such activities include, but are not limited to, walking briskly, jogging, bicycling, and swimming, and lead to increased breathing.

1. I am currently physically active?	YES	NO
2. I intend to become physically active in the next 6 months.	YES	NO

In order for **planned physical activity** to be considered **regular**, it must add up to a total of 30 min or more per day and be done at least 5 days per week. For example, you could take one 30-min walk or three 10-min walks each day.

3. I currently engage in **regular** physical activity.	YES	NO
4. I have been regularly physically active for the past 6 months.	YES	NO

Weight Loss
Please check the box beside the answer that best applies to the following question: Are you currently trying to lose weight?

- YES, I have been ACTIVELY trying to lose weight for **MORE than 6 months**
- YES, I have been ACTIVELY trying to lose weight for **FEWER than 6 months**
- NO, but I INTEND to actively try losing weight in the **NEXT 30 days**
- NO, but I INTEND to actively try losing weight in the **NEXT 6 months**
- NO, and I do NOT INTEND to try losing weight in the **NEXT 6 months**

Attachment D: 4-Day Food Record Instructions and Tracking Sheet

Instructions

1. Please record your food & beverage intake over three (3) week days & one (1) weekend day. Each day recorded should correspond with your 4-day physical activity records.
2. Please record each food & beverage item you consume on a separate line. Be sure to include all snacks & all beverages (including water).
3. Please record the time the food/beverage was consumed.
4. Record each item after weighing in exact amounts:

    - liquids in cups or **fluid** ounces
    - vegetables and fruits in cups, grams, or ounces
    - beans, grains, and pasta in cups **dry** or cups **cooked** (please be specific)
    - bread in slices, indicate what kind of bread (brand name and type)
    - meats, fish, poultry and cheeses in ounces
    - nuts in cups, ounces, or grams
    - chips or other snack type foods in cups, ounces, or grams
    - Spread (butter, cream cheese, margarine, etc.) in tsp or Tbs

5. Please specify if food is consumed raw. Also indicate if it was prepared from fresh, frozen, or canned products.
6. Indicate how the foods were prepared, such as fried, baked, boiled, etc.
7. If a food has a mixture of ingredients (sandwich or casserole), list the major ingredients separately in their proportions or amounts.
8. Use brand names whenever possible, or mention comparable brand.
9. For fruits and vegetables, please indicate if the skin was removed.
10. Indicate if dairy products are whole, 2%, 1%, or skim.
11. Be sure to include sauces, gravies, marinades, milk/sugar in coffee, etc.
12. Check food labels for weights, etc. Candy bars, cheeses, cookies, juices are all labeled with their weights -----Write this information down!
13. Provide any other information you feel might be helpful, such as food labels and/or recipes.
14. Record EVERYTHING edible that goes in your mouth.
15. MOST IMPORTANTLY, eat as you normally would -- please don't change your usual eating habits or modify your portion size.

Please measure and weigh all food and beverages you eat throughout the day and write them down as you eat them. Remember to give as many details as possible and keep any food labels if you think it will help describe the food better than you are able to. Providing us with recipes for homemade foods is helpful for us, too. Please list any vitamin or mineral supplements or any other supplements taken on the backside of this form and attach these labels if possible. It's best to be as descriptive as possible!

Meal or Snack	Time	Food or Beverage item	Brand/source (manufacturer)	Type of preparation (bake, boil, fry, etc.)	Amount/Wt (ounces, grams, fluid ounces, cups, tsp, TBS)
Meal	*8:15 am*	*Total Cereal*	*General Mills*	*NA*	*1 oz/1 cup*
M	*8:15 am*	*Light Soy milk, vanilla*	*Silk*	*NA*	*4 fl oz / .5 cup*

Meal or Snack	Time	Food or Beverage item	Brand/source (manufacturer)	Type of preparation (bake, boil, fry, etc.)	Amount/Wt (ounces, grams, fluid ounces, cups, tsp, TBS)

List any vitamin/mineral pills or other supplements here:

Add any additional comments here:

Attachment E: 4-Day Physical Activity Record Instructions and Tracking Log

1. Please maintain your normal activity level -- do NOT increase your activity level or change your normal intensity (how difficult) or duration (how long) of activities.
2. Record all your daily activities for three (3) week days and one (1) weekend day.
3. Please record all activity for the same 24-hour periods as your food intake records, starting at 5am each day and continuing until 5am the next day. Estimate as closely as possible the length of time sleeping as well as length of time for each activity.

   Example:

   Wednesday 5am - Thursday 5am = day 1
   Thursday 5am - Friday 5am = day 2
   Friday 5am - Saturday 5am = day 3
   Saturday 5am - Sunday 5am = day 4
4. Be as prompt as possible when recording your activities. Try to record all daily physical activities on your activity log as soon as you have completed them in **minutes**. Also, be as specific and accurate as possible when recording intensity and length of time the activity was performed.
5. How to estimate intensity:

   Resting = sleeping, watching tv, reading
   Very light = desk work or activities that still allows you to sing a song
   Light = Activity allows you to converse freely and breathing fine (full sentences)
   Moderate = Activity allows you to converse, but you find yourself needing to take a breath every few words (partial sentences)
   Heavy = unable to converse due to exertion level (minimal words)

Example of how to record in log:

			Intensity of Activity (record minutes)				
Clock Time	**Total Minutes**	**Activity Description**	Resting	Very Light	Light	Moderate	Heavy
5:00am - 7:15am	135	sleeping	135				
7:16am - 8:30am	74	Eat, shower, dress		64	10		
8:31am - 8:54am	23	House chores		4	6	10	3
8:55am - 10:59pm	848	walk to work & sit		793	50	5	
11:00pm - 5:00am	360	sleeping	360				
TOTAL = 1440 minutes **Total the minutes for each level of intensity:**			495	861	66	15	3

Clock Time	Total Minutes	Activity Description	Intensity of Activity (allocate minutes)				
			Resting	Very Light	Light	Moderate	Heavy
5:00 AM -							

Total=	1440 minutes	Total Minutes for each level of intensity					

Attachment F: 24-h Food Recall

WHEN	WHERE	FOOD/BEV DESCRIPTION	AMOUNT	PREP METHOD	FOOD/MEAL CODE

Attachment G: Letter for Medical Clearance

Dear Doctor________________________________:

Your patient ____ would like to participate in Losing Inches Through Exercise and Nutrition (LITEN Up!) a diet and exercise research study being conducted by Melinda M. Manore, PhD, RD, CSSD through the Department of Nutrition and Exercise Sciences at Oregon State University. The purpose of the study is to reduce the risk for Metabolic Syndrome and related chronic diseases by reducing body weight and waist circumference through an energy-restricted diet and an exercise program.

The exercise program includes a high intensity interval exercise training program. Each supervised exercise class alternates low-moderate intensity (50-80% HR_{max}) aerobic exercise with high intensity (85-90% HR_{max}) aerobic exercise for a total of 30-60 min, 3 days/week. Participants will also be responsible for unsupervised moderate intensity exercise (e.g. walking) 2 days/week.

Your patient is considered to be at **moderate risk** for cardiovascular events, as defined by the American College of Sports Medicine (ACSM). Any person classified as moderate risk should have a medical clearance before participating in vigorous (i.e. high intensity) exercise.

The purpose of this letter is to notify you that your patient wishes to participate in this study and to obtain your medical opinion regarding her ability to participate. By signing this document, you are not assuming any responsibility for our exercise program.

Physician's Recommendations

	YES, my patient may participate and has no current unstable medical problems that are a contraindication to participating in this exercise program.
	YES, my patient may participate, but I urge caution because:
	NO, my patient should not participate in this program due to her current medical status.

Physician's signature		Date
Physician's name (print)	Phone	Fax
Address	City	State & Zip

Table A.1: Food List: Exchange Method for Diabetes

Food List	Carbohydrate (g)	Protein (g)	Fat (g)	Calories
Carbohydrates				
Starch: breads, cereal, grains, starchy vegetables, crackers, snacks, beans, lentils, peas	15	0-3	0-1	80
Fruits	15	-	-	-
Milk:				
Fat free	12	8	0	80
Low fat, 1%	12	8	3	100
Reduced fat, 2%	12	8	5	120
Whole	12	8	8	160
Sweets, desserts, and other carbohydrates	15	Varies	Varies	Varies
Nonstarchy Vegetables	5	2	-	25
Meat and Meat Substitutes				
Lean	-	7	0-3	45
Medium-Fat	-	7	4-7	75
High-Fat	-	7	8+	100
Plant-based proteins	Varies	7	Varies	Varies
Fats	-	-	5	45
Alcohol	Varies	-	-	100

Table A.2: Sample Menu for 1800 kcal diet with 25% protein

Meal	Food	Exchange	Energy (kcal)	Pro (g)	CHO (g)	Fat (g)
Breakfast	1 cup low fat milk	1 LF dairy	100	8	12	3
	1 cup cooked oatmeal	2 starch	160	3	30	1
	½ banana	1 fruit	60	0	15	0
	Whey Protein*		80	15	2	1
Snack	5 whole wheat crackers	1 starch	80	1.5	15	.5
	1 string cheese	1 pro + 1 fat	90	7	0	7
Lunch	2 slices whole wheat bread	2 starch	160	3	30	1
	2 oz slice turkey	2 protein	90	14	0	1
	½ TB reduced fat mayo	½ fat	22.5	0	0	2.5
	2 cup spinach	1 vegetable	25	2	5	0
	½ cup tomato	½ vegetable	11.5	1	2.5	0
	½ cup carrots	½ vegetable	11.5	1	2.5	0
	½ TB reduced fat dressing	½ fat	22.5	0	0	2.5
	1 small apple	1 fruit	60	0	15	0
Snack	6 oz fat free strawberry yogurt	1 FF dairy + 1 starch	160	8	28	0
	½ banana	1 Fruit	60	0	15	0
	Whey Protein*		80	15	2	1
Dinner	3 oz grilled chicken	3 protein	135	21	0	1.5
	½ cup sweet potato	1 starch	80	1.5	15	.5
	1 ½ cup steamed broccoli	3 vegetable	75	6	15	0
	1 slice whole wheat bread	1 starch	80	1.5	15	.5
	1 TB vegetable oil spread	1 fat	45	0	0	5
Snack	2 small cookies	1 starch + 1 fat	125	1.5	15	5.5
Total	1815 kcal/day			102 g	234 g	34 g
% energy				23%	52%	17%

Table A.3 Definition of Variables for Analysis

Variable	Definition
Vegetable servings	Amounts that count as 1 cup of vegetables (1 cup cooked leafy greens, 1 cup raw vegetables, 2 cups of raw leafy greens, ½ cup 100% vegetable juice). For our purposes, only non-starchy vegetables will be included in the analysis. Starchy vegetables as potatoes, peas, and corn were counted as a starch exchange in the dissertation project.
Fruit servings	Amounts that count as 1 cup of fruit (1/2 large apple or banana, 1 cup grapes, 1 large peach, ½ cup dried fruit). 100% fruit juice will also be considered a fruit although participants were encouraged to consume the majority of fruits in their whole, unprocessed form.
Whole-grain servings	Amounts equivalent to 1 ounce of whole grains (1 regular slice of whole grain bread, 5 whole wheat crackers, ½ whole grain English muffin, ½ cup cooked oatmeal, 1 cup whole grain cereal, ½ cup brown rice, whole grain pasta, bulgar, 1 corn tortilla).
Low-fat/fat-free servings	Amounts equivalent to 1 cup of dairy (1 cup low fat or fat free milk or yogurt, ½ cup ricotta cheese, 1 ½ ounces hard cheese, 2 cups cottage cheese). Using the exchange method, cheese is considered to be in the protein group. We encouraged low-fat or fat-free dairy products and thus will only use these in our analysis. Regular fat and reduced fat cheese, ice cream, and other full fat dairy desserts, will be considered a high-fat dairy product.
Fiber (g)	Grams of fiber will be obtained from the analysis of the 4-d food records and the 24-h recalls.
High calorie beverages	High calorie beverages are those providing excess calories, sugar, fat, or all three with little additional nutritive value. Examples include: sugar sweetened beverages such as soda, energy drinks, flavored coffee drinks, alcoholic beverages, and sugar sweetened fruit beverages (i.e. fruit punch, Sunny Delight).
PA: Moderate	≥3 metabolic equivalents (METs); Heart Rate > 65%max; RPE of 14-16 on Borg Scale, self report of intensity, and individualized target heart rates
PA: High-intensity	> 6 METs; Heart Rate > 85% max; RPE of 17-20 on Borg Scale, self report of intensity, and individualized target heart rate.

Figure A.1: Dietary Exchanges Tracking Tool

Date	S	V	FR	D	P	FA
Daily Target						
Food						
Total						
Balance						
Protein Supplement ☐ ☐ Other Supplements:						

Figure A.2: Physical Activity Tracking Tool

	HR	Time	Intesity	RPE
☐ Zumba				
☐ Other Exercise (describe) ______________				
☐ Non Exercise Day				

Notes:

Body Weight ______________ **Daily Step Count** ______________