

## PART D: SCIENCE BASE

### Section 2: Energy

This section addresses five major questions related to physical activity and energy intake:

1. How is physical activity related to body weight and other nutrition-related aspects of health?
2. How much physical activity is needed to avoid weight regain in weight-reduced persons?
3. What are the optimal proportions of dietary fat and carbohydrate to maintain body mass index (BMI)<sup>1</sup> and to achieve long-term weight loss?
4. What is the relationship between the consumption of energy dense foods and BMI?
5. What is the relationship between portion size and energy intake?

The search strategies used to find the scientific evidence related to Questions 1 through 5, are shown in Appendix G-3. Questions 1, 2, and 3 have been addressed by expert panels that have published evidence-based reviews. Table D2-1 lists the BMI ranges for underweight, normal weight, overweight, and obese individuals.

The Committee conducted a literature search on three additional questions: “Is there a level of activity below which one cannot regulate weight?” “What is the relationship of breakfast consumption to BMI?” and “What is the evidence to support caloric compensation for liquids versus solid foods?” The search on the first question did not result in a sufficient body of evidence to address this topic in this report. The Committee decided that the literature on the latter two questions was not sufficient to make conclusive statements, and these questions are addressed at the end of this section as Unresolved Issues.

The Committee included a strong focus on physical activity and energy expenditure in part because overweight and obesity in the United States among adults and children (Flegal et al., 2002) have increased at an alarming rate. Among adults, the prevalence of obesity has doubled in the past two decades (31 percent of adults have a BMI  $\geq 30$ ) (Flegal et al., 2002). Overweight among children has more than doubled since 1980 (7 to 16.5 percent in 1999–2002), while overweight among adolescents has tripled (5 to 16 percent in 1999–2002) (Hedley et al., 2004; Ogden et al., 2002). Information on differences in the prevalence of obesity by racial/ethnic group appears in Part B, the Introduction.

A high prevalence of overweight and obesity is of great public health concern because excess body fat leads to a much higher risk for premature death and many serious

---

<sup>1</sup> **Body Mass Index** or BMI is a tool for indicating weight status in adults. It is a measure of weight for height. BMI = [Weight in Pounds/(Height in Inches)<sup>2</sup>] x 703 (CDC Web site, <http://www.cdc.gov/nccdphp/dnpa/bmi/bmi-adult-formula.htm>).

disorders, including diabetes mellitus, hypertension, dyslipidemia, cardiovascular disease, stroke, gall bladder disease, respiratory dysfunction, gout, osteoarthritis, and certain kinds of cancers (NIH, NHLBI, 1998; Pi-Sunyer, 1993). A sedentary lifestyle poses risks for premature death; coronary artery disease; hypertension; type 2 diabetes; overweight and obesity; osteoporosis; certain types of cancer; anxiety; depression; decreased health-related quality of life; and decreased cardiorespiratory, metabolic, and musculoskeletal fitness (U.S. Department of Health and Human Services[HHS], 1996).

## **QUESTION 1: HOW IS PHYSICAL ACTIVITY RELATED TO BODY WEIGHT AND OTHER NUTRITION-RELATED ASPECTS OF HEALTH?**

### **Conclusions**

Regular physical activity is essential to the maintenance of a healthy weight and reduces risk for the development of a number of chronic diseases. At least 30 minutes of moderate physical activity on most days provides important health benefits in adults. More than 30 minutes of moderate to vigorous physical activity on most days provides added health benefits. Many adults may need up to 60 minutes of moderate to vigorous physical activity on most days to prevent unhealthy weight gain.

Vigorous physical activity (e.g., jogging or other aerobic exercise) provides greater benefits for physical fitness than does moderate physical activity and burns calories more rapidly per unit of time.

Exercise that loads the skeleton has potential to reduce the risk of osteoporosis by increasing peak bone mass during growth, maintaining peak bone mass during adulthood, and reducing the rate of bone loss during aging.

Resistance exercise training increases muscular strength and endurance and maintains or increases lean body weight. These benefits are seen in adolescents, adults, and older adults who perform 8 to 10 resistance exercises 2 or more days per week.

Children and adolescents need at least 60 minutes of moderate to vigorous physical activity on most days for maintenance of good health and fitness and for healthy weight during growth. Reducing sedentary behaviors, including television and video viewing time, appears to be an effective way to treat and prevent overweight among children and adolescents.

### **Rationale**

#### **Adults**

These conclusions are based on the Committee's systematic review of 36 longitudinal studies and 2 intervention studies addressing this issue (see Appendix G-3).

#### ***Physical Activity and the Prevention of Excessive Weight Gain***

Overweight and obesity result from inadequate physical activity and/or excess calorie consumption. A sedentary lifestyle is a lifestyle characterized by little or no physical

activity. Data suggest that physical activity levels are low for most Americans. For example, beyond the light activity of day-to-day living, in 2002, 38 percent of adult Americans engaged in no leisure-time physical activity (NHIS, 2002).

Thirty of 36 longitudinal studies (Appendix G-3) show an inverse relationship between physical activity and overweight status. Of six of the remaining longitudinal studies, five show no significant relationship between physical activity and weight status, and one (Bild et al., 1996) found an increase in body weight associated with a large amount of vigorous physical activity at baseline.<sup>2</sup>

The role of physical activity in the prevention of weight gain was studied in a systematic review of 16 observational studies (Fogelholm and Kukkonen-Harjula, 2000). In a separate systematic review, Erlichman and colleagues (2002) included studies only if they could estimate the Physical Activity Level equivalent (PAL) of the specified activities as a means of standardizing their approach. An expert panel convened by the International Association for the Study of Obesity (IASO)<sup>3</sup> reviewed the evidence presented by Erlichman et al. (2002). That panel concluded that approximately 45 to 60 minutes of moderate intensity daily physical activity is needed to prevent the transition from a healthy weight to overweight or from overweight to obesity (Saris et al., 2003).<sup>4</sup> Table D2-2 gives examples of moderate physical activities.

Based on an extensive compilation of cross-sectional doubly-labeled water studies in humans, the Institute of Medicine (IOM)(2002) reported that two-thirds of adults who maintain energy balance expended an equivalent amount of energy to that which would be expended by engaging in 60 minutes per day at moderate intensity. Thus, it appears that many adults need up to 60 minutes per day of at least moderate intensity physical activity to prevent unhealthy weight gain (IACR,<sup>5</sup> 2002; IOM,<sup>6</sup> 2002; Saris et al., 2003).

---

<sup>2</sup> Vigorous physical activity, such as running 5 miles per hour, is any activity that burns more than 7 kcal per min or the equivalent of 6 or more metabolic equivalents (METs) and results in achieving 74 to 88 percent of a person's peak heart rate.

<sup>3</sup> The International Association for the Study of Obesity is a professional organization concerned with obesity that works in more than 50 countries around the world. Its membership is drawn from national associations of clinicians, scientists and allied health professionals. As a nongovernmental organization, IASO collaborates with the World Health Organization and other NGOs including the International Diabetes Federation, the World Hypertension League, the World Heart Federation, the International Union of Nutritional Sciences, the International Pediatric Association and the International Federation for the Surgery of Obesity.

<sup>4</sup> Moderate physical activity, such as walking 3.5 miles per hour) is any activity that burns 3.5 to 7 kcal per minute or the equivalent of 3 to 6 METs and results in achieving 60 to 73 percent of the person's peak heart rate

<sup>5</sup> The International Agency for Research on Cancer (IARC) is part of the World Health Organization. IARC's mission is to coordinate and conduct research on the causes of human cancer, the mechanisms of carcinogenesis, and to develop scientific strategies for cancer control. The Agency is involved in both epidemiological and laboratory research and disseminates scientific information through publications, meetings, courses, and fellowships.

<sup>6</sup> The Institute of Medicine is a component of the National Academies. The objective in all their work is to improve decision making by identifying and synthesizing relevant evidence to inform the deliberative process. The Institute provides unbiased, evidence-based, and authoritative information and advice

### **Physical Activity and Physical Fitness**

Physical fitness is a multi component trait related to the ability to perform physical activity. The components of physical fitness include cardiorespiratory endurance, muscular strength and endurance, and flexibility. Regular participation in physical activity maintains or increases physical fitness. However, the effects of activity on fitness are specific to the types of physical activity performed. Regular participation in sustained large-muscle activity (e.g., brisk walking, jogging, cycling, swimming) increases or maintains cardiorespiratory fitness. Resistance exercise (e.g., weight lifting, callisthenic exercises) increases muscular strength and endurance, and stretching exercises promote maintenance of joint flexibility. Maintenance of good physical fitness enables one to meet the physical demands of work and leisure comfortably. Compared with their low-fit counterparts, persons with higher levels of physical fitness are at lower risk of developing chronic disease (Blair et al., 1989, 1995).

### **Physical Activity and Other Aspects of Health**

The consensus public health recommendation for physical activity in adults— at least 30 minutes of at least moderate intensity physical activity daily—was developed with a primary focus on the chronic disease risk reduction and fitness enhancement effects (HHS, 1996; Pate et al., 1995). Most authorities also acknowledge that vigorous physical activity for at least 20 minutes on at least 3 days per week is another appropriate way to perform physical activity for health and fitness (ACSM,<sup>7</sup> 1998). Examples of vigorous physical activities appear in Table D2-3. The health benefits of regular physical activity include the reduction of risk of a number of chronic conditions and diseases that relate to diet as well. Among these are high blood pressure, stroke, coronary artery disease, type 2 diabetes, colon cancer, and osteoporosis. (Pate et al., 1995; Shephard, 2001).

Decreases in blood pressure and the prevention of stroke seem best achieved by a moderate rather than a high intensity of physical activity (Shephard, 2001). Vigorous intensity seems necessary to augment bone health (HHS, 1996; Pate et al., 1995). Although some health benefits are dependent on the intensity of physical activity (i.e., moderate or vigorous), most aspects of metabolic health depend on the total volume of activity. That is, vigorous physical activity can have greater effects than moderate physical activity of the same duration, but it is the combination of intensity (moderate or vigorous) and the duration of this activity that affects both caloric expenditure and overall health (Kesaniemi et al., 2001; Shephard, 2001).

Physical inactivity is an *independent* risk factor for atherosclerotic cardiovascular disease, type 2 diabetes, colon cancer, and other chronic diseases (American Heart

---

concerning health and science policy to policymakers, professionals, leaders in every sector of society, and the public at large.

<sup>7</sup> Position Stands are official statements of the American College of Sports Medicine (ACSM) on topics related to sports medicine and exercise science. Position Stands are based on solid research and scientific data and serve as a valued resource for professional organizations and governmental agencies. Position Stands are first published in the College's scientific journal, *Medicine & Science in Sports & Exercise*.

Association, 1992; HHS, 1996). Increases in physical activity are associated with reduced risk of chronic disease and mortality from all causes (Blair et al., 1995; Paffenbarger et al., 1993), and this effect is mediated by numerous physiological adaptations including improvements in weight status and body composition. However, the health effects of physical activity and physical fitness are not explained primarily by its effect on body weight. Overweight persons derive important health benefits from maintaining good levels of physical activity and physical fitness (Lee et al., 1999).

### ***Resistance Exercise Training***

Resistance exercise (e.g., weight training, using weight machines, callisthenic exercises, and resistance band activities) increases muscular strength and maintains or increases lean muscle mass in persons of all ages (ACSM, 2002). In the elderly, resistance exercise assists in balance and locomotion, thereby reducing the risk of falling (Evans, 1999). The health benefits of resistance exercise accrue to those who perform, on 2 or more days per week, 1 or more sets of 8 to 10 exercises that condition the major muscle groups.

### ***Exercise and Bone Health***

Building maximal peak bone mass during growth and minimizing the loss of bone during one's later years are strategies for reducing the risk of fracture. Rapid accrual of bone mass occurs during puberty (Bailey et al., 1999) and continues throughout adolescence and into young adulthood (Heaney et al., 2000). Approximately 20 to 50 percent of the variation in bone mass is thought to be modified by lifestyle choices including physical activity and nutrition.

Bone adapts to the loads applied to it (Frost, 1990; Rubin and Lanyon, 1985). The skeletal response to exercise is greatest in people who are least active. Loading can occur by gravitational forces and muscle pull. A systematic review of weight-bearing physical activity intervention studies in children and adolescents showed a positive effect on bone mass (French et al., 2000). Pediatric studies relating exercise and bone gain reviewed by the Committee are summarized in Appendix G-3. Thirteen of 15 physical activity intervention trials in children show a positive effect of exercise intervention on one or more bone sites. Exercise interventions have greater impact on bone mass if initiated during prepubertal years than later in life. Perhaps even more importantly, in children exercise can lead to changes in bone geometry that can confer greater strength (Bass et al., 2001; Haapasalo et al., 1996; Specker and Binkley, 2003).

Weight-bearing exercise also appears to be important in preserving peak bone mass in adulthood. Relatively short-term (<2 year) intervention studies and epidemiological studies show mixed results (Singh, 2004). All seven meta analyses of controlled trials of exercise and bone in pre- and postmenopausal women show increases in bone mineral density at the lumbar spine of approximately 1 to 1.5 percent per year with aerobic and resistance training (Berard et al., 1997; Kelley et al., 2001; Kelley 1998a, 1998b, 1998c; Wallace and Cummings, 2000; Wolff et al., 1999) (Appendix G-3).

A physically active lifestyle that includes regular participation in weight-bearing exercise is beneficial to weight management, fitness, and bone health. Hip fracture incidence was

30 to 50 percent lower in adults with a history of daily physical activity than in sedentary individuals (Coupland et al., 1993; Cummings et al., 1995; Farmer et al., 1989). For example, in 9,704 women over age 65 participating in the *Study of Osteoporosis Fracture*, the incidence of fracture over 7.6 years was 27 percent lower with low-intensity activity and 45 percent lower with moderate physical activity (Gregg et al., 1998).

Specific recommendations for the type, frequency, intensity, and duration of exercise should be individualized with respect to lifestage and health (Singh, 2004). Because the effects of loading are site specific and load dependent (Kerr et al., 1996), the most effective types of physical activity for bone health are weight-bearing exercises such as jogging, walking, aerobics, stair climbing, and strength training (Kohrt et al., 1997; Nelson et al., 1991; Snow-Harter et al., 1992). Extreme exercise that leads to growth plate injury or estrogen-deficiency associated with amenorrhea is detrimental to bone (Forwood and Burr, 1993).

### **Children**

Two types of evidence are available related to physical activity and weight status in children: considerations of amounts of physical activity consistent with a healthy body weight and studies of sedentary activity (mainly television viewing).

#### ***Increasing Physical Activity***

Although the relevant scientific literature is limited, most expert panels have come to consensus that children and youth need at least 60 minutes of moderate to vigorous physical activity per day on most days of the week to help promote healthy growth and development and to help avoid unhealthy weight gain (Cavill et al., 2001). This recommendation considers the increasing prevalence of overweight among children and their current physical activity levels: most children and youth already engage in 30 minutes of physical activity daily, but many do not meet a 60-minute standard (Biddle et al., 1998; Kimm et al., 2002).

#### ***Television Viewing***

The average child or adolescent watches nearly 3 hours of television per day, not including time spent watching videotapes or playing video games (Nielsen, 1998). A 1999 study of a large nationally representative sample found that 2- to 18-year-olds spend an average of 5 hours and 29 minutes per day with various media combined (Roberts et al., 1999). The prevalence of overweight has been shown consistently to be directly related to the amount of time children and adolescents watch television (Andersen et al., 1998; Berkey et al., 2000; Deheeger et al., 1997; Dietz and Gortmaker, 1985; DuRant et al., 1994; Gortmaker et al., 1996; Grund et al., 2001; Guillaume et al., 1997; Hanley et al., 2000; Hernandez et al., 1999; Maffei et al., 1998; Muller et al., 1999; Ross and Pate, 1987, Sallis et al., 1995); and reductions in television and video viewing time appear to be effective strategies to treat and prevent overweight. One school-based study demonstrated a 2 percent decrease in the prevalence of overweight over the course of two school years as a result of a curriculum that focused on reduced television viewing time (Gortmaker et al., 1999). A second school-based study demonstrated reduced rates of

weight gain in children who reduced television time (Robinson, 1999). The American Academy of Pediatrics recommends limiting television and video viewing to a maximum of 2 hours per day as a strategy to prevent overweight in children (AAP, 2003).

### **Pregnancy**

Epidemiologic data suggest that physical activity may be beneficial in the primary prevention of gestational diabetes, particularly in pregnant women with a prepregnancy BMI > 33 (ACOG, 2002; Dempsey et al., 2004; Dye et al., 1997). Rössner (1999) reported smaller increase in skinfold measurements in pregnant women who exercised, indicating less gain in body fat by those who exercised than by those who did not. The physiologic and morphologic changes of pregnancy may interfere with a woman's ability to engage safely in some forms of physical activity. Activities with a high risk of falling or of abdominal trauma should be avoided during pregnancy. In the absence of either medical or obstetric complications, 30 minutes or more of moderate physical activity per day on most, if not all, days of the week is recommended for pregnant women (ACOG, 2002).

### **Lactation**

Dewey et al. (1991) have shown that the level of physical activity of the nursing mother does not affect lactation. Neither acute nor regular exercise has adverse effects on a mother's ability to successfully breastfeed successfully (Larson-Meyer, 2002).

### **Older Adulthood**

Participation in a regular program of physical activity is an effective method to reduce a number of declines in function that are associated with aging and can help in the management of weight and constipation and the prevention of osteoporosis. Endurance training can help maintain and improve various aspects of cardiovascular function. Strength training helps offset the loss in muscle mass and strength typically associated with aging. Even octo- and nonagenarians have demonstrated the ability to adapt to both endurance and strength training. Strength training can improve bone health, increase muscle mass, and improve postural stability thus reducing the risk of falling and associated injuries and fractures (ACSM, 1998).

## **QUESTION 2: HOW MUCH PHYSICAL ACTIVITY IS NEEDED TO AVOID WEIGHT REGAIN IN WEIGHT-REDUCED PERSONS?**

### **Conclusions**

Although the contribution of physical activity to weight loss usually is modest, acquiring a routine of regular physical activity will help an adult to maintain a stable body weight after successful weight loss. The amount of physical activity that weight-reduced adults need to avoid weight regain is estimated to be from 60 to 90 minutes daily at moderate intensity.

### **Rationale**

This conclusion is based on the Committee's review of cross-sectional data from the National Weight Control Registry, two metabolic studies using the doubly-labeled water

(DLW) technique, and a published extensive systematic review of observational studies and randomized clinical interventions. Overall, studies have shown that individuals who follow a regular regimen of physical activity after they lose weight are much more likely to maintain their lower weight than those who rely only on diet control, as described below (see Appendix G-3 for a summary of relevant studies).

Cross-sectional data from the National Weight Control Registry show that individuals who have maintained a weight loss of approximately 30 kg for about 6 years participate in a large amount of leisure-time physical activity (2,545 kcal per week of physical activity for women and 3,293 kcal per week for men) (McGuire et al., 1999). This amount of physical activity is comparable to about 60 to 90 minutes per day of moderate intensity physical activity, such as brisk walking (Wing and Hill, 2001). The reported calorie expenditure of the weight maintainers was 450 kcal per day more than that of the persons who had regained the weight they had lost ( $P=0.02$ ), showing that the inclusion of a physical activity regimen helps to maintain reduced weight.

Metabolic studies using the DLW technique can provide useful estimates of an individual's level of physical activity. Using this approach to estimate the physical activity levels of a group of 32 women after weight loss, Schoeller and colleagues (1997) reported that weight was maintained for 1 year when the subjects averaged the equivalent of 80 minutes of moderate activity every day. Another study using DLW to estimate the physical activity level reported similar results: the weight-reduced subjects maintained their weight for 1 year when they engaged in moderate activity for 77 minutes per day, but those who engaged in much less physical activity regained weight (Weinsier et al., 2002). The results of these studies are consistent with the findings from the National Weight Control Registry reported above.

The role of physical activity in the prevention of weight regain was studied in a systematic review both of observational studies and randomized clinical interventions (Fogelholm and Kukkonen-Harjula, 2000). Nineteen studies with a nonrandomized weight reduction phase and an observational followup were reviewed. Of these, 16 studies found an inverse relationship between physical activity and weight regain, and 3 found no significant relationship. The design of several of these studies (Ewbank et al., 1995; Hartman et al., 1993; Schoeller et al., 1997) allowed estimation of the difference in energy expenditure of the low- and high-exercise groups. In particular, the difference ranged from 1,300 to 2,000 kcal per week. The low-activity group gained approximately 5 to 8 kg more per year than did the high-activity group. Fogelholm and Kukkonen-Harjula (2000) also reviewed reports of three interventions involving physical activity during the weight maintenance phase. The results were inconsistent. Leermakers et al. (1999) reported that the exercise group gained *more* weight than the weight-focused group. Fogelholm et al. (2000) found that the moderate walking group gained less weight than the control group, but the heavy walking group did not differ from the control group. Perri et al. (1989) reported that the weight regain of the extended treatment group did not differ from that of the standard group at 20 weeks, but the extended treatment group showed significantly greater mean weight loss at 40 and 72 weeks. Since the weekly amount of prescribed physical activity in these trials varied from 80 to 300 minutes per



week (about 11 to 43 minutes per day), the amount of physical activity may have been too small to have a statistically significant effect on weight maintenance. When looking at the full body of evidence, Fogelholm and Kukkonen-Harjula (2000) concluded that the physical activity equivalent of 1,500 to 2,000 kcals per week is associated with weight maintenance. This range of calories is equivalent to approximately 60 to 90 minutes of moderate physical activity per day.

Finally, an expert panel convened by the International Association for the Study of Obesity reviewed the existing studies, including the systematic review by Fogelholm and Kukkonen-Harjula (2000). The panel concluded, “there is compelling evidence that prevention of weight regain in formerly obese individuals requires 60 to 90 minutes of moderate intensity activity or lesser amounts of vigorous intensity activity” (Saris et al., 2003).

Thus, a broad range of evidence supports a recommendation that weight-reduced persons take part in 60 to 90 minutes of moderate physical activity daily to maintain their lower body weight and avoid regain of weight. This is a longer duration of physical activity than is needed by never-obese persons to avoid weight gain.

### **QUESTION 3: WHAT ARE THE OPTIMAL PROPORTIONS OF DIETARY FAT AND CARBOHYDRATE TO MAINTAIN BMI AND TO ACHIEVE LONG-TERM WEIGHT LOSS?**

#### **Conclusions**

Weight maintenance depends on a balance of energy intake and energy expenditure, regardless of the proportions of fat, carbohydrate, and protein in the diet. Weight loss occurs when energy intake is less than energy expenditure, also regardless of the proportions of fat, carbohydrate, and protein in the diet. For adults, well-planned weight loss diets that are consistent with the Accepted Macronutrient Distribution Ranges (IOM, 2002) for fat, carbohydrate, and protein can be safe and efficacious over the long term. The recommended ranges for fat calories (20 to 35 percent of total calories), carbohydrate calories (45 to 65 percent of total calories), and protein calories (10 to 35 percent of total calories) provide sufficient flexibility to accommodate weight maintenance for a wide variety of body sizes and food preferences.

#### **Rationale**

These conclusions are based on the Committee’s consideration of short- and long-term intervention studies reviewed by an expert IOM Committee (IOM, 2002). Additionally, this Dietary Guidelines Advisory Committee conducted a systematic review of the scientific literature published since 1999 (after the conclusion of the IOM review). The search covered intervention and longitudinal studies, and the results included 12 clinical trials and 3 observational studies. (See Table D2-4 for intervention studies up to the year 2000; and see Appendix G-3 for a summary of relevant results of the search of publications after 1999.)

## **Weight Reduction**

**Background Information.** A sound long-term weight loss plan includes a reduction of caloric intake, the intake of recommended amounts of nutrients, and increased physical activity. Lifestyle change in diet and physical activity is the best first choice for weight loss. (See “Supplemental Information—Scientific Support for Weight Loss and Weight Management Recommendations” below for Federal guidelines for weight reduction.)

Diets balanced in macronutrients have traditionally been recommended for weight loss (American Heart Association, 2001; Frantz et al., 2002; NIH, NHLBI, 1998; St. Jeor et al., 2001). Numerous studies attest to their efficacy (Diabetes Prevention Program Research Group, 2002; Tuomilehto et al., 2001; Wing and Hill, 2001). However, many persons are going on very-low carbohydrate or very-low fat diets. These popular weight-loss diets encompass a very wide range of carbohydrate/fat ratios, ranging from less than 10 percent of calories from fat to more than 50 percent of calories from fat. They have not been tested adequately over the long-term and are best followed only for short periods of time.

**Low-Carbohydrate, High-Fat Diets.** The propounded theory behind low-carbohydrate, high-fat diets is that a drastically reduced carbohydrate intake will lower insulin levels, allow uninhibited lipolysis, increase fat oxidation, initiate ketone production, and decrease appetite (Atkins, 1999). Another expectation of diets with an extremely low ratio of carbohydrate to fat is that they will facilitate compliance and increase water losses. Five randomized controlled trials (Brehm et al., 2003; Fleming, 2002; Foster et al., 2003; Samaha et al., 2003; Westman et al., 2002) recently have compared weight loss after 6 months to a year on diets that have low carbohydrate-to-fat ratios with weight loss on more balanced diets. The low-carbohydrate diets initially provided less than 20 to 30 g of carbohydrate per day (followed by 40 to 60 g of carbohydrate per day after the first 2 weeks in both Brehm et al. (2003) and Foster et al. (2003)). Control diets provided 60 percent of calories from carbohydrate, 25 to 30 percent of calories from fat, and 15 percent of calories from protein (Brehm et al., 2003; Fleming, 2002; Foster et al., 2003; Samaha et al., 2003; Westman et al., 2002). All studies found that the low-carbohydrate diets produced greater initial weight loss, but the difference was modest. For example, Foster and colleagues (2003) reported that mean weight loss at 6 months was 7.0 percent below baseline for those on the low-carbohydrate diet compared with 3.2 percent below baseline for those on the control diet. At 18 months, however, there was no statistically significant difference in weight loss. Some of the early weight loss on a low-carbohydrate diet is due to water loss (Yang and Van Itallie, 1976; Bortz et al., 1967). Whether the remaining difference in initial weight loss is due to a lower energy intake, a larger energy expenditure, or a combination of the two is not known. In any case, differences in weight loss tend to diminish, and by 12 to 18 months no real difference remains.

The long-term safety of any diet needs to be considered. Unfortunately, only short-term data (6 to 12 months) are available for these diets. Within this period of followup, no evidence of serious adverse effects has been published. However, the diets require that

dietary supplements be taken regularly because the diets are low in vitamins E, A, thiamin, B<sub>6</sub>, and folate; calcium; magnesium; iron; potassium; and dietary fiber (Freedman et al., 2001). Very-low-carbohydrate diets often include a high percentage of protein along with the high percentage of fat. Usually, this includes large amounts of animal protein, which adds substantially to the saturated fat and cholesterol intake. A recent study has cautioned that such diets also can lead to a high urinary calcium loss and kidney stones (Reddy et al., 2002). Uric acid production is increased and may lead to elevated blood uric acid concentrations. There are very few long-term trials of high-protein weight loss diets. Skov et al. (1999) showed a greater weight loss with a higher protein diet (25 percent of total energy) than with a lower protein diet (12 percent of total energy) (loss of 8.9 kg and 5.1 kg, respectively) over 6 months. Another study, 10 weeks long, showed no difference in the body composition, cholesterol, triglycerides, uric acid, percent body fat, or nutrient intake in sedentary, overweight women following 1,200 calorie diets with varying macronutrient distributions (Alford et al., 1990). Interestingly, blood lipid values in the various studies of high-fat diets were found to have improved at least as much as in the lower-fat control diets (Foster et al., 2003; Samaha et al., 2003). LaRosa et al. (1980), however, reported an increase in serum low-density lipoprotein (LDL) cholesterol on a high-protein/high-fat diet.

The concern regarding the long-term safety of high-fat, low-carbohydrate diets is warranted given that (1) they have a high saturated fat, high cholesterol, and low fiber content;<sup>8</sup> (2) they result in a very low intake of fruits, vegetables, and grains (which could lead to deficiencies in essential vitamins, minerals, and fibers over the long-term); and (3) they originally were designed for short-term use during a weight loss period and have not been evaluated long-term.

**High-Carbohydrate, Low-Fat Diets.** A diet with a high-carbohydrate/fat ratio (that is, a very low-fat diet) has been popularized by Ornish (1990) and Pritikin (1988). This diet suggests decreasing fat intake to about 10 percent of calories, keeping protein at 15 percent of calories, and eating about 75 percent of calories as carbohydrates. The high-carbohydrate content is compatible with achieving more than the recommended intake of fruits, vegetables, and fiber. However, the very-low fat content may increase the risk of essential fatty acid deficiency (IOM, 2002) and may reduce the bioavailability of some fat-soluble vitamins (IOM, 2002; Roodenburg et al., 2000). In a weight-loss study Mueller-Cunningham et al. (2003) prescribed a diet with less than 15 percent of total calories from fat and reported a decrease in the intakes of vitamin E (as  $\alpha$ -tocopherol) and of n-3 fatty acids. Freedman et al. (2001) described these high-carbohydrate/low-fat diets as being low not only in vitamin E, but also in vitamin B<sub>12</sub> and zinc. The other negative consequence of a low-fat diet is that it usually is a high-carbohydrate diet, which can lead to increased levels of triglycerides (see Part D, Section 4, “Fats”).

### **Weight Maintenance**

For weight maintenance, the desirable diet is one that prevents weight gain, meets nutrient needs, and can be consumed for a long time without adverse effects. One of the

---

<sup>8</sup> The negative consequences of high saturated fat and cholesterol intake is discussed in Part D, Section 4 of this report. The negative consequences of low fiber intake is discussed in Part D, Section 5 of this report.

questions is how much fat should be in such a diet. The majority of observational studies and surveys support an association between dietary fat intake and BMI. Bray and Popkin (1998) summarized data from a variety of populations in more than 20 countries and reported an association between greater fat intake and higher BMI. However, Willett (1998) points out that this relationship is not consistent across countries and that the effect of fat intake on BMI is rather minor.

For adults, the Acceptable Macronutrient Distribution Ranges (AMDRs) for fat, protein, and carbohydrate are estimated to be 20 to 35 percent, 10 to 35 percent, and 45 to 65 percent of energy, respectively (IOM, 2002). The upper range for fat, 35 percent of total calories, is based on the increased risk of overconsuming calories and of obesity with fat intakes above that range (Astrup et al., 2000; Saris et al., 2000; Shepard et al., 2001; Tremblay et al., 1991). Thus, diets with very-low carbohydrate to fat ratios (i.e., diets high in fat) may not be desirable for weight maintenance. The lower limit of fat recommended 20 percent of calories and aims at avoiding (1) fatty acid deficiency when fat intake is too low (Mueller-Cunningham et al., 2003), and (2) excess carbohydrate intake, which may have adverse effects on the blood lipid profile (see Part D, Section 4, “Fats”).

Both the low-carbohydrate diet and the low-fat diet limit the variety of foods that can be eaten and, therefore, may be difficult to follow long-term (Foster et al., 2003). This probably explains the extremely high dropout rates in studies of these diets. There is insufficient evidence to make recommendations for or against the use of these diets for weight loss, but there is great concern about their long-term use for weight maintenance (Bravata et al., 2003).

Although both low-fat diets and low-carbohydrate diets have been shown to result in weight reduction if followed, the maintenance of a reduced weight ultimately will depend on a change in lifestyle from the one that resulted in the need for weight reduction to one that meets nutrient needs while maintaining a balance between energy consumption and energy expenditure (Freedman et al., 2001).

### ***Special Groups***

***Pregnant Women.*** Weight gain rather than weight maintenance or weight loss is indicated for pregnant women. The IOM has recommended the following gains in weight for women according to their prepregnancy BMI: (1) underweight (BMI <19.8), 28 to 40 pounds; (2) normal weight (BMI 19.8–26.0), 25 to 35 pounds; (3) overweight (BMI 26–29), 15 to 25 pounds; (4) obese (BMI >29), at least 15 pounds (IOM, 1990). For the obese woman, the amount of weight gain should not exceed 20 pounds. It is important for the pregnant woman to get adequate protein (71 g per day) (IOM, 2002). A low-protein intake during pregnancy is associated with a higher incidence of low-birth-weight infants and should be avoided (IOM, 2002). However, taking too much protein also is unwise. Randomized controlled studies have shown that supplementary protein can decrease birth weight and increase mortality (Rush et al., 1980; Sloan et al., 2001). In addition, the Recommended Dietary Allowance (RDA) for carbohydrate for pregnant

women is 175 g per day (IOM, 2002), and is important for prevention of hypoglycemia. Thus, a low-carbohydrate high-protein diet is not appropriate during pregnancy. AMDRs for protein and carbohydrate intake for pregnant women are 10 to 35 percent and 45 to 65 percent, respectively (IOM, 2002).

**Lactation.** Moderate weight reduction while breastfeeding is safe and does not compromise weight gain of the infant (ACOG, 2002). The RDA for protein for breastfeeding women is 71-g per day (IOM, 2002). The RDA for carbohydrate increases during lactation to 210 g per day (IOM, 2002). AMDRs for protein and carbohydrate intake for breastfeeding women are 10 to 35 percent and 45 to 65 percent respectively (IOM, 2002).

## **SUPPLEMENTARY INFORMATION—SCIENTIFIC SUPPORT FOR WEIGHT LOSS AND WEIGHT**

### **Management Recommendations**

The National Heart, Lung, and Blood Institute, in cooperation with the National Institute of Diabetes and Digestive and Kidney Diseases, released the first Federal guidelines on the identification, evaluation, and treatment of overweight and obesity using an evidence-based model and methodology (NIH, NHLBI, 1998). The guidelines present recommendations for the assessment of overweight and obesity and establish principles of safe and effective weight loss.

The guidelines' definition of overweight is based on research that relates BMI to the risk of death and illness. The 24-member expert panel that developed the guidelines identified overweight as a BMI of 25 to 29.9 and obesity as a BMI of 30 and above, which is consistent with the definitions used in many other countries. BMI describes body weight relative to height and is strongly correlated with total body fat content in adults. According to the guidelines, a BMI of 30 is about 30 pounds overweight and is equivalent to 221 pounds in a 6' person and to 186 pounds in someone who is 5'6". The BMI values apply to both men and women. Some very muscular people may have a high BMI without health risks, but they represent a very small percentage of the population.

Also recommended in the guidelines is the determination and tracking of waist circumference, which is strongly associated with abdominal fat. Excess abdominal fat is an independent predictor of disease risk. A waist circumference of over 40 inches in men and over 35 inches in women signifies increased risk in those whose BMI is 25 to 34.9.

According to the guidelines, the most successful strategies for weight loss include calorie reduction, increased physical activity, and behavior therapy designed to improve eating and physical activity habits. Recommendations regarding the goal and rate of weight loss follow:

- The initial goal of treatment should be to reduce body weight by about 10 percent from baseline, an amount that reduces obesity-related risk factors. With success, and if warranted, further weight loss can be attempted.

- A reasonable timeline for a 10 percent reduction in body weight is 6 months of treatment, with a weight loss of 1 to 2 pounds per week.

#### **QUESTION 4: WHAT IS THE RELATIONSHIP BETWEEN THE CONSUMPTION OF ENERGY DENSE FOODS AND BMI?**

##### **Conclusions**

Available data are insufficient to determine the contribution of energy dense foods to unhealthy weight gain and obesity. However, consuming energy dense meals may contribute to excessive caloric intake. Conversely, eating foods of low energy density may be a helpful strategy to reduce energy intake when trying to maintain or lose weight.

##### **Rationale**

This conclusion is supported by the Committee's review of six short-term studies, one longitudinal study, and two longer-term randomly controlled trials, as summarized below.

The energy density of a food (kcal/100 g) depends on its content of fat, carbohydrate, protein, and water. Of particular importance are the content of fat (which provides twice the calories per g compared to carbohydrate and protein) and of water (which provides no calories). The air content of foods contributes to their volume rather than to their energy density.

##### **Short-Term Studies**

Short-term studies (ranging in length from a single test meal to 5 days of feeding) consistently demonstrate that the *ad libitum* consumption of foods results in significantly higher total energy intakes when the food offered is high in energy density than when it is low in energy density (Bell et al., 1998; Bell and Rolls, 2001; Duncan et al., 1983; Rolls et al., 1999a; Stubbs et al., 1998). In a study by Duncan et al. (1983), satiety ratings from low energy density (LED) and high energy density (HED) meals were compared in a group of obese and nonobese subjects. Individuals on the LED diet reached satiety at a mean daily energy intake that was one-half that of the mean daily energy intake of the individuals on the HED diet (1,570 versus 3,000 kcal). This higher intake of energy for those consuming HED meals *ad libitum* has been attributed to a delay in the development of satiety with more energy-dense foods (Duncan et al., 1983; Rolls et al., 1999a). In the Duncan study, the energy density of the HED diet was approximately twice that of the LED diet. Thus, in consuming half the mean daily energy intake of the HED, those on the LED consumed roughly the same amount of food (by weight) as those on the HED diet.

In the studies discussed in the above paragraph, the LED and HED diets varied from each other in macronutrient distribution. Results similar to those reported above were obtained in studies in which energy density was manipulated without altering the macronutrient distribution. This was achieved through covert changes in energy density (Rolls et al., 1999a; Stubbs et al., 1998) or by increasing the water content of foods (Rolls et al., 1999b). Therefore, the short-term effects of energy density on satiety, total energy intake, and body weight are not necessarily dependent on the fat or carbohydrate content

or the percentage of fat or carbohydrate calories in the meal. In most studies, protein and fiber are held constant.

The lower the energy density of a food, the higher the amount (by weight) of food that needs to be consumed to reach a given caloric intake. To discriminate between the effects of energy density and food volume, Rolls and colleagues (2000a) manipulated food volume by adding variable amounts of air to test meals of identical macronutrient composition and energy content. This study demonstrated that higher-volume meals significantly reduce energy intake, even when the macronutrient distribution is unchanged. In this case, the study focused on volume, and showed that for total energy intake both mass and volume are important.

### ***Randomized Controlled Trials***

Two longer-term, randomized controlled trials involving overweight individuals provide useful information regarding the satiety and compensatory effects of diets with different energy densities. Although these studies were not conducted to investigate the effect of energy density on caloric consumption specifically, the energy density in the test foods was manipulated, and so the results are useful in this discussion.

In a 9-month *ad libitum* study, Lovejoy and colleagues (2003) replaced one-third of the fat calories with the fat substitute Olestra®, which provides no calories. This study showed that the lower-density Olestra treatment resulted in a weight loss of 6.27 kg during the study period, compared with 4.0 kg in the control group ( $p = 0.06$ ).

A 10-week *ad libitum* food-intake study by Raben et al. (2002) supplemented a standard diet with sweetened drinks and foods. The foods for the control group were sweetened with sucrose, and the foods for the experimental group were artificially sweetened. The result was a significant difference ( $p = < 0.001$ ) in body weight: the control group gained an average of 1.6 kg, whereas the artificial sweetener group lost an average of 1.0 kg.

### ***Other Studies***

One cross-sectional study found that the consumption of energy-dense, nutrient-poor foods was a predictor of being overweight (Nicklas et al., 2003), but intake of the foods with low nutrient density explained less than 5 percent of the variance in overweight status. This relationship between the consumption of energy dense, nutrient-poor foods and weight was not confirmed by others (Bandini et al., 1999; Kant, 2003).

In summary, short-term studies have linked energy density with total energy intake over a period of 1 meal to 5 days. While not specifically performed to investigate the effects of energy density on satiety, two longer randomized trials showed that, compared with diets of high energy density, diets low in energy density resulted in a weight loss relative to the control group. However, evidence that the consumption of energy dense foods contributes to a change in BMI is still lacking.

## **QUESTION 5: WHAT IS THE RELATIONSHIP BETWEEN PORTION SIZE AND ENERGY INTAKE?**

### **Conclusion**

The amount of food offered to a person influences how much he or she eats; and, in general, more calories are consumed when a large portion is served rather than a small one. Thus, steps are warranted for consumers to limit the portion size they take or serve to others, especially for foods that are energy dense.

### **Rationale**

These conclusions are supported by the Committee's review of six short-term feeding studies, one longitudinal study, and three observational studies, as described below.

### **Short-Term Studies**

Studies using a short-term *ad libitum* intake model demonstrate that serving larger portions results in a larger volume of food consumed and a higher energy intake (Diliberti et al., 2004; Fisher et al., 2003; Rolls et al., 2002, 2004a). In a study of 51 men and women, these results occurred whether the portion served was placed on the individual's plate or was selected by the individual from a serving dish (Rolls et al., 2002a). The response of 5-year-old children to portion size appears to be similar to that of adults: increased energy intake from larger portion sizes (Rolls et al., 2000b). This study showed that children younger than 3 years consumed similar volumes of food when served different portion sizes; but, by age 5, they increased their intake when served larger portions (Rolls et al., 2000a). Another study by the same group showed that large portion sizes have different effects on energy intake in children age 3 to 5 depending on whether the food is served on individual plates or the children serve themselves from a serving dish (Fisher et al., 2003). When children served themselves, they spontaneously controlled their portion size and consumed similar amounts of energy from large and small serving dishes.

At a given level of caloric intake, selecting lower energy-density foods allows individuals to consume a larger quantity of food and thus reach satiety sooner (Rolls et al., 2000a, 2002a, 2004b).

### **Other Studies**

The Committee's search did not identify any randomized controlled trials evaluating the role of portion size on energy intake or BMI (Hannum et al., 2004). One longitudinal study in children reported a positive relationship ( $p < 0.05$ ) between portion size and body weight (McConahy et al., 2002). Several other observational studies have reported that a secular increase in portion size coincides with the rise in obesity in the United States over the past decades (Nielsen and Popkin, 2003; Smickilas-Wright et al., 2003; Young and Nestle, 2002, 2003).

Overall, the evidence supports the conclusion that servings that are too large may be part of the "obesogenic" environment, inasmuch as they facilitate excess consumption of energy.



## UNRESOLVED ISSUES

### What Is the Relationship Between Breakfast Consumption and BMI?

One randomized clinical trial (RCT) and two longitudinal studies in the literature were reviewed. The purpose of the RCT was to study the effect of eating or not eating breakfast on the outcome of a weight-loss trial (Schlundt et al., 1992). The breakfast group ate 3 meals a day and the no-breakfast group ate 2 meals a day. The energy content of the two diets was identical. There was no significant difference in weight loss at 12 weeks.

Two longitudinal studies, one in children (Berkey et al., 2003) and one in adults (Ma et al., 2003), provide relevant data. Berkey et al. (2003) studied more than 14,000 children age 9 to 14 years in 1996, using data from mailed questionnaires. Overweight children who never ate breakfast lost more body fat over the year of followup than overweight children who ate breakfast nearly every day; however, normal weight children who never ate breakfast gained weight comparable to that of normal weight children who ate breakfast nearly every day. Thus, this study is inconclusive.

The *Seasonal Variation Blood Cholesterol Study* conducted in 1994–1998 evaluated the relationship between eating patterns and obesity. Odds ratios were adjusted for other obesity risk factors including age, sex, physical activity, and total energy intake. A greater number of eating episodes per day was associated with a lower risk of obesity (odds ratio for 4 or more eating episodes versus 3 or fewer episodes was 0.55, 95 percent confidence interval: 0.33, 0.91.) In contrast, skipping breakfast was associated with an increased prevalence of obesity (odds ratio = 4.5, 95 percent confidence interval: 1.57, 12.90) (Ma et al., 2003).

A number of cross-sectional studies have reported positive associations between measures of adiposity in children and skipping breakfast (Gibson and O’Sullivan, 1995; Ortega et al., 1998; Pastore et al., 1996; Summerbell et al., 1996; Wolfe et al., 1994).

Information from the U.S. National Weight Loss Registry indicates that eating breakfast is an important factor in maintaining weight-loss over time (Wyatt et al., 2002).

Using data from the 1977–1978 *Nationwide Food Consumption Survey*, Morgan and colleagues reported that skipping breakfast lowered the nutritional quality of the diets of adults (Morgan et al., 1986) and of the elderly (Morgan and Zabik, 1984).

Thus, there is suggestive evidence from cross-sectional studies and longitudinal studies that eating breakfast is likely to promote healthy weight and improve the nutritional quality of the diet, but more studies are needed before a definitive conclusion can be reached. However, while the evidence is inconclusive that eating breakfast may help to manage body weight, eating breakfast regularly does not increase the risk of gaining weight. Therefore, adults and children should not skip breakfast because of concerns that

breakfast leads to overweight or obesity. Additionally, skipping breakfast may lower the nutritional quality of the diet.

### **What Is the Evidence To Support Caloric Compensation for Liquids versus Solid Foods?**

People of normal weight typically balance their energy intake throughout the day (or over a few days). If a person eats a large breakfast, he or she will tend to consume fewer calories at lunch, and vice-versa. Meal-to-meal *caloric compensation* (the ability to regulate energy intake with minimal conscious effort, such as reducing the amount of food consumed on some occasions to compensate for increased consumption at other times) is an important mechanism to avoid excess caloric intake and undesired weight gain. While several studies have shown that fluid calories cause less compensation and therefore may result in the overconsumption of calories, others have yielded opposite or inconclusive results.

At least 62 studies have examined the impact of liquid and solid foods on satiety and energy compensation. The numerous factors that influence satiation must be considered when evaluating this body of literature. They include the amount or volume of food; the food's palatability, consistency, viscosity, and texture; the time the food was administered; the time between the pre-load and the next meal; the subjects' psychological and physiological characteristics; the sample size; and the methods used to measure satiety and consumption. Other critical factors include the subjects' metabolic regulatory systems, such as the blood glucose response to food (Almiron-Roig et al., 2003; Anderson and Woodend, 2003; Mattes and Rothacker, 2001).

Some studies on pre-loading have shown that solids were more satiating than liquids, other studies found the opposite, and yet others found no differential effects at all. A review by Almiron-Roig et al. (2003) summarizes the contradictions in 18 studies. An earlier literature review of 40 pre-load studies by Mattes revealed that dietary compensation for changes in energy intake via fluids is less precise than when solid foods are manipulated (Mattes, 1996). On the other hand, a review by Anderson and Woodend (2003), quantifies the reduction of food intake after pre-loads of various sugars. A study that used a within-subject design in the laboratory showed that, compared with a sugar-containing liquid, a sugar-containing solid had an equal impact on food ingestion if the pre-load periods were the same (Almiron-Roig and Drewnowski, in press 2004).

In recent years, concurrent with the obesity epidemic, satiety studies have examined the effects of increased consumption of energy-containing, nutrient-poor beverages on subsequent intake (Almiron-Roig et al., 2003). Soft drinks are often described as primarily thirst-quenching liquids, but juices and milk are said to be liquid foods with a greater satiating power. One recent within-subjects designed study (n = 32) found that 3 energy-containing beverages (regular cola, 1 percent milk, and orange juice) did not differ in their effects on satiation or the temporal profiles of hunger, fullness, or thirst; they were, however, more satiating than sparkling water (p<0.01) (Almiron-Roig and Drewnowski, 2003).

Some of the confusion results from interactions among physical volume, energy density, and portion size. A controlled study of 36 women found that doubling the volume of a liquid food without changing the energy content significantly decreased the liquid's palatability ratings and increased sensory-specific satiety ( $p < 0.05$ ) (Bell et al., 2003). Another study found that increases in portion size and energy density led to independent and additive increases in energy intake ( $p < .0001$ ) (Tanja et al., 2004). A further study with 28 lean men found that increasing the volume of a pre-load beverage by incorporating air, independent of energy density, reduced energy intake ( $p < 0.04$ ) (Rolls et al., 2000a).

A few studies have compared calorie compensation in obese and non-obese subjects. Duncan et al. (1983) indicated that obese and nonobese subjects are comparable in their satiety ratio, energy consumption, eating time, and food acceptance. Rolls and Roe (2002) found that energy intake by both lean and obese women were affected by the volume of liquid food infused intragastrically. Further, Rolls et al. (1999a) and Bell and Rolls (2001) found that both lean and obese women were influenced by energy density across all fat contents in food. However, further research is necessary to evaluate eating cues and calorie compensation in obese as well as nonobese subjects.

Studies of children suggest that they respond to dietary energy density and that, although their individual meal intakes are erratic, 24-hour energy intakes are relatively well regulated. These studies also report that children's early learning about food is constrained by their genetic predispositions, including the unlearned preference for sweet and salty tastes, and the rejection of sour and bitter tastes. Evidence of individual differences in the regulation of energy intake has been documented in preschool children. These individual differences in self-regulation are associated with differences in child-feeding practices and with children's adiposity. Initial evidence indicates that imposition of stringent parental controls can potentiate preferences for high-fat, energy-dense foods, limit children's acceptance of a variety of foods, and disrupt children's regulation of energy intake by altering their responsiveness to internal cues of hunger and satiety (Birch and Fisher, 1998).

In summary, the evidence is conflicting that liquid and solid foods differ in their effect on calorie compensation.

## **SUMMARY**

Thirty minutes of at least moderate physical activity on most days provides important short- and long-term health benefits for adults and up to 60 minutes of at least moderate-intensity physical activity might be needed to avoid unhealthy weight gain. Children and adolescents need at least 60 minutes of moderate to vigorous physical activity on most days for maintenance of good health and fitness and for healthy weight during growth. The amount of physical activity that weight-reduced adults need to avoid weight regain is estimated to be from 60 to 90 minutes daily at moderate intensity.

Resistance exercise training increases muscular strength and endurance and maintains or increases lean body weight. Physical activity that involves loading the skeleton is especially beneficial for bone health.

Weight maintenance depends on a balance of energy intake and energy expenditure, regardless of the proportions of carbohydrate, fat, and protein in the diet. To promote recommended nutrient intakes and the adoption of healthy lifestyle changes while losing or maintaining weight, the Committee recommends diets that provide 45 to 65 percent of calories from carbohydrate, 20 to 35 percent of calories from fat, and 10 to 35 percent of calories from protein. Eating foods of low energy density may be a helpful strategy to reduce energy intake when trying to maintain or lose weight. Similarly, limiting the portion size of food eaten or served to others may help control calorie intake.

## REFERENCES

American Academy of Pediatrics Policy Statement. Prevention of Pediatric Overweight and Obesity. *Pediatrics* 112(2):424-430, 2003.

American College of Obstetricians and Gynecologists Committee Opinion No. 267. Exercise during pregnancy and the postpartum period 99(1):171-173, 2002.

American College of Sports Medicine (ACSM) Position Stand. Exercise and physical activity for older adults. *Med Sci Sports Exerc* 30(6):992-1008, 1998.

ACSM. position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 34(2):364-80, 2002.

ACSM Position Stand. The recommended quantity and Quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med Sci Sports Exerc* 30(6):975-91, 1998.

Alford BB, Blankenship AC, Hagen RD. The effects of variations in carbohydrate, protein, and fat content of the diet upon weight loss, blood values, and nutrient intake of adult obese women. *J Am Diet Assoc* Apr;90(4):534-40, 1990.

Almiron-Roig, E and Drewnowski A. No difference in satiety or in subsequent energy intakes between a beverage and a solid food. *Physiology and Behavior*, In press 2004.

Almiron-Roig, E, Chen Y, and Drewnowski A. Liquid calories and the failure of satiety: how good is the evidence? *Obes Rev* 4(4): p. 201-12, 2003.

Almiron-Roig, E and Drewnowski A. Hunger, thirst, and energy intakes following consumption of caloric beverages. *Physiol Behav* 79(4-5): p.767-73, 2003.

American Heart Association. Statement on Exercise: benefits and recommendations for physical activity programs for all Americans: a statement for health professionals by the Committee on Exercise and Cardiac Rehabilitation of the Council on Clinical Cardiology, American Heart Association. *Circulation* 86:340-344, 1992.

Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 279(12):938-942, 1998.

Anderson, GH and Woodend D. Consumption of sugars and the regulation of short-term satiety and food intake. *Am J Clin Nutr* 78(4): p.843S-849S, 2003.

Astrup A, Ryan L, Grunwald GK, Storgaard M, Saris W, Melanson E, Hill JO. The role of dietary fat in body fatness: evidence from a preliminary meta-analysis of ad libitum low-fat dietary intervention studies. *Br J Nutr* 83:S25-S32, 2000.

Atkins C. *Dr. Atkins' New Diet Revolution*. New York, NY: Avon Books, 1999.

Bailey DA, McKay HA, Minward RI, Crocker PRE, Faulkner RA. A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in young children: The University of Saskatchewan bone mineral accrual study. *J Bone Miner Res* 14:1672-1679, 1999.

Bandini LG, Vu D, Must A, Cyr H, Goldberg A, Dietz WH. Comparison of high-calorie, low-nutrient-dense food consumption among obese and non-obese adolescents. *Obes Res* 7(5):438-443, 1999.

Bass SL, Saxon L, Daly R, et al. The effect of mechanical loading in the size and shape of cortical bone in pre-, peri- and post-pubertal tennis players. *J Bone Miner Res* 2002; 17:2274-2280.

Bell EA, Castellanos VH, Pelkman CL, Thorwart ML, Rolls BJ. Energy density of foods affects energy intake in normal-weight women. *Am J Clin Nutr* 67:412-420, 1998.

Bell EA, Rolls BJ. Energy density of foods affects energy intake across multiple levels of fat content in lean and obese women. *Am J Clin Nutr* 73:1010-1018, 2001.

Bell, EA, Roe LS, Rolls BJ. Sensory-specific satiety is affected more by volume than by energy content of a liquid food. *Physiol Behav* 78(4-5): p. 593-600, 2003.

Berard A, Bravo G, Gauthier P. Meta-analysis of the effectiveness of physical activity for the prevention of bone loss in the postmenopausal women. *Osteoporosis Int* 7:331-337, 1997.

Berkey CS, Rockett HRH, Gillman MW, Field AE, Colditz GA. Longitudinal study of skipping breakfast and weight change in adolescents. *Int J Obes Relat Metab Disord* 27:1258-1266, 2003.

Berkey CS, Rockett HRH, Field AE, Gillman MW, Frazier AL, Camargo CA, Colditz GA. Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. *Pediatrics* 105:E56, 2000.

Biddle S, Sallis JF, Cavill NA. *Young and active? Young people and health enhancing physical activity. Evidence and implication*. London: Health Education Authority; 1998.

Bild DE, Sholinsky P, Smith DE, Lewis CE, Hardin JM, Burke GL. Correlates and predictors of weight loss in young adults: the CARDIA study. *Int J Obes Relat Metab Disord* 20(1):47-55, 1996.

Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. *Pediatrics* 101(3 Pt 2): p. 539-549, 1998.

Blair SN, Kohl HW III, Barlow CE, Paffenbarger RS Jr, Gibbons LW, Macera CA. Changes in fitness and all-cause mortality: a prospective study of healthy and unhealthy men. *JAMA* 273:1093-1098, 1995.

Blair SN, Kohl HW III, Paffenbarger RS Jr, Clark DG, Cooper KH, Gibbons LW. Physical fitness and all-cause mortality. A prospective study of healthy men and women. *JAMA* Nov 3;262(17):2395-401, 1989.

Bortz WM, Wroldson A, Morris P, Issekutz B Jr. Fat, carbohydrate, salt, and weight loss. *Am J Clin Nutr* 20(10):1104-1112, 1967.

Bravata DM, Sanders L, Huang J, Krumholz HM, Olkin I, Gardner CD, Bravata DM. Efficacy and safety of low-carbohydrate diets. *JAMA* 289:1837-1850, 2003.

Bray GA, Popkin BM. Dietary fat intake does affect obesity! *Am J Clin Nutr* 68(6):1157-1173, 1998.

Brehm BJ, Seeley RJ, Daniels SR, D'Allesio DA. A randomized trial comparing a very low carbohydrate diet and a calorie restricted low fat diet on body weight and cardiovascular risk factors in healthy women. *J Clin Endocrin Metab* 88:1617-1623, 2003.

Cavill N, Biddle S, Sallis JF. Health enhancing physical activity for young people: Statement of the United Kingdom Expert Consensus Conference. *Pediatric Exercise Science* 13:12-25, 2001.

Coupland C, Wood D, Cooper C. Physical inactivity is an independent risk factor in the elderly. *J Epidemiol Community Health* 47:441-443, 1993.

Cummings SR, Nevitt MC, Browner WS, Stone K, Fox KM, Ensrud KE, Cauley J, Black D, Voght TM. Risk factor for hip fracture in white women. *N Engl J Med* 332:767-773, 1995.

Deheeger M, Rolland-Cachera MF, Fontvieille AM. Physical Activity and body composition in 10 year old French children: linkages with nutritional intake? *Int J Obes Relat Metab Disord* 21(5):372-379, 1997.

Dempsey JC, Sorensen TK, Williams MA, Lee IM, Miller RS, Dashow EE, Luthy DA. Prospective study of gestational diabetes mellitus risk in relation to maternal recreational physical activity before and during pregnancy. *Am J Epidemiol* 159(7):663-670, 2004.

Dewey KG, Heinig MJ, Nommsen LA, Lonnerdal B. Maternal versus infant factors related to breast milk intake and residual milk volume: the DARLING study. *Pediatrics* 87(6):829-837, 1991.

Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *New Eng J Med* 346:393-403, 2002.

Dietz WH Jr, Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics* 75(5):807-812, 1985.

Diliberti N, Bordi PL, Conklin MT, Roe LS, Rolls BJ. Increased portion size leads to increased energy intake in a restaurant meal. *Obes Res* 12:562-568, 2004.

Duncan KH, Bacon JA, Weinsier RL. The effects of high and low energy density diets on satiety, energy intake, and eating time of obese and nonobese subjects. *Am J Clin Nutr* 37:763-767, 1983.

DuRant RH, Baranowski T, Johnson M, Thompson WO. The relationship among television watching, physical activity, and the body composition of young children. *Pediatrics* 94(4 pt 1):449-455, 1994.

Dye TD, Knox KL, Artal R, Aubry RH, Wojtowycz MA. Physical activity, obesity, and diabetes in pregnancy. *Am J Epidemiol* 146(11):961-965, 1997.

Erlichman J, Kerbey AL, James WP. Physical activity and its impact on health outcomes. Paper 2: Prevention of unhealthy weight gain and obesity by physical activity: an analysis of the evidence. *Obes Rev* 3(4):273-287, 2002.

Evans WJ. Exercise training guidelines for the elderly. *Med Sci Sports Exerc* 31(1):12-7, 1999.

Ewbank PP, Darga LL, Lucas CP. Physical activity as a predictor of weight maintenance in previously obese subjects. *Obes Res* 3:257-263, 1995.

Farmer ME, Harris T, Madares JH, Wallace RB, Carnoni-Huntley J, White LH. Anthropometric indicators and hip fracture: the NHANES I epidemiologic follow-up study. *J Am Geriatr Soc* 37:9-16, 1989.

Fisher JO, Rolls BJ, Birch LL. Children's bite size and intake of an entrée are greater with large portions than with age-appropriate or self-selected portions. *Am J Clin Nutr* 77:1164-1170, 2003.

Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among U.S. adults, 1999-2000. *JAMA* 288:1723-1727, 2002.

Fleming, RM. The effect of high-, moderate-, and low-fat diets on weight loss and cardiovascular disease risk factors. *Prev Cardiol* 5:110-118, 2002.

Fogelholm M, Kukkonen-Harjula K, Nenonen A, Pasanen M. Effects of walking training on weight maintenance after a very-low-energy diet in pre-menopausal obese women. A randomized controlled trial. *Arch Int Med* 160: 2177-2184, 2000.

Fogelholm M, Kukkonen-Harjula K. Does physical activity prevent weight gain – a systematic review. *Obes Rev* 1:95-111, 2000.

Forwood MR, Burr DB. Physical activity and bone mass: exercise in futility? *Bone Mine* 21:89-112, 1993.

Foster GD, Wyatt HR, Hill JO, McGucken BG, Brill C, Mohammed BS, Szapary PO, Rader DJ, Edman I, Klein S. A randomized trial of a low-carbohydrate diet for obesity. *N Engl J Med* 348:2082-2090, 2003.

Frantz MJ, Bantle JP, Beebe CA, Brunzell JD, Chiasson J-L, Garg A, Holzmeister LA, Hoogwerf B, Mayer-Davis E, Mooradian AD, Purnell JQ, Wheeler M. Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications. *Diabetes Care* 25:148-198, 2002.

Freedman MR, King J, Kennedy, E. Popular diets: a scientific review. *Obes Res* 9 suppl 1:1S-40S, 2001.

French SA, Fulkerson JA, Story M. Increasing weight-bearing physical activity and calcium intake for bone mass growth in children and adolescents: a review of intervention trials. *Prev Med* 31:722-731, 2000.

Frost H. Skeletal structural adaptations to mechanical usage (SATMU). 2. Redefining Wolff's law: the remodeling problem. *Anat Rec* 26:403-413, 1990.

Gibson SA, O'Sullivan KR. Breakfast cereal consumption patterns and nutrient intakes of British schoolchildren. *J R Social Health* 115:366-370, 1995.



Gortmaker SL, Must A, Sobol AM, Peterson K, Colditz GA, Dietz WH. Television viewing as a cause of increasing obesity among children in the United States, 1986-1990. *Arch Pediatr Adolesc Med* 150(4):356-362, 1996.

Gortmaker SL, Peterson K, Wiecha J, Sobol AM, Dixit S, Fox MK, Laird N. Reducing obesity via school-based interdisciplinary intervention among youth: Planet Health. *Arch Pediatr Adolesc Med* 153(4):409-418, 1999.

Gregg E, Cauley J, Seeley D, Ensrud K, Bauer D. Physical activity and osteoporotic fracture risk in older women. *Ann Intern Med* 129:81-88, 1998.

Grund A, Krause H, Siewers M, Rieckert H, Muller MJ. Is TV viewing an index of physical activity and fitness in overweight and normal weight children? *Public Health Nutr* 4(6):1245-1251, 2001.

Guillaume M, Lapidus L, Bjorntorp P, Lambert A. Physical activity, obesity, and cardiovascular risk factors in children: The Belgian Luxembourg Child Study II. *Obes Res* 5(6):549-556, 1997.

Haapasalo H, Sievanen H, Kannus P, Heinonen A, Oja P, Vuori I. Dimensions and estimated mechanical characteristics of the humerus after long-term tennis loading. *J Bone Miner Res* 11:864-72, 1996.

Hanley AJ, Harris SB, Gittelsohn J, Wolever TM, Saksvig B, Zinman B. Overweight among children and adolescents in a Native Canadian community: prevalence and associated factors. *Am J Clin Nutr* 71(3):693-700, 2000.

Hannum SM, Carson L, Evans EM, Canene KA, Petr EL, Bui L, Erdman JW Jr. Use of portion-controlled entrees enhances weight loss in women. *Obes Res* 12(3):538-46, 2004.

Hartman WM, Stroud M, Sweet DD, Saxton J. Long-term maintenance of weight loss following supplemented fasting. *Int J Eating Disord* 14:87-93, 1993.

Healthy People 2010, 2nd ed. *Understanding and improving health and objectives for improving health*. Washington, DC: U.S. Government Printing Office 2 vol.: P. 19-3, 2000.

Heaney RP, Abrams S, Dawson-Hughes B, Looker A, Marcus R, Matkovic V, Weaver C. Peak bone mass. *Osteoporosis Int* 11:985-1009, 2000.

Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR, Flegal KM. Prevalence of overweight and obesity among U.S. children, adolescents, and adults, 1999-2002. *JAMA*. 291(23):2847-2850, 2004.

Hernandez B, Gortmaker SL, Colditz GA, Peterson KE, Laird NM, Parra-Cabrera S. Association of obesity with physical activity, television programs and other forms of video viewing among children in Mexico City. *Int J Obes Relat Metab Disord* 23(8):845-854, 1999.

Institute of Medicine (IOM). Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids. Washington DC: National Academies Press, 2002.

IOM. Nutrition during lactation. Washington DC: National Academies Press, 1991.

IOM. Nutrition during pregnancy: weight gain and nutrient supplements report. Washington DC: National Academies Press, 1990.

International Agency for Research on Cancer (IARC) Handbooks of Cancer Prevention. *Weight control and physical activity*, Volume 6: 315 pages, 2002.

Kant AK. Reported consumption of low-nutrient-density foods by American children and adolescents: nutritional and health correlates, NHANES III, 1988 to 1994. *Arch Pediatr Adolesc Med* 157(8):789-796, 2003.

Kelley GA, Kelley KS, Tran ZV. Resistance training and bone mineral density in women: a meta-analysis of controlled trials. *Am J Phys Med Rehab* 80:65-77, 2001.

Kelley GA. Aerobic exercise and lumbar spine bone mineral density in postmenopausal women: a meta analysis. *J Am Geriatr Soc* 1998a; 46:143-152.

Kelley GA. Aerobic exercise and bone density at the hip in postmenopausal women: a meta-analysis. *Prevent Med* 27:798-807, 1998b.

Kelley GA. Exercise and regional bone mineral density in postmenopausal women: a meta-analytic review of randomized trials. *Am J Phys Med Rehabil* 77:76-78, 1998c.

Kerr DA, Morton A, Dick I, Prince R. Exercise effects on bone mass in postmenopausal women are site-specific and load-dependent. *J Bone Miner Res* 11:218-225, 1996.

Kesaniemi YK, Danforth E Jr., Jensen MD, Kopelman PG, Lefebvre P, Reeder BA. Dose-response issues concerning physical activity and health: an evidence-based symposium. *Med Sci Sports Exerc* 33(6 Suppl):S351-358, 2001.

Kimm SY, Glynn NW, Kriska AM, Barton BA, Kronsberg SS, Daniels SR, Crawford PB, Sabry Zi, Lui K. Decline in physical activity in black girls and white girls during adolescence. *N Engl J Med* 347(10):709-715, 2002.

Kohrt WM, Ehsani AA, Birge SJ. Effects of exercise involving predominantly either joint-reaction or ground-reaction forces on bone mineral density in older women. *J Bone Miner Res* 12:1253-1261, 1997.

Larosa JC, Gordon A, Muesing R, Rosing DR. Effects of high-protein, low-carbohydrate dieting on plasma lipoproteins and body weight. *J Am Diet Assoc* 77: 264-270, 1980.

Larson-Meyer DE. Effect of postpartum exercise on mothers and their offspring: a review of the literature. *Obes Res*10(8):841-53, 2002.

Lee CD, Blair SN, Jackson AS. Cardiorespiratory fitness, body composition, and all-cause and cardiovascular disease mortality in men. *Am J Clin Nutr* 69(3):373-380, 1999.

Leermakers EA, Perri MG, Shigaki CL, Fuller PR. Effects of exercise-focused versus weight-focused maintenance programs on the management of obesity. *Addict Behav* 24:219-227, 1999.

Lovejoy JC, Bray GA, Lefevre M, Smith SR, Most MM, Denkins YM, Volaufova J, Rood JC, Eldridge AL, Peters JC. Consumption of a controlled low-fat diet containing olestra for 9 months improves health risk factors in conjunction with weight loss in obese men: the Olé Study. *Int J Obes Relat Metab Disord* 27:1242-1249, 2003.

Ma Y, Bertone ER, Stanek III EJ, Reed GW, Hebert JR, Cohen NL, Merriam PA, Ockene IS. Association between eating patterns and obesity in a free-living US adult population. *Am J Epidemiol* 158:85-92, 2003.

Maffeis C, Talamini G, Tato L. Influence of diet, physical activity, and parents' obesity on children's adiposity: a four-year longitudinal study. *Int J Obes Relat Metab Disord* 22:758-764, 1998.

Mattes RD. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiology and Behavior* 59(1):179-187, 1996.

Mattes, R.D. and D. Rothacker, Beverage viscosity is inversely related to postprandial hunger in humans. *Physiology and Behavior* 74(4-5): p. 551-557, 2001.

McConahy KL, Smiciklas-Wight H, Birch LL, Mitchell DC, Picciano MF. Food portions are positively related to energy intake and body weight in early childhood. *J Pediatr* 140:340-347, 2002.

McGuire MT, Wing RR, Klem ML, Hill JO. Behavioral strategies of individuals who have maintained long-term weight losses. *Obes Res* 7(4):334-341, 1999.

Morgan KJ, Zabik ME, Stampely GL. The role of breakfast in the diet adequacy of the U.S. population. *J Am Coll Nutr* 5:551-563, 1986.

Morgan KJ, Zabik ME. The influence of RTE cereal consumption at breakfast on nutrient intakes of individuals 62 years and older. *J Am Coll Nutr* 3:27-44, 1984.

Mueller-Cunningham WM, Quintana R, Kasim-Karakas SE. An ad libitum, very low-fat diet results in weight loss and changes in nutrient intakes in postmenopausal women. *J Amer Diet Assoc.* 103:1600-1606, 2003.

Muller MJ, Koertzing I, Mast M, Langnase K, Grund A, Koertringer I. Physical activity and diet in 5 to 7 year old children. *Public Health Nutr* 2:443-444, 1999.

National Health Interview Survey (NHIS) results. Leisure-Time Physical Activity Among Adults: United States, 1997–98. Advance data from vital health statistics. 325, 2002.

Nelson ME, Fisher EC, Dilmaniam FA, Dallal GE, Evans WJ. 1-year walking program and increased dietary calcium in post menopausal women: effects on bone. *Am J Clin Nutr* 53:1304-1311, 1991.

Nicklas TA, Yang SJ, Baranowski T, Zakeri I, Berenson G. Eating patterns and obesity in children. *Am J Prev Med* 25(1):9-16, 2003.

Nielsen SJ, Popkin BM. Patterns and trends in food portion sizes, 1977-1998. *JAMA* 289:450-453, 2003.

Nielsen Media Research. *Report on Television*. New York: A. C. Nielsen Company, 1998.

NIH,NHLBI. *Clinical Guidelines on the identification, evaluation, and treatment of overweight and obesity in adults*. HHS, PHS p.29-41, 1998.

Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999-2000. *JAMA* 288(14):1728-1732, 2002.

Ornish D. *Dr. Dean Ornish's Program for Reversing Heart Disease*. New York: Random House; 1990.

Ortega RM, Requejo AM, Lopez-Sobaler AM, Quintas ME, Andres P, Redondo MR, Navia B, Lopez-Bonilla MD, Rivas T. Difference in the breakfast habits of overweight/obese and normal weight schoolchildren. *Int J Vitam Nutr Res* 68:125-132, 1998.

Paffenbarger RS, Hyde RT, Wing AL, Lee I, Jung DL, Kampert JB. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *N Engl J Med* 328: 538-545, 1993.

Pastore DR, Fisher M, Friedman SB. Abnormalities in weight status, eating attitudes, and eating behaviors among urban high school students: correlations with self-esteem and anxiety. *J Adolesc Health* 18:312-319, 1996.

Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, Buchner D, Ettinger W, Heath GW, King AC, et al. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 273:402-407, 1995.

Perri MG, Nezu AM, Patti ET, McCann KL. Effect of length of treatment on weight loss. *J Consult Clin Psychol* 57(3): 450-452, 1989.

Pi-Sunyer X. Medical hazards of obesity. *Ann Intern Med* 119:655-660, 1993.

Pritikin, BRJ. Pritikin approach to cardiac rehabilitation. *In: Goodgold, J. (ed.) Rehabilitation Medicine*. St. Louis, MO: CV Mosby Co, 1988.

Raben A, Vasilaras TH, Moller AC, Astrup A. Sucrose compared with artificial sweeteners: different effects on ad libitum food intake and body weight after 10 wk of supplementation in overweight subjects. *Am J Clin Nutr* 76:721-729, 2002.

Reddy ST, Wang CY, Sakhaee K, Brinkley L, Pak CY. Effect of low-carbohydrate high-protein diets on acid-base balance, stone-forming propensity, and calcium metabolism. *Am J Kidney Dis* 40: 265-274, 2002.

Roberts DF, Foehr UG, Rideout VJ et. al. *Kids and media @ the new millennium*. Monlo park, CA: Henry J. Kaiser Family Foundation, 1999.

Robinson TN. Reducing children's television viewing to prevent obesity: a randomized controlled trial. *JAMA* 282(16):1561-1567, 1999.

Rolls BJ, Bell EA, Castellanos VH, Chow M, Pelkman CL, Thorwart ML. Energy density but not fat content of foods affected energy intake in lean and obese women. *Am J Clin Nutr* 69:863-871, 1999a.

Rolls BJ, Bell EA, Thorwart ML. Water incorporated into a food but not served with a food decreases energy intake in lean women. *Am J Clin Nutr* 70:448-455, 1999b.

Rolls BJ, Bell EA, Waugh BA. Increasing the volume of a food by incorporating air affects satiety in men. *Am J Clin Nutr* 72:361-368, 2000a.

Rolls BJ, Engell D, Birch LL. Serving portion size influences 5-year-old but not 3-year-old children's food intakes. *J Am Diet Assoc* 100:232-234, 2000b.

Rolls BJ, Morris EL, Roe LS. Portion size of food affects energy intake in normal-weight and overweight men and women. *Am J Clin Nutr* 76:1207-1213, 2002a.

Rolls BJ, Roe LS, Kral TVE, Meengs JS, Wall DE. Increasing the portion size of a packaged snack increases energy intake in men and women. *Appetite* 42:63-69, 2004a.

Rolls BJ, Roe LS, Meengs JS, Wall DE. Increasing the portion size of a sandwich increases energy intake. *J Am Diet Assoc* 104:367-362, 2004b.

Rolls BJ, Roe LS. Effect of the volume of liquid food infused intragastrically on satiety in women. *Physiol Behav* 76:623-631, 2002b.

Rolls, BJ, Bell EA, Waugh BA. Increasing the volume of a food by incorporating air affects satiety in men. *Am J Clin Nutr* 72(2): p. 361-368, 2000.

Roodenburg AJ, Leenen R, van het Hof KH, Weststrate JA, Tijburg LB. Amount of fat in the diet affects bioavailability of lutein esters but not of alpha-carotene, beta-carotene, and vitamin E in humans. *Am J Clin Nutr* 71(5):1187-93, 2000.

Ross JG, Pate RR. The national children and youth fitness study II: A summary of findings. *J Phys Ed Recreation and Dance* 58(9):51-56, 1987.

Rössner S. Physical activity and prevention and treatment of weight gain associated with pregnancy: current evidence and research issues. *Med Sci Sports Exerc* 31(11 Suppl):S560-563, 1999.

Rubin CT, Lanyon LE. Regulation of bone mass by mechanical strain magnitude. *Calcif Tissue Int* 37:411-7, 1985.

Rush D, Stein Z, Susser M. A randomized controlled trial of prenatal nutritional supplementation in New York City. *Pediatrics*. Apr;65(4):683-97, 1980.

Sallis JF, Broyles SL, Frank-Spohrer G, Berry CC, Davis TB, Nader PR. Child's home environment in relation to mother's adiposity. *Int J Obes Relat Metab Disord* 19(3):190-197, 1995.

Samaha F, Iqbal N, Seshadri P, et al. A low-carbohydrate as compared with a low-fat diet in severe obesity. *N Engl J Med* 348:2074-2081, 2003.

Saris WH, Astrup A, Prentice AM, Zunft HJ, Formiguera X, Verboeket-van de Venne WP, Raben A, Poppitt SD, Seppelt B, Johnston S, Vasilaras TH, Keogh GF. Randomized controlled trial of changes in dietary carbohydrate/fat ratio and simple vs complex carbohydrates on body weight and blood lipids: the CARMEN study. *Int J Obes Relat Metab Disord* 24:1310-1318, 2000.

Saris, WH, Blair, SN, van Baak, MA, Eaton, SB, Davies, PSW, Di Pietro, L, Fogelholm, M, Rissanen, A, Schoeller, D, Swinburn, B, Tremblay, A, Westerterp, KR, and Wyatt, H. How much physical activity is enough to prevent unhealthy weight gain? Outcome of the IASO 1st Stock Conference and consensus statement. *Obesity Reviews* 4:101-114, 2003.

Schlundt DG, Hill JO, Pope-Cordle J, Sharp T. The role of breakfast in the treatment of obesity: a randomized clinical trial. *Am J Clin Nutr* 55:645-651, 1992.

Schoeller DA, Shay K, Kushner RF. How much physical activity is needed to minimize weight gain in previously obese women? *Am J Clin Nutr* 66:551-556, 1997.

Shepard TY, Weil KM, Sharp TA, et al. Occasional physical inactivity combined with a high-fat diet may be important in the development and maintenance of obesity in human subjects. *Am J Clin Nutr* 73:703-708, 2001.

Shephard RJ. Absolute versus relative intensity of physical activity in a dose-response context. *Med Sci Sports Exerc* 33(6 Suppl):S400-418, 2001.

Singh MA. Exercise and bone health. In: Holick MF and Dawson-Hughes B, (eds.) *Nutrition and Bone Health*, Humana Press pp. 515-548, 2004.

Skov AR, Toubro S, Ronn B, Holm L, Astrup A. Randomized trial on protein vs carbohydrate in ad libitum fat reduced diet for the treatment of obesity. *Int J Obes Relat Metab Disord* 23:528-536, 1999.

Sloan NL, Jordan E, Winikoff B. Effects of iron supplementation on maternal hematologic status in pregnancy. *Am J Public Health* Feb;92(2):288-293, 2002.

Snow-Harter C, Boussein M, Lewis B, Carter D, Marcus R. Effects of resistance and endurance exercise on bone mineral status of young women: a randomized exercise intervention trial. *J Bone Miner Res* 7: 761-769, 1992.

Specker BL, Mulligan L, Ho ML. Longitudinal study of calcium intake, physical activity, and bone mineral content in infants 6-18 months of age. *J Bone Miner Res* 1999;14:569-576.

Specker BL, Binkley T. Randomized trial of physical activity and calcium supplementation on bone mineral content in 3-5 year old children. *J Bone Miner Res* 18:885-892, 2003.

Smiciklas-Wright H, Mitchell DC, Mickle SJ, Goldman JD, Cook A. Foods commonly eaten in the United States, 1989-1991 and 1994-1996: Are portion sizes changing? *J Am Diet Assoc* 103:41-47, 2003.

St. Jeor ST, Howard BV, Prewitt TE, Bovee V, Bazzarre T, Eckel RH. Dietary protein and weight reduction: a statement for healthcare professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association. *Circulation*. 2001; 104: 1869-1874.

Stubbs RJ, Johnstone AM, O'Reilly LM, Barton K, Reid C. The effect of covertly manipulating the energy density of mixed diets on ad libitum food intake in 'pseudo free-living' humans. *Int J Obes Relat Metab Disord* 22:980-987, 1998.

Summerbell CD, Moody RC, Shanks J, Stock MJ, Geissler C. Relationship between feeding pattern and BMI in 220 free-living people in four age groups. *Eur J Clin Nutr* 50: 513-519, 1996.

Tanja, VE, Roe LS, Rolls BJ, Combined effects of energy density and portion size on energy intake in women. *Am J Clin Nutr* 79(6): p. 962-968, 2004.

Tremblay A, Lavallee N, Almeras N, Allard L, Despres JP, Bouchard C. Nutritional determinants of the increase in energy intake associated with a high-fat diet. *Am J Clin Nutr* 53: 1134-1137, 1991.

Tuomilehto J, Lindstrom J., Eriksson JG, Valle TT, Hamalainen H, Ilanne-Parikka P, Keinanen-Kiukaanniemi S, Laasko M, Louheranta A, Rastas M, Salminen V, Uusitupa M. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med* 344:1343-1350, 2001.

U.S. Department of Health and Human Services (HHS). *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, GA: HHS, Centers for Disease Control and Prevention. National Center for Disease Prevention and Health Promotion, 1996.

Wallace BA, Cumming RG. Systematic review of randomized trials of the effect of exercise in bone mass in pre- and postmenopausal women. *Calcif Tissue Int* 67:10-18, 2000.

Weinsier RL, Hunter GR, Desmond RA, Byrne NM, Zuckerman PA, Darnell BE. Free-living activity energy expenditure in women successful and unsuccessful at maintaining a normal body weight. *Am J Clin Nutr* 75(3):499-504, 2002.

Westman EC, Yancy WS, Edman JS, et al. Effect of 6-month adherence to a very low carbohydrate diet program. *Am J Med* 113:30-36, 2002.

Willett WC. Is dietary fat a major determinant of body fat? *Am J Clin Nutr* 67:556S-62S, 1998.

Wing RR, Hill J. Successful weight loss maintenance. *Annu Rev Nutr* 21:323-341, 2001.

Wolfe WS, Campbell CC, Frongillo Jr EA, Haas JD, Melnik TA. Overweight schoolchildren in New York State: prevalence and characteristics. *Am J Public Health* 84:807-813, 1994.

Wolff I, van Creonborg JJ, Kepmer HC, Kostense PJ, Twisk JW. The effect of exercise training



programs on bone mass: a meta-analysis of published controlled trials in pre- and postmenopausal women. *Osteopor Int* 9:1-12, 1999.

Wyatt HR, Grunwald GK, Mosca CL, Klem ML, Wing RR, Hill JO. Long-term weight loss and breakfast in subjects in the national weight control registry. *Obes Res* 10:78-82, 2002.

Yang MU, Van Itallie TB. Composition of weight lost during short-term weight reduction. Metabolic responses of obese subjects to starvation and low-calorie ketogenic and nonketogenic diets. *J Clin Invest* 58(3):722-730, 1976.

Young LR, Nestle M. Expanding portion sizes in the US marketplace: Implications for nutrition counseling. *J Am Diet Assoc* 103:231-234, 2003.

Young LR, Nestle M. The contribution of expanding portion sizes to the US obesity epidemic. *Am J Pub Health* 92:246-249, 2002.

**Table D2-1. BMI Classifications**

Classification	BMI (kg/m <sup>2</sup> )
Underweight	<18.5
Normal	18.5-24.9
Overweight	25.0-29.9
Obesity	30.9-39.9
Extreme Obesity	40.0+

(NIH/NHLBI Web site <http://www.nhlbi.nih.gov/>)

**Table D2-2. Examples of Moderate Physical Activities<sup>1</sup> and Corresponding METS and kcals Burned/Hour for a 154-lb Person**

<sup>1</sup>**Moderate physical activities**—any activity that burns 3.5 to 7 calories per minute (kcal/min) or the equivalent of 3 to 6 metabolic equivalents (METs) (CDC) and results in achieving 60 to 73 percent of the peak heart rate (ASCM). Other examples include: mowing the lawn or swimming. A person should feel some exertion but should be able to carry on a conversation comfortably during the activity (CDC Web site <http://www.cdc.gov/nccdphp/dnpa/physical/terms/index.htm>).

<b>Moderate PA</b>	<b>Estimated METS<sup>2</sup></b>	<b>kcals Burned/Hr<sup>3</sup></b>
Hiking	4.9	367
Light Gardening/Yard Work	4.5	331
Dancing	4.5	331
Golf (walking and carrying clubs)	4.5	331
Bicycling (<10 mph)	4.0	294
Walking (3.5 mph)	3.8	279
Weight Lifting (general light workout)	3.0	220
Stretching	2.5	184

Conversion:  $[\text{METs} \times 3.5 (\text{body weight in lb}/2.2)]/200 = \text{kcal/min}$

<sup>2</sup> METs – the resting metabolic rate (approximately the amount of energy it takes to sit quietly)

<sup>3</sup> For a 154-lb individual, calories burned per hour will be higher for persons who weigh more than 154 lbs and lower for persons who weigh less than 154 lbs.

**Table D2-3. Examples of Vigorous Physical Activities<sup>1</sup> and Corresponding METS and kcals Burned/Hour for a 154-lb Person**

<sup>1</sup>**Vigorous physical activities**—any activity that burns more than 7 kcal/ min or the equivalent of 6 or more metabolic equivalents (METs) (CDC) and results in achieving 74 to 88 percent of your peak heart rate (ASCM). Other examples include: mowing the lawn with a nonmotorized pushmower and participating in high-impact aerobic dancing. Vigorous-intensity physical activity is intense enough to represent a substantial challenge to an individual and results in a significant increase in heart and breathing rate (CDC Web site <http://www.cdc.gov/nccdphp/dnpa/physical/terms/index.htm>).

<b>Vigorous PA</b>	<b>Estimated METS<sup>2</sup></b>	<b>kcals Burned/Hr<sup>3</sup></b>
Running/Jogging (5 mph)	8.0	588
Bicycling (>10 mph)	8.0	588
Swimming (slow freestyle laps)	6.9	514
Aerobics	6.5	478
Walking (4.5 mph)	6.3	464
Heavy Yard Work (chopping wood)	6.0	441
Weight Lifting (vigorous effort)	6.0	441
Basketball (vigorous)	6.0	441

Conversion: [METs x 3.5 (body weight in lb/2.2)]/200 = kcal/min

<sup>2</sup> METs – the resting metabolic rate (approximately the amount of energy it takes to sit quietly)

<sup>3</sup> For a 154-lb individual, calories burned per hour will be higher for persons who weight more than 154 lbs and lower for persons who weigh less.

**Table D2-4. Decreased Fat Intake and Body Weight Change in Nonobese or Moderately Obese Subjects [IOM Table 11.1 (IOM, 2002)]**

Reference	Study Design	Dietary Fat ( percent of energy)	Weight Change (kg)		Comments
<i>Short-term studies (&lt; 1 year)</i>					
Boyar et al., 1988	19 women 6 mo-intervention Ad libitum diet	34 → 21	-5.1		Decreased fat intake associated with decreased energy intake
Buzzard et al., 1990	29 postmenopausal women 3-mo parallel Ad libitum diet	38 → 23 39 → 35	-2.8 -1.3		Decreased fat intake associated with decreased energy intake
Bloemberg et al., 1991	80 men 26-wk parallel Ad libitum diet	39 → 34 38 → 37	-0.94 +0.06		
Kendall et al., 1991	13 women 11-wk crossover Controlled diet	20-25 35-40	-2.54 -1.26		Decreased fat intake associated with decreased energy intake Low-fat diet hypocaloric
Leibel et al., 1992	13 men and women 15- to 56-d intervention Controlled diet	0, 40, or 70	No significant changes in body weight		Isocaloric diets
Westerterp et al., 1996	217 men and women 6-mo parallel Ad libitum diet	35 → 33 36 → 41	+0.3 +1.1		
Raben et al., 1997	11 women 14-d crossover Ad libitum	46 → 28	-0.7		Decreased fat intake associated with decreased energy intake
Gerhard et al., 2000	22 women 4-wk crossover Controlled diet	20 40	-1.1 -0.3		Low-fat diet hypocaloric
Saris et al., 2000	398 men and women 6-mo parallel Ad libitum diet	36 → 26 36 → 28 36 → 37	-0.9 -1.8 +0.8		Decreased fat intake associated with decreased energy intake
<i>Long-term studies (≥ 1 year)</i>					
Lee-Han et al., 1988	57 women 1-year parallel Ad libitum diet	36 → 23 → 26 36 → 34 → 36	<u>6 mo</u> -1.16 +0.07	<u>12 mo</u> -0.93 +0.62	Decreased fat intake associated with decreased energy intake

Reference	Study Design	Dietary Fat ( percent of energy)		Weight Change (kg)		Comments
Boyd et al., 1990	206 women 1-year parallel Ad libitum diet	37 → 21 37 → 35		-1.0 0		
Sheppard et al., 1991	276 women 1- and 2-year parallel Ad libitum diet	<u>0 to 1 y</u> 39 → 22		-3.0		Decreased fat intake associated with decreased energy intake
		39 → 37		-0.4		
		<u>1 y to 2 y</u> 22 → 23		+ 1.1		
Baer, 1993	70 men 1-year parallel Ad libitum diet	38 → 31		-5.0		Decreased fat intake associated with decreased energy intake
		37 → 36		+1.0		
Kasim et al., 1993	72 women 1-year parallel Ad libitum diet	36 → 18		-3.4		Decreased fat intake associated with decreased energy intake
		36 → 34		-0.8		
Black et al., 1994	76 men and women 2-year parallel Ad libitum diet	40 → 21		-2.0		
		39 → 39		-1.0		
Knopp et al., 1997	137 men 1-year parallel Ad libitum diet	36 → 27		-2.9		
		35 → 22		-2.9		
Stefanick et al., 1998	177 postmenopausal women and 190 men 1-year parallel Ad libitum diet	<u>Women</u> 23	<u>Men</u> 22	<u>Women</u> -2.7	<u>Men</u> -2.8	Decreased fat intake associated with decreased energy intake
		28	30	+0.8	+0.5	
Kasim- Karakas et al., 2000	54 postmenopausal women 1-year intervention Controlled diet 4 mo Ad libitum diet 8 mo	34 → 14 → 12		<u>4 mo</u> -1.3	<u>12 mo</u> -5.9	