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Part G. Section 4: Energy Balance

Introduction

Overweight and obesity are linked to increased risk of morbidity from hypertension, dyslipidemia, type 2 diabetes, coronary heart disease, stroke, gallbladder disease, osteoarthritis, sleep apnea and respiratory problems, and endometrial, postmenopausal breast, prostate, and other cancers (1;2). In addition, obesity is associated with excess overall mortality (3). Unfortunately, the prevalence of overweight and obesity has increased dramatically over the past 20 years in the United States to 70.8% and 31.1% for adult men, and 61.8% and 33.2% for adult women, respectively (4). This increase has been attributed to changes in environment and lifestyle factors because the escalating prevalence has been occurring in a constant genetic milieu. The focus in this chapter is on the role that physical activity plays in energy balance.

Review of the Science

Overview of Questions Addressed

This chapter addresses 5 major questions related to physical activity and energy balance.

1. How much physical activity is needed for weight stability and weight loss?

2. How much physical activity is needed to prevent weight regain in previously overweight individuals?

3. What is the effect of physical activity on body composition parameters (e.g., waist circumference, intra-abdominal fat, abdominal obesity, total body fat) that are related specifically to metabolic disorders?

4. What effects do sex and age have on the role of physical activity in energy balance?

5. How do the physical activity requirements for weight maintenance differ across racial/ethnic and socioeconomic groups?

Data Sources and Process Used to Answer Questions

The Energy Balance subcommittee used the *Physical Activity Guidelines for Americans* Scientific Database as its primary source for each question (see ***Part F. Scientific Literature Search Methodology,*** for a complete description of the Database). It also used other databases, reviews, and meta-analyses to obtain evidence bearing on each question. Specific search strategies are described for each question.

Caveats

Four points need to be mentioned at the outset of this chapter on physical activity and energy balance. First, in contrast to outcomes addressed in other chapters, in which physical activity can be discussed as the primary variable affecting the outcome, achieving energy balance is dependent on both energy intake and energy expenditure. With the availability of inexpensive and easily accessed high-calorie, highly palatable foods, it is far easier to increase energy intake than to increase energy expenditure in our society. In support, the 2005 Dietary Guidelines Advisory Committee Report (5) indicated that most Americans are consuming energy in excess of energy needs, and it is not likely to change in the near future. Consequently, final recommendations related to the level of physical activity needed for weight maintenance, weight loss, or prevention of weight regain after weight loss must consider energy intake issues as well.

Second, when a caloric deficit induced by exercise is compared with an equivalent caloric deficit created by a reduction in caloric intake, there is little or no difference in weight loss (6). However, in many weight loss studies, the proportion of the caloric deficit due to physical activity is only a small fraction of the overall caloric deficit, and consequently, the contribution that physical activity makes to weight loss is relatively small. This must be remembered as we address the role of physical activity **alone** on weight-related issues.

Third, secular trends have increased the use of automation and labor-saving devices on the job, at home and in the community and increased passive leisure-time physical activity (e.g., TV/VCR, computer use). These trends influence the amount of physical activity needed to achieve energy balance.

Finally, if we did not have an overweight and obesity problem in our society, we would still need a physical activity recommendation to maintain health and prevent disease. That simple message is lost on many who focus solely on the role of physical activity in preventing overweight and obesity. Consequently, the level of physical activity needed to maintain health and prevent disease is the baseline for any physical activity recommendation for energy balance.

Question 1: How Much Physical Activity Is Needed for Weight Stability and Weight Loss?

Conclusions

All study designs provide clear evidence of a dose-response relation between physical activity and weight loss. However, few data are available on weight stability over the long term. Available data on weight stability are from short-term clinical trials. Based on these trials, a dose of physical activity in the range of 13 to 26 MET-hours per week resulted in a modest 1% to 3% weight loss, consistent with weight stability over time (7-9). Thirteen MET-hours per week is equivalent to walking at a 4 mile per hour pace for 150 minutes per week or jogging at a 6 mile per hour pace for 75 minutes per week. The magnitude of weight loss resulting from studies of resistance exercise is typically less than 1 kilogram (2.2 pounds). However, this result may be affected by the relatively short duration of these studies and gains in fat-free mass that accompany such interventions. In contrast, it is clear that if one wants to achieve weight loss (i.e., more than 5% decrease in body weight), a dietary intervention also is needed. The dietary intervention could include either a maintenance of baseline caloric intake, or a reduction in caloric intake to accompany the physical activity intervention. The magnitude of change in weight due to physical activity is additive to that associated with caloric restriction.

Definitions

To aid in the study of patterns of weight change, the scientific literature has operationally defined the concept of weight stability. St. Jeor and colleagues (10) define weight stability as a change of 2.3 kilograms (5 pounds) or less of initial body weight. In this study, participants' weights were monitored over a period of time using this criterion. It was determined that 62%, 52%, 49%, and 46% of participants were classified as maintaining their body weight at 1, 2, 3, and 4 years of follow-up, respectively. The Pound of Prevention Study also defined weight maintenance as a change of 2.3 kilograms (5 pounds) or less (11) of initial body weight. When examined over a 3-year period, 40% of men and 38% of women were classified as "maintainers," with a mean weight change of 0.3 kilograms (0.7 pounds) and 0.2 kilograms (0.4 pounds), respectively. Moreover, across the entire sample of 957 individuals, the mean weight gain over a 3-year period was 1.7 kilograms (3.7 pounds) for men and 1.8 kilograms (4 pounds) for women. This would suggest that the mean weight gain across the population may be approximately 0.6 kilograms (1.3 pounds) per year.

More recently, Stevens and colleagues (12) have recommended that weight maintenance be defined as less than a 3% change in body weight. Moreover, they recommended that a change in body weight of 3% to less than 5% of initial weight be considered as small fluctuations in body weight, and a change of 5% or more of body weight be considered clinically significant. Considering these standards, an obese individual weighing 91 kilograms (200 pounds) would need to reduce body weight by 4.5 kilograms (10 pounds) to have a significant weight loss, and a weight change of 2.7 kilograms (6 pounds) would be considered weight stability. These standards should be considered when evaluating the effect of physical activity on body weight change to determine whether various doses and modes of physical activity result in weight stability or clinically relevant weight loss.

Rationale

A search of the *Physical Activity Guidelines for Americans* Scientific Database identified 126 research articles on the effect of physical activity on weight loss and weight stability. Additionally, pertinent reviews available through a MEDLINE search were considered.

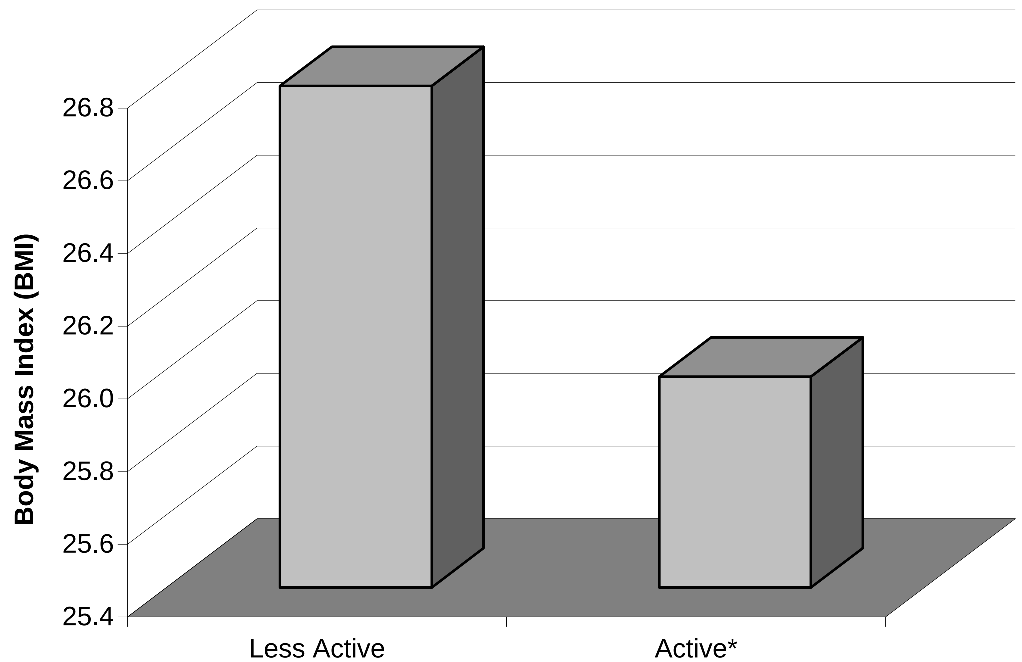
Cross-Sectional Studies

Twenty-four cross-sectional studies were identified that examined the association between physical activity and body weight. Of these 24 studies, 23 reported results suggesting an inverse relationship between physical activity and body weight and/or body mass index (BMI) (13-35). These studies tended to illustrate a dose-response relationship between physical activity and body weight or BMI. For example, Giovannucci and colleagues (14) reported that when 0.9, 4.8, 11.3, 22.6, and 46.8 MET-hours per week were used to define quintiles of physical activity, corresponding BMI values were 25.4, 25.3, 25.1, 24.7, and 24.4 kg/m^2, respectively. More recently, Kavouras and colleagues (15) reported that individuals participating in physical activity that is consistent with the current consensus public health recommendations of at least 30 minutes per day on 5 days a week had a significantly lower BMI (25.9 kg/m^2) when compared to the BMI (26.7 kg/m^2) of less active individuals (Figure G4.1). Thus, based on these findings, it appears that levels of physical activity that are consistent with a range of 30 to 60 minutes per day on at least 5 days per week (150 to 300 minutes per week) is sufficient to maintain and/or significantly reduce body weight.

Prospective Studies

Nine prospective studies were identified that reported on the benefits of physical activity to prevent weight gain and/or result in weight loss (36-44). Three studies, which had a follow-up period of 1 to 3 years, all reported a favorable association between physical activity and weight-related outcomes (36;37;39). The remaining 6 studies, which had a follow-up period of 6.5 years or greater, also reported a favorable association between physical activity and weight-related outcomes (38;40-44). Berk and colleagues (43) found that individuals who initially reported less than 60 minutes per week of physical activity and increased to 134 minutes per week of physical activity had an increase in BMI of 0.4 kg/m^2 across a 16-year follow-up period, but this was not significantly different from the 0.9kg/m^2 increase observed for individuals who remained sedentary (less than 60 minutes per week) at both assessment periods. These data suggest that less than 150 minutes per week of physical activity will result in a non-significant blunting of weight gain compared to individuals who remain sedentary. However, individuals who were classified as active at both assessment periods were participating in 261 minutes per week of physical activity, and had a significantly smaller change in BMI compared to individuals who were initially active (more than 60 minutes per week) at baseline but became inactive at follow-up (less than 60 minutes per week). This supports the need to maintain a physically activity lifestyle to manage body weight long-term.

Figure G4.1. Differences in Body Mass Index Due to Level of Physical Activity



*Active is defined as the consensus public health recommendation for physical activity (3 or more days per week of 20 minutes per day at vigorous intensity or 5 or more days per week of 30 minutes per day at moderate intensity).
Source: Adapted from Kavouras and colleagues, 2007 (15).

Figure G4.1. Data Points

	Less Active	Active*
BMI	26.7	25.9

Randomized Trials

Endurance Exercise

Twenty studies were identified that examined the effect of endurance exercise on body weight. However, 7 studies were not reviewed due to the intent of the study to focus on marathon training, a dietary intervention to counter or enhance the weight loss effects of exercise, the inclusion of only subjects with serious psychiatric disabilities, the lack of a consistent training paradigm across the observation period, or the exercise volume not expressed in as minutes per week. The remaining 13 studies were reviewed in greater detail. Twelve used a randomized design, although 3 of them did not have a control group and/or the physical activity was in addition to a dietary intervention (45-47), and 1 used a non-randomized design to examine the effect of physical activity but did not include a comparison group (48). In addition, the primary purpose of 5 of the studies was on something other than weight loss (49-53). The remaining 4 studies (7-9;54) had sufficient statistical power to evaluate the effect of physical activity on body weight and body composition.

These studies ranged in duration from 8 to 16 months, and physical activity level ranged from 180 minutes of moderate-intensity physical activity per week to 360 minutes of moderate- to vigorous-intensity physical activity per week. In addition, one study (9) evaluated 3 levels of physical activity, and 2 (7;8) established, post hoc, tertiles of physical activity participation (adherence) based on activity logs and/or pedometer records to evaluate a dose-response pattern. Typical weight losses were 1 to 3 kilograms (2.2 to 6.6 pounds), which corresponded to less than 3% change in body weight, but evidence of a dose-response relationship was clear, with those doing the greatest amount of physical activity achieving weight losses of 4% to 6% (the latter associated with an energy expenditure of 668 kcal per session, 5 days per week). A dose of physical activity in the range of 13 to 26 MET-hours per week resulted in a modest 1% to 3% weight loss, consistent with weight stability over time.

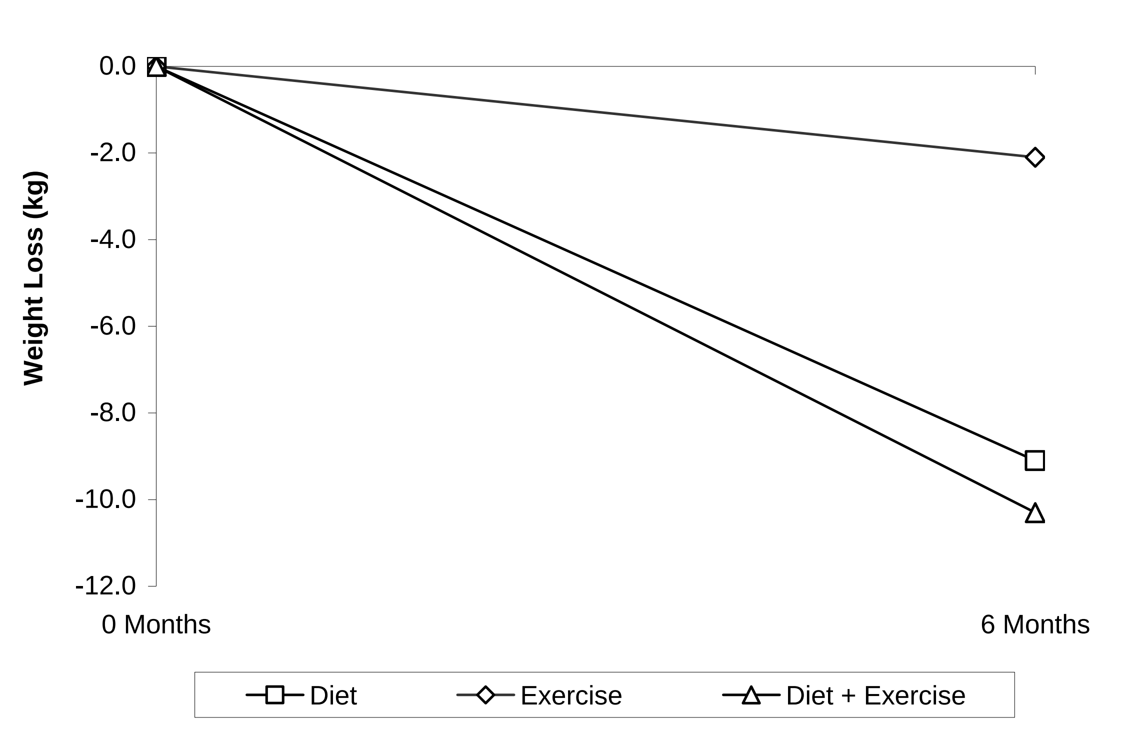
Resistance Exercise

An alternative form of physical activity is resistance exercise. Ten studies were reviewed that examined the impact of this form of exercise on change in body weight, and all of these studies showed a modest reduction (less than 1 kilogram) or a non-significant change in body weight (55-64). This finding of a modest impact of resistance exercise on body weight was confirmed in a literature review (65). A potential explanation for this lack of a reduction in body weight is that many of these studies reported an increase in fat-free mass resulting from resistance exercise training, which resulted in a reduction in percent body fat, but did not change absolute body weight or fat mass. Thus, changes in body composition may be a desirable outcome to examine when determining the effect of resistance exercise on body weight parameters. However, the lack of a sufficient dose of physical activity to elicit a significant energy deficit may also explain these findings, as many of these studies were relatively short in duration and included only 2 to 3 days per week of resistance exercise.

Five studies from the *Physical Activity Guidelines for Americans* Scientific Database examined the combination of endurance and resistance exercise on change in body weight. Two studies used randomized designs to assign participants to a physical activity group or a control group (66;67), 1 used a randomized cross-over design involving 8 weeks of physical activity and 8 weeks of no physical activity (68), and 2 examined the effect of physical activity but did not include a control group (69;70). Four of these studies reported no effect of combined endurance plus resistance exercise on change in body weight (66-69), and 1 study that did not include a control group (70) reported a significant effect. A potential limitation of these studies is that they ranged from 8 to 10 weeks in duration, which may have been too short a time to significantly affect body weight.

In general, regular participation in moderate-to-vigorous physical activity is associated with weight maintenance over time. In contrast, it is clear that if one wants to achieve clinically relevant weight loss (a decrease of 5% or more in body weight), a dietary intervention is usually needed. This is shown clearly in Figure G4.2, adapted from Wing, 1999 (71).

Figure G4.2. Weight Loss Related to a Diet Intervention, an Exercise Intervention, and a Diet + Exercise Intervention



Source: Adapted from Wing, 1999 (71)

Figure G4.2. Data Points—Weight Loss in kg

	0 Months	**6 Months**
Diet	0	-9.1
Exercise	0	-2.1
Diet + Exercise	0	-10.3

The magnitude of weight loss due to physical activity is additive to caloric restriction, but physical activity is generally insufficient by itself to bring about clinically significant weight loss. Consistent with this, McTiernan and colleagues (8) estimated that the physical activity intervention in their study should have produced a weight loss of 7.8 kilograms, rather than the 1.4 kilograms (women) and 1.8 kilograms (men) observed, **if caloric intake had remained stable.** Further, studies in which the caloric intake was held constant (by design) from baseline showed that the weight loss associated with the physical activity intervention was what one would predict from the physical activity energy expenditure (6). Consequently, the addition of a dietary restraint **to not increase caloric intake** may have resulted in clinically significant weight loss, rather than just weight stability with the physical activity intervention mentioned above. The magnitude of weight loss reported in these studies is consistent with earlier reviews on this topic by Wing (71) and the Expert Panel of Clinical Guidelines for the Treatment of Obesity (1).

Question 2. How Much Physical Activity Is Needed to Prevent Weight Regain in Previously Overweight Individuals?

Conclusions

Most of the available literature indicates that "more is better" when it comes to the amount of physical activity needed to prevent weight regain following weight loss. However, the literature has some considerable shortcomings regarding the appropriate research design needed to directly address this question. Given these limitations, the estimated gross energy expenditure needed to achieve weight maintenance following substantial weight loss is about 31 kilocalories per kilogram week or 4.4 $kcal \cdot kg^{-1} \cdot d^{-1}$, which is equivalent to walking 54 minutes per day at a 4 mile per hour pace, walking 80 minutes per day at a 3 mile per hour pace, or jogging 26 minutes per day at a 6 mile per hour pace (72-74).

Rationale

Initial references were obtained with a search of the *Physical Activity Guidelines for Americans* Scientific Database. Key words included adults, exercise, physical activity, obesity, adiposity, weight, and BMI. Eight systematic reviews or meta-analyses also were reviewed for pertinent references. Studies that investigated special populations (e.g., physically disabled), included individuals with a disease known to affect weight (e.g., cancer), or weight loss drugs, were excluded. To be included, studies had to target a period of weight loss followed by a period of weight maintenance using physical activity as the strategy for preventing weight regain.

Eight randomized trials met the above criteria and were used for this review. Of the eight studies, only three had a design in which participants were randomized after weight loss and only two used a control group. Three observational or prospective cohort studies were identified that met the above criteria and were used for this review. Four position papers or reports also were used as references.

It is generally accepted that individuals can lose weight but most cannot maintain significant weight loss. Because it has an energy equivalent, physical activity is universally promoted as a necessary component of strategies to maintain weight loss (1;75;76). Indeed, physical activity is often cited as the best predictor of weight maintenance after weight loss (77;78). A systematic review of physical activity to prevent weight regain subsequent to weight loss was completed by Fogelholm and Kukkonen-Harjula (79). The majority of studies included in this review were observational studies and studies of individuals who were randomized at baseline to exercise or no exercise, or to different levels of physical activity. Follow-up varied from several months to several years and generally showed that individuals who engaged in exercise experienced less regain than those individuals who did not, and those individuals who engaged in greater amounts of physical activity experienced less regain than those who did more moderate levels. Only 3 studies used a design in which individuals were randomized to physical activity after weight loss (80-82), and the results were inconsistent, showing that physical activity had an indifferent, negative, or positive effect on prevention of weight regain.

Despite the accepted concept that physical activity is necessary for successful weight maintenance after weight loss, the amount that is needed remains uncertain. The 1995 Centers for Disease Control/American College of Sports Medicine (CDC/ACSM) recommendations for physical activity specified the accumulation of 30 minutes of moderate-intensity physical activity for most days of the week (83). These guidelines were provided for health promotion and disease prevention. However, they were widely interpreted to also be useful for weight management. Minimum levels of 150 minutes per week (30 minutes per day, 5 days a week) of moderate-intensity physical activity were also recommended by the ACSM Position Stand for “Appropriate Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults” (75). However, recent evidence suggests that greater levels of physical activity may be necessary to prevent weight regain after weight loss. For example, individuals in the National Weight Control Registry who have maintained weight loss have shown levels of energy expenditure equivalent to walking about 28 miles a week (77). Schoeller and colleagues (74) used doubly-labeled water to study women who recently lost 23±9 kilograms of weight in order to estimate the energy expenditure needed to prevent weight regain. Retrospective analyses of these data were performed to determine the level of physical activity that provided maximum differentiation between gainers and maintainers. Based on these analyses, it was determined that individuals would need to expend about 4.4 kilocalories per kilogram per day in physical activity (which is equivalent to about 80 minutes per day of moderate-intensity physical activity or 35 minutes per day of vigorous physical activity) to prevent weight regain.

Jakicic and colleagues (73;84) and Andersen and colleagues (85) provided data from randomized trials showing that individuals who performed large amounts of physical activity maintained weight loss better at follow-up of 18 months, 12 months, and 12 months, respectively, than did those doing smaller amounts of physical activity. In particular, Jakicic and colleagues (73;84) showed very little weight regain in individuals who performed more than 200 minutes per week of moderate-intensity physical activity. Ewbank and colleagues (72) also found similar results 2 years after weight loss by very-low-energy diet. Retrospectively grouping participants by levels of self-reported physical activity, individuals who reported greater levels (i.e., walking about 16 miles per week,) had significantly less weight regain than individuals reporting less physical activity per week (4.8 to 9.1 miles per week). However, it is important to note that individuals in all 3 studies above were grouped into physical activity categories retrospectively and were not randomly assigned to those groups after weight loss. Thus, the amount of physical activity was self-selected and therefore does not provide clear evidence for the amount needed to prevent weight regain.

To explore the effects of levels of physical activity greater than those normally recommended in weight management programs, Jeffery and colleagues (86), targeted energy expenditures of 1,000 kilocalories per week and 2,500 kilocalories week for 18 months in 2 groups of participants; these levels were randomly assigned at baseline. The actual reported energy expenditure at 18 months was 1,629 ± 1,483 and 2,317 ± 1,854 kilocalories per week for the 1,000 and 2,500 kilocalories per week groups, respectively. At 6 months, weight loss did not differ between the groups, but there were significant differences at 12 and 18 months (weight maintenance) follow-up, with the 2,500 kilocalories per week group showing significantly greater weight losses (6.7 ± 8.1 kilograms versus 4.1 ± 8.3 kilograms). The energy equivalent for walking for the 2,500 kilocalories per week group and 1,000 kilocalories per week group was about 3.3 miles per day and about 2.3 miles day, respectively. This study showed that greater levels of physical activity resulted in significantly lower levels of weight regain. However, the results must be interpreted with caution, as the percentage of individuals meeting the targeted energy expenditure varied greatly, and the behavioral interventions were not equal.

In general, large volumes of physical activity are needed to prevent weight regain in those who have lost a great deal of weight. Studies by Ewbank and colleagues (72), Jakicic and colleagues (73), and Schoeller and colleagues (74) indicate that the volume of physical activity needed for that purpose is approximately 31 MET-hours per week or 4.4 MET-hours per day.

Question 3. What Is the Effect of Physical Activity on Body Composition Parameters (e.g., Waist Circumference, Intra-Abdominal Fat, Abdominal Adiposity, Total Body Fat) That Are Specifically Related to Metabolic Disorders?

Conclusions

A dose-response relation exists between volume of physical activity and decreases in total and abdominal adiposity in overweight and obese individuals. In the absence of coincident caloric restriction, aerobic physical activity in the range of 13 to 26 MET-hours per week results in decreases in total and abdominal adiposity that are consistent with improved metabolic function. Thirteen MET-hours per week is equivalent to walking at a 4 mile per hour pace for 150 minutes per week or jogging at a 6 mile per hour pace for 75 minutes per week (7-9). However, larger volumes of physical activity (e.g., 42 MET-hours per week) result in decreases in intra-abdominal adipose tissue that are 3 to 4 times those seen with 13 to 26 MET-hours per week, even without weight loss. The evidence thus far suggests that abdominal fat loss with increased physical activity is proportional to overall fat loss.

Definitions

The obesity phenotype that conveys the greatest health risk of metabolic disorders, such as the metabolic syndrome and type 2 diabetes, is one that favors an accumulation of adipose tissue in the abdominal region. Regular physical activity is recognized as an effective method of preventing excessive weight and fat gain throughout adulthood, and although physical activity is commonly prescribed to reduce overall obesity, the influence of exercise-induced weight loss on abdominal adiposity is not clear. Abdominal adiposity is characterized several ways in the scientific literature. Modern imaging techniques such as MRI, DXA, and CT provide highly-precise quantification of total body fat content (expressed in relative [%] or absolute [kilogram] terms), as well as specific measures of abdominal fat, such as the subcutaneous and visceral (intra-abdominal) fat areas (cm^2). Although less precise than the imaging measures, the waist circumference (measured in centimeters and usually defined at the level of the lowest rib) is the most widely-used anthropometric measure of abdominal adiposity and therefore has the most clinical utility of all these measures.

Rationale

The *Physical Activity Guidelines for Americans* Scientific Database was accessed using the following delineation terms: 1) **population sub-group:** adults/older adults; 2) **study design:** randomized controlled trials (RCTs); longitudinal experimental studies (before/after); and prospective observational studies; and 3) **health outcomes:** adiposity measures (e.g., total fat, percent fat, abdominal fat area [visceral and subcutaneous], waist circumference) related specifically to metabolic disorders. Evidence obtained using the Scientific Database was supplemented with recently-published scientific papers and review articles.

Favorable body composition changes (reduced fat mass and increased lean mass) occur with the adoption of regular physical activity — even among individuals aged 75 years and older, and evidence suggests that current activity is more protective than past activity (87;88). What is not clear at this time is the amount and type of activity necessary to result in meaningful alterations in abdominal fat, which in turn can preserve or improve metabolic function. Unfortunately, few large-scale RCTs have been directed toward this question. The data that do exist are from relatively small RCTs and controlled intervention studies. Nonetheless, these studies paint a consistent picture of energy expenditure requirements for minimizing fat gain and/or reducing excess total and abdominal fat.

Several RCTs and controlled interventions report the benefits of moderate- to vigorous-intensity aerobic exercise to overall improvements in body weight, body fat, and lean mass in middle-aged and older adults (7;8;89-93). The data are equivocal, however, with regard to the ability to significantly alter regional distribution of body fat with endurance training (7-9;54;91;93-95). In general, aerobic exercise, without dieting, appears to have a beneficial effect on overall and abdominal adiposity. However, the exercise dose necessary to result in these alterations is rather high. In Irwin and colleagues (7), 176 minutes per week of moderate- to vigorous-intensity physical activity performed over 12 months resulted in a reduction in subcutaneous fat and intra-abdominal fat of 5.4% and 5.8%, respectively, with the impact being even larger when contrasted with the control group. In addition, McTiernan and colleagues (8) used a higher volume/longer duration aerobic exercise regimen (60 minutes or more of moderate- to vigorous-intensity physical activity on 6 days per week) over 12 months of training and also reported modest decreases in the subcutaneous abdominal fat (5% in women and 11% in men) and intra-abdominal fat (6% in women and 8% in men) depots and in the waist circumference (2% in women and 3% in men). Data from the Studies of Targeted Risk Reduction Interventions through Defined Exercise (STRRIDE) show that the highest amount of exercise performed (equivalent of jogging approximately 20 miles per week) over 8 months resulted in, at best, a 7% decrease in visceral and subcutaneous fat in men and women aged 40 to 65 years (9). Ross and colleagues (93) report an 18% reduction in total fat and a 20% reduction in abdominal fat among non-dieting abdominally-obese women who exercised every day for about 60 minutes (or 500 kilocalorie expenditure) for 14 weeks. Together, these findings (7-9;93) and others (6) support the contention that in the absence of coincident caloric restriction, aerobic physical activity in the range of 13 to 26 kilocalories per kilogram per week results in decreases in total and abdominal adiposity that are consistent with improved metabolic function. However, as mentioned above, when more physical activity is done per week (e.g., 42 MET-hours per week), decreases in intra-abdominal adipose tissue approach 3 to 4 times the level seen with 13 to 26 MET-hours per week, even without weight loss (93).

A recent study employing 45 minutes of resistance exercise training twice weekly also reports small, yet favorable changes in total and abdominal fat (56) in middle-age and older adults, but not in younger, non-obese women (96). In a 2-year study of resistance training in overweight and obese premenopausal women, Schmitz and colleagues (56) report a 4% decrease in total fat in the exercise group versus a negligible change in the control group ($P<0.01$). Interestingly, intra-abdominal fat increased over 2 years by 7% in the exercise group and by 21% in the control group, underscoring the benefits of resistance training (without caloric restriction) in at least minimizing intra-abdominal fat gain in middle-aged women. The benefits of resistance training may be most noticeable among obese and older populations, who typically have the greatest amount of abdominal fat.

Generally, short-term (less than 6 months) exercise interventions will have a positive effect on body composition. However, the magnitude of these alterations in body fat or lean mass may be of limited biological significance (48). Studies that employ moderate- to vigorous-intensity aerobic exercise of at least 55-75% VO_{2peak} (4.5-6 METs), on most days of the week (i.e., 4 or more days), over intervention periods of at least 9 months, report the most significant changes in body composition (7-9;91;93). In general, the amount of adiposity present in study subjects at baseline will affect the amount of fat lost with a given intervention. Indeed, studies employing overweight or obese subjects (7;8;56;92;93) report greater improvements in body composition than those studies using subjects of normal weight (48;96). Also important is the dose-response relation highlighted by Ross and colleagues (93) between exercise-induced weight loss and fat loss — that is, greater total weight loss will result in greater fat loss (7;93). Nonetheless, Ross and colleagues (93) report that, even without coincident weight loss, 60 minutes per day of vigorous-intensity exercise (approximately 500 kilocalories per day) on 7 days per week still resulted in statistically significant reductions in total (7%), abdominal (10%), and intra-abdominal (18%) fat in abdominally-obese premenopausal women.

Overall, regular participation in aerobic physical activity causes decreases in both total and abdominal adiposity, changes that are consistent with improved metabolic function. The greater the volume of physical activity, the larger the change in adiposity.

Question 4: What Effects Do Sex and Age Have on the Role of Physical Activity in Energy Balance?

Conclusions

Some evidence indicates that the amount of physical activity needed to maintain a constant weight differs between men and women and increases with age. This may be due to a number of physiologic and behavioral factors that also vary by sex and by age. However, the evidence is not sufficient to recommend differential physical activity prescriptions based on sex or on age alone.

Rationale

The *Physical Activity Guidelines for Americans* Scientific Database was accessed using the following delineation terms: 1) **population sub-group:** adults/older adults; 2) **study design:** randomized controlled trials, longitudinal experimental studies (before/after), prospective observational studies, and cross-sectional studies; 3) **health outcomes:** body weight; and 4) **search term:** aging, age, gender, men, women. Studies identified using the Scientific Database were supplemented by recently-published or in press scientific papers and review articles. Findings presented here were limited to studies having a forward study design (i.e., prospective observational and/or longitudinal experimental studies) with adequate statistical power to distinguish moderate effect sizes from chance alone.

Sex

The prevalence of obesity is higher among women compared with men, particularly among women from ethnic minority groups (4;97). Although women report less physical activity than men, it is not clear whether this is actually so, or whether it is a consequence of measurement error resulting from the low sensitivity of traditional physical activity surveys (83;98;99). In any case, potential sex differences in the influence of physical activity on weight stability are important to consider in maximizing the utility of future public health guidelines.

Cross-sectional and longitudinal epidemiologic studies generally have demonstrated inverse associations between physical activity and weight gain in both men and women (e.g., 100-105). Dose-response relationships have been somewhat less consistent in women than in men. However, as stated previously, this may be attributable to measurement error associated with self-reported data (100;106). Indeed, objective measurements of energy expenditure (e.g., doubly-labeled water) have either stronger inverse associations in men than in women or no biological sex differences in response to different amounts of physical activity (107). The few intervention studies that included both men and women (along with sex-specific analyses) report weight or fat losses only in men (107), no change in either sex (67), or similar changes in both men and women (e.g., 8;58;89;108;109).

It is likely that differences in findings among these intervention studies reflect dissimilarities among study protocols. However, even within particular study samples, observed sex differences in weight loss responses to exercise can be attributed to a number of factors. For instance, several highly controlled laboratory-based intervention studies have noted that women are more resistant to weight loss or may require greater energy expenditure compared with men to maintain a healthy body weight (54;100;107). Indeed, this suggests that a similar absolute energy expenditure (e.g., 1,200 kilocalories per week) may not yield the same results in men and women. This may be due to a greater proportion of less lipolytically responsive gluteofemoral adipose tissue in younger and middle-aged women than in men of the same age. Animal studies also have observed a sex dimorphism in the control of energy homeostasis that might be attributed to a differential interaction between adiposity hormones and food intake control systems in the brain (110;111). These biological sex differences in responsiveness to weight change may be difficult to discern in large community-based interventions or at the population level, however, due to measured or unmeasured sex differences in: 1) how a similar level of physical activity is performed (walking vs. water aerobics vs. running); 2) adherence to a given exercise prescription; or 3) dietary intake. Because a number of other physiological (body mass, peak aerobic capacity) or behavioral factors (cigarette smoking, drinking, hormone replacement therapy) also may vary between men and women, studies that measure sex differences in weight loss responses to exercise must be careful to control for these covariables either by matching in experimental designs or by appropriate statistical adjustments when feasible.

Age

Because the risk of chronic disease increases markedly with sedentary lifestyles and with age, the public health burden associated with inactivity is substantial among middle-aged and older adults (88). In general, lower levels of physical activity are associated with higher body weight and body fat in middle-aged and older adults (4;87;112-114). The epidemiologic studies to date provide clear longitudinal evidence linking habitual physical activity to the prevention of excess weight gain in both men and women (100-105;115) and this is true even in older age. Although the effect sizes from these observational studies appear small, over the lifespan these small savings in excess weight gain accumulate into net savings that are quite meaningful with regard to minimizing the risk of obesity-related disorders. Moreover, the longitudinal epidemiologic evidence suggests that as people progress from young adulthood to old age, they require increasing amounts of daily energy expenditure to maintain a constant body weight (37;104;105;115). More than likely, this is due to a combination of physiologic (e.g., sex hormone depletion, decline in peak aerobic capacity) and lifestyle changes (e.g., retirement) that occur with aging that make older people more susceptible to positive energy balance and thus to weight gain.

An active lifestyle also is beneficial in preventing weight **loss,** an increasingly important concern for the oldest sectors of the population (those older than 85 years) because of its relation to metabolic disorders and functional ability. Several observational studies have demonstrated the longitudinal benefits of even modest levels of physical activity on preventing excess weight loss in older age, presumably through the maintenance and preservation of lean mass (116-118).

Among intervention studies, training protocols are too variable and sample sizes are often too small to establish dose-response relations between changes in weight and activity type, duration, and intensity for different age subgroups. Nonetheless, some intervention studies have demonstrated statistically significant improvements in various weight-related outcomes (e.g., BMI, body fat distribution) with aerobic and resistance training in older participants (e.g., 8;89;108), whereas others have not (104;105). The magnitude of improvement observed in many of these intervention studies is similar, but is smaller than what is often observed in younger populations given the same relative exercise dose. A similar relative stimulus (say 75% of VO_{2peak}) will translate into a lower absolute exercise dose in older compared with younger people (due to lower levels of lean mass and aerobic capacity) and therefore, may not result in an adequate stimulus for fat loss in older people. This may be especially true for older women.

Question 5: How Do the Physical Activity Requirements for Weight Maintenance Differ Across Racial/Ethnic and Socioeconomic Groups?

Conclusions

Although some evidence suggests possible ethnic differences, the paucity of data, particularly from the stronger longitudinal cohort or randomized, controlled intervention study designs, makes it unwise to draw conclusions as to whether physical activity requirements for weight stability or reduction differ by racial/ethnic or socioeconomic groups.

Overview

Racial/ethnic disparities in obesity prevalence are robust and persistent across socioeconomic groupings (e.g., 119-121). African Americans, American Indians/Alaska Natives, Latinos and Pacific Islanders have substantially higher BMIs than do whites and Asian Americans, and a significant interaction exists between ethnicity and sex (122). For example, 54% of African American women are obese, compared with 42% of Mexican American women and 30% of white women (4). This contrasts with the similar obesity rates among men: 34% of African Americans, 32% of Mexican Americans, and 31% of whites (4).

Greater obesity implies a lesser ability to maintain weight and avoid weight gain, which may be associated with less physical activity, more physical inactivity, or both. However, racial/ethnic differences in the contribution of physical activity to weight maintenance have been systematically examined only infrequently. Therefore, in addition to the reasons to examine whether general physical activity recommendations should differ between racial/ethnic groups (See ***Part G. Section 11: Understudied Populations,*** for a detailed discussion of this topic), specifically exploring the possible need for different recommendations to promote weight maintenance also is warranted. Available evidence suggests at least 2 possible reasons for differential influences of physical activity on weight maintenance by race/ethnicity:

1. Differences in the energy cost of physical activity, such that some ethnic groups would appear to derive lesser benefits for weight maintenance at the same level of physical activity (e.g., 123).

2. Differences in the relative contribution of physical activity and excess calories (energy expenditure versus energy intake) to weight gain, such that some ethnic groups would receive less benefit than others because physical activity contributes less to the overall equation (124).

Experimental studies in exercise physiology have suggested that lower resting energy expenditures and/or activity-related energy expenditures may contribute to higher rates of obesity in Pima Indians and African Americans than in whites (123;125;126). However, recent studies have demonstrated that these physiological differences may, in fact, be explained by racial variations in body morphology (e.g., trunk versus limb length, organ size) (127-129) that would not necessarily influence the ability to maintain weight. The precise role in weight maintenance of racial/ethnic differences in resting or activity-related energy metabolism (as opposed to age or sex-related differences) in body composition is an important area for future research.

Rationale

The Energy Balance subcommittee used a search strategy to generate 236 articles from the *Physical Activity Guidelines for Americans* Scientific Database (all age group combinations except youth, with weight and BMI as the outcome of interest, excluding studies focused on weight loss). These articles were further screened to identify studies that linked physical activity to weight-related outcomes and met the following criteria: 1) targeting an ethnic minority group; **or** 2) including subgroup analyses by ethnicity, not simply treating race/ethnicity as a co-variate and adjusting for it; **and** 3) specifying the racial/ethnic minority groups included in the analyses, not aggregating in the analyses as “non-white;” **and** 4) having a sample size of 30 or more participants or at least 30 participants per study arm; **and** 5) having a “general audience” sample (i.e., not focusing on a specific subgroup such as elite athletes or postpartum women). Even very recent studies in US locations that have large ethnic minority populations, such as Baton Rouge, LA (130) and St. Louis, MO (131), did not characterize their samples by race/ethnicity. A MEDLINE search using similar parameters to those of the Scientific Database (key words: ethnic groups AND (body composition OR body weight OR obesity) AND (physical activity OR exercise OR walking) yielded 399 articles, most of which were already included in the Scientific Database. These articles were then further screened by applying the above racial/ethnic minority inclusiveness and sample size criteria, and eliminating those intervention studies in which physical activity was not the dominant intervention component (i.e., nutrition was equally strong or stronger). Reviews of relevant studies published after 1996 (132-135) and expert referral produced an additional in press publication.

Of the 24 articles identified by this systematic review, half reported on studies that were conducted outside the United States, including 9 in Asia/Pacific Islands (China, Japan, Taiwan, India, New Zealand), 2 in Africa (Nigeria, South Africa), and 1 in Central America (Mexico). Three were longitudinal cohort studies, 7 were interventions, and 14 were cross-sectional studies.

Few of the 24 studies were population-based, and thus, findings may not be representative even of subgroups with similar sociodemographic characteristics to those studied. Relatively few studies included Latinos, currently the largest minority group in the United States, and even fewer studies included American Indians, with their tremendous intra-ethnic heterogeneity from diverse tribal origins and affiliations. Most studies of Asian Americans or Pacific Islanders took place outside of the United States, introducing further complexity. International studies were included, however, because so few domestic studies included substantive racial/ethnic diversity, particularly among those with more rigorous designs. These studies may assist in clarifying any influence of some biological or cultural differences which may persist after migration to the United States, though they are likely to be less applicable with regard to differences influenced by the specific environmental or sociocultural context.

Of the 14 cross-sectional studies, which were conducted across a broad variety of racial/ethnic minority groups, including African Americans, Nigerians, South Africans, Pima Indians, Latinos, Asian Americans, Asians, and East Indians, most found an inverse association between physical activity level and weight/waist circumference/body fat percentage (29;103;113;136-146). This finding was consistent with studies in predominantly white populations (147). Among elderly Chinese, tai chi or swimming were associated with body fat distribution (lower levels in the thigh and/or abdomen), but not with total body adiposity (145). The exceptions were found in: (1) a study of 7,503 Mexican-American immigrants in Harris County, Texas, in which physical inactivity was correlated with obesity in women but not in men (103); (2) a study of 44 African American women (14% BMI less than 25, 25% to 30% Class II or III obese) in rural areas and small cities in North Carolina, in which 3-day pedometer step counts were not correlated with BMI or waist circumference (146); and (3) a study of 263 middle-aged Chinese in Hong Kong

(40% obese, 30% completely sedentary), in which low levels of physical activity were not correlated with BMI or waist circumference (144). In these instances, it is likely that BMI and/or physical activity was insufficiently variable to detect an effect.

Longitudinal studies in predominantly white populations generally demonstrate associations between increases in physical activity and decreases in the magnitude of weight gain (147). Of the 3 longitudinal studies identified in ethnic minority populations, however, only one, a 4-city convenience sample across several US regions, The Study of Women's Health Across the Nation or SWAN, replicated this association (113). SWAN study outcomes revealed associations between increases in daily routine physical activity (active transportation and less TV viewing) and exercise/sports, and less weight gain. On the other hand, increases in physical activity, compared to baseline, were not associated with smaller increases in weight, as reflected in findings of no change or decreases in waist circumference (113). The findings of the two nationally representative samples in the United States and Japan (114;148) were essentially null. He and Baker (148) found that, between 1992 and 2000, regular recreational physical activities, of any intensity, and work-related activities were not associated with less weight gain. Race (Asian or white), education, and income were not correlated with weight gain in multivariate analyses (148). However, although data were adjusted for race/ethnicity, it is not clear whether differences in the physical activity-weight gain association were analyzed by ethnicity. Lee and colleagues (114) found no baseline association between physical activity and weight, though the mean BMIs were 23.5-23.7 across activity levels. This study apparently did not examine the relationship between changes in physical activity and BMI changes. Thus, too few studies are available to draw conclusions about the influence of race/ethnicity on the association between physical activity and weight change over time.

Intervention studies selected for this review generally demonstrated that resistance training, alone or in combination with moderate- to vigorous-intensity aerobic physical activity, was necessary to produce changes in BMI or body composition/distribution in ethnic minority populations (48;67;89;149-152), despite the effectiveness of aerobic physical activity alone in improving non-weight-related aspects of the metabolic profile, such as reducing blood pressure (67;149). Wilmore and colleagues (48) presented the only within-study "head-to-head" inter-racial comparisons, with subgroup analyses after endurance training using advancing intensity and duration on cycle ergometers. The magnitude of weight loss for both whites and blacks was small; 0.2 kilogram (0.4 pound) mean weight loss in both groups. The change was statistically significant in whites but not blacks likely due to the larger sample size for whites (n=398) than blacks (n=159). Changes in various measures of body fat followed a similar pattern, with small but somewhat greater changes occurring in whites than blacks (e.g., change in sum of skinfolds for whites = -7.1 ± 0.8, blacks = -4.1 ± 1.5, $P<0.05$ for both). The ages (34.8 and 32.3 years for whites and blacks, respectively) and BMI (25.0 and 26.6 kg/m^2, respectively) were similar. Adjustments for the subtle racial/ethnic variations identified in experimental exercise physiology studies (e.g., 128) apparently were not performed (48). Wilmore and colleagues (48) concluded that the magnitude of the changes in body composition was not biologically significant in either blacks or whites and that a physical activity intervention of greater volume or longer duration was needed to produce meaningful changes in body weight and fat. In another study, in Japan, even quantities/intensities of walking sufficient to increase VO_{2max} (13,500 to 14,500 steps per day in the experimental groups versus 5,800 in the control group) did not alter BMI, although the participants in this study were normal weight or minimally overweight (24.6 to 24.7 and 25.2 kg/m^2, respectively) (149). Participants were presumably Japanese, although race/ethnicity of study samples is rarely specified in these international studies. Contrasting findings were reported in another international study. In this secondary analysis of data collected routinely on government health and social services workers in Mexico, Lara and colleagues (152) demonstrated a 0.32 kg/m^2 BMI decrease, a 1.0 kilogram (2.2 pound) weight loss, and a 1.6 centimeter (1.6 inch) decrease in waist circumference at the end of 1 year after integrating mandatory 10-minute structured group aerobic-calisthenic exercise breaks during paid work time in this group of mostly middle-aged, overweight and abdominally obese workers. Although the study had no control group, secular trends documented in Mexico at that time were similar to the United States mean increases of 1 to 2 pounds (0.45 to 0.9 kilograms) in body weight and 0.5 inches (1.27 centimeters) in waist circumference per year (113;152). The fact that the subjects of the Mexican study were not volunteer participants, but rather a sample more typical of the general population, and their overweight status, compared with the mostly normal weight Japanese sample, may account for the discrepant findings.

As noted in earlier reviews (e.g., 132-134;153) there is an extreme paucity of evidence on racial/ethnic minority groups with regard to the effects of physical activity on weight maintenance. In this review, no 2 studies examined the same ethnic-sex samples — Japanese middle-aged men, Japanese elderly adults, Japanese adults 30 to 69 years of age, Alaska Native women, African American peri-menopausal women, African American and white young and middle-aged adults, Mexican middle-aged adults — much less measures of activity duration or intensity. Consequently, broad generalizations about the influence of race/ethnicity on the physical activity requirements for weight stability or reduction are premature.

Overall Summary and Conclusions

The overall conclusions of this chapter on physical activity and energy balance can be summarized as follows:

Physical Activity, Weight Stability, and Weight Loss

Regular participation in physical activity provides benefits for weight stability, but with few data on this topic from long-term studies, the optimal amount is not known. Available data from short-term clinical trials indicate that a dose of physical activity in the range of 13 to 26 MET-hours per week results in a modest 1% to 3% weight loss, consistent with weight stability over time (7-9). Thirteen MET-hours per week is equivalent to walking at a 4 mile per hour pace for 150 minutes per week or jogging at a 6 mile per hour pace for 75 minutes per week. Aerobic physical activity done at this level would reduce upward migration of individuals from one BMI category to the next. The wide range of physical activity levels (13 to 26 MET-hours per week) needed for weight stability probably reflects individual variation in the inherent (non-structured) level of physical activity and the degree to which caloric intake is increased over time when a physical activity intervention is initiated. The magnitude of weight loss resulting from resistance exercise in this review was typically less than 1 kilogram (2.2 pounds). However, this may have been affected by the relatively short duration of the study period and the increase in fat-free mass associated with this type of intervention. Although a weight loss of 5% or more of body weight can be achieved with large volumes of physical activity, a coincident dietary intervention is typically needed to achieve this goal. The dietary intervention could include maintenance of (at pre-intervention levels) or an actual reduction in caloric intake.

Physical Activity and Weight Regain

Most of the available literature indicates that "more is better" when it comes to the amount of physical activity needed to prevent weight regain following weight loss. However, as indicated above, the literature has some considerable shortcomings regarding the appropriate research design needed to directly address this question. Studies by Ewbank and colleagues (72), Jakicic and colleagues (73) and Schoeller and colleagues (74) indicate that the volume of physical activity needed to prevent weight regain following weight loss is approximately 31 MET-hours per week or 4.4 MET-hours per day. This is equivalent to walking 54 minutes per day at 4 miles per hour or 80 minutes per day at 3 miles per hour, or jogging for 26 minutes per day at 6 miles per hour.

Physical Activity and Body Composition Parameters

Ample evidence exists for a positive dose-response relation between the volume (frequency, intensity, and duration) of endurance and/or resistance exercise, the training duration, and the amount of total and regional fat loss. Moreover, the evidence suggests that regional fat loss is greater with greater amounts of exercise-induced total weight loss and among those with the greatest levels of adiposity. In the absence of coincident caloric restriction, aerobic physical activity in the range of 13 to 26 MET-hours per week results in decreases in total and abdominal adiposity that are consistent with improved metabolic function (7-9). Thirteen MET-hours per week is equivalent to walking at a 4 mile per hour pace for 150 minutes per week or jogging at a 6 mile per hour pace for 75 minutes per week. However, when more physical activity is done (e.g., 42 MET-hours per week), decreases in intra-abdominal adipose tissue approach 3 to 4 times the level seen with this range of physical activity (93).

The Effect of Sex and Age on Physical Activity and Energy Balance

Some evidence suggests that the amount of exercise necessary to maintain a constant body weight differs between men and women and increases with age due to a variety of physiological and lifestyle factors. Moreover, even within a given sex- or age-group, weight loss responses to exercise vary substantially. Thus, it is quite difficult to make a standard daily activity recommendation that relates to optimal weight maintenance for everyone. On the other hand, the evidence base is too sparse at this time to recommend differential physical activity prescriptions based on sex or on age alone.

Physical Activity Requirements Across Race/Ethnicity and Socioeconomic Groups

Although some evidence suggests possible ethnic differences, the paucity of data, particularly from longitudinal cohort or randomized, controlled intervention study designs, makes it unwise to draw conclusions as to whether the effects of physical activity on weight maintenance or loss differ by race/ethnicity or socioeconomic groups. Some of the questions outlined in this section have yet to be fully addressed, although evidence is suggestive, for example, that socioeconomic constraints, cultural preferences, and baseline levels of sedentariness or obesity make low-intensity, social-environmental interventions feasible, sustainable, and effective in many racial/ethnic minority groups (152;154-160). However, simply conducting studies that include representative sample populations will not suffice, because there likely will be too few members of any one group to disaggregate findings by socioeconomic status, race/ethnicity, and sex, or to examine interactions between these critical sociodemographic factors.

Research Needs

This review of physical activity and energy balance identified a number of research needs in each of the topic areas covered in the chapter.

Physical Activity, Weight Stability, and Weight Loss

Studies that are appropriately designed, with sufficient statistical power, and of sufficient length are needed to specifically examine the effects of varying doses of physical activity on weight loss and weight stability across a variety of population groups, especially for those in the normal BMI range. Further examination of effects of physical activity mode, intensity, duration, and frequency on weight loss and/or weight stability also would make a valuable contribution to this area. Finally, research is needed to further examine intervention strategies that are most effective at promoting and maintaining sufficient doses of physical activity that will facilitate weight loss and/or weight stability.

Physical Activity and Weight Regain

Most available literature is observational or has relied on retrospective analysis of self-selected and self-reported levels of physical activity. Use of state-of-the art technology and complete energy balance designs are absent from the literature. Specifically, adequately powered studies of sufficient duration with randomization to different levels of physical activity after weight loss appear to be lacking. This limitation needs to be addressed to adequately explore the question of how much physical activity is needed to prevent weight regain following weight loss.

Physical Activity and Body Composition Parameters

There remains a need for more RCTs to distinguish exercise effects on total and regional fat loss from those of weight loss *per se*. In addition, the large-scale use of imaging techniques is necessary to distinguish the responsiveness of subcutaneous and visceral fat depots to endurance and/or resistance training. The ability of studies to translate imaging findings into simple anthropometric measures, such as waist or abdominal circumference, would increase the clinical and personal utility of the research. Finally, there is a need to identify and to study people who are very susceptible to weight gain in the current social environment and who thus may be most resistant to weight or fat loss with exercise.

The Effect of Sex and Age on Physical Activity and Energy Balance

Journal requirements stipulating that sex- and age-specific analyses be conducted with sufficient statistical power would help to address the dearth of information pertaining to individual and population differences in body weight response to physical activity. In addition, it would be helpful to identify and study people in the current social environment who are very susceptible to weight gain and who thus may be most resistant to weight or fat loss with exercise. Studies of how susceptibility to weight gain or resistance to weight/fat loss may vary by sex and age would contribute substantially to the obesity literature.

Physical Activity Requirements Across Race/Ethnicity and Socioeconomic Groups

Two clear mandates emerge from this research synthesis. The first is to increase attention and resources for studies that focus on diverse race/ethnicity groups and lower socioeconomic status populations, or that include sufficient numbers to permit subgroup analyses by race/ethnicity or socioeconomic status. The second is to establish standards for peer-review journals that require investigators to report race/ethnicity of samples. These standards also should require investigators to conduct subgroup analyses by race/ethnicity and/or socioeconomic status if sample sizes are sufficient, rather than simply treating these as co-variates and adjusting for them.

Reference List

1. National Heart, Lung, and Blood Institute, National Institute of Diabetes and Digestive and Kidney Diseases. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. [Bethesda, Md.]: National Institutes of Health, National Heart, Lung, and Blood Institute; 1998.

2. Renehan AG, Tyson M, Egger M, Heller RF, Zwahlen M. Body-mass index and incidence of cancer: a systematic review and meta-analysis of prospective observational studies. Lancet 2008 Feb 16;371(9612):569-78.

3. Flegal KM, Graubard BI, Williamson DF, Gail MH. Cause-specific excess deaths associated with underweight, overweight, and obesity. JAMA 2007 Nov 7;298(17):2028-37.

4. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. JAMA 2006 Apr 5;295(13):1549-55.

5. United States.Agricultural Research Service. Report of the Dietary Guidelines Advisory Committee on Dietary Guidelines for Americans, 2005 2005 Available from http://www.health.gov/dietaryguidelines/dga2005/report/default.htm.

6. Ross R, Dagnone D, Jones PJ, Smith H, Paddags A, Hudson R, Janssen I. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. A randomized, controlled trial. Ann.Intern.Med. 2000 Jul 18;133(2):92-103.

7. Irwin ML, Yasui Y, Ulrich CM, Bowen D, Rudolph RE, Schwartz RS, Yukawa M, Aiello E, Potter JD, McTiernan A. Effect of exercise on total and intra-abdominal body fat in postmenopausal women: a randomized controlled trial. JAMA 2003 Jan 15;289(3):323-30.

8. McTiernan A, Sorensen B, Irwin ML, Morgan A, Yasui Y, Rudolph RE, Surawicz C, Lampe JW, Lampe PD, Ayub K, et al. Exercise effect on weight and body fat in men and women. Obesity.(Silver.Spring) 2007 Jun;15(6):1496-512.

9. Slentz CA, Aiken LB, Houmard JA, Bales CW, Johnson JL, Tanner CJ, Duscha BD, Kraus WE. Inactivity, exercise, and visceral fat. STRRIDE: a randomized, controlled study of exercise intensity and amount. J.Appl.Physiol 2005 Oct;99(4):1613-8.

10. St Jeor ST, Brunner RL, Harrington ME, Scott BJ, Daugherty SA, Cutter GR, Brownell KD, Dyer AR, Foreyt JP. A classification system to evaluate weight maintainers, gainers, and losers. J.Am.Diet.Assoc. 1997 May;97(5):481-8.

11. Sherwood NE, Jeffery RW, French SA, Hannan PJ, Murray DM. Predictors of weight gain in the Pound of Prevention study. Int.J.Obes.Relat Metab Disord. 2000 Apr;24(4):395-403.

12. Stevens J, Truesdale KP, McClain JE, Cai J. The definition of weight maintenance. Int.J.Obes.(Lond) 2006 Mar;30(3):391-9.

13. Folsom AR, Arnett DK, Hutchinson RG, Liao F, Clegg LX, Cooper LS. Physical activity and incidence of coronary heart disease in middle-aged women and men. Med.Sci.Sports Exerc. 1997 Jul;29(7):901-9.

14. Giovannucci E, Ascherio A, Rimm EB, Colditz GA, Stampfer MJ, Willett WC. Physical activity, obesity, and risk for colon cancer and adenoma in men. Ann.Intern.Med. 1995 Mar 1;122(5):327-34.

15. Kavouras SA, Panagiotakos DB, Pitsavos C, Chrysohoou C, Anastasiou CA, Lentzas Y, Stefanadis C. Physical activity, obesity status, and glycemic control: The ATTICA study. Med.Sci.Sports Exerc. 2007 Apr;39(4):606-11.

16. Katzel LI, Fleg JL, Busby-Whitehead MJ, Sorkin JD, Becker LC, Lakatta EG, Goldberg AP. Exercise-induced silent myocardial ischemia in master athletes. Am.J.Cardiol. 1998 Feb 1;81(3):261-5.

17. Williams PT. Coronary heart disease risk factors of vigorously active sexagenarians and septuagenarians. J.Am.Geriatr.Soc. 1998 Feb;46(2):134-42.

18. Van Pelt RE, Davy KP, Stevenson ET, Wilson TM, Jones PP, Desouza CA, Seals DR. Smaller differences in total and regional adiposity with age in women who regularly perform endurance exercise. Am.J.Physiol 1998 Oct;275(4 Pt 1):E626-E634.

19. Rimbert V, Montaurier C, Bedu M, Boirie Y, Morio B. Behavioral and physiological regulation of body fatness: a cross-sectional study in elderly men. Int.J.Obes.(Lond) 2006 Feb;30(2):322-30.

20. Brien SE, Katzmarzyk PT. Physical activity and the metabolic syndrome in Canada. Appl.Physiol Nutr.Metab 2006 Feb;31(1):40-7.

21. Oppert JM, Thomas F, Charles MA, Benetos A, Basdevant A, Simon C. Leisure-time and occupational physical activity in relation to cardiovascular risk factors and eating habits in French adults. Public Health Nutr. 2006 Sep;9(6):746-54.

22. Williams PT. Nonlinear relationships between weekly walking distance and adiposity in 27,596 women. Med.Sci.Sports Exerc. 2005 Nov;37(11):1893-901.

23. Kyle UG, Genton L, Gremion G, Slosman DO, Pichard C. Aging, physical activity and height-normalized body composition parameters. Clin.Nutr. 2004 Feb;23(1):79-88.

24. Schroder H, Marrugat J, Elosua R, Covas MI. Relationship between body mass index, serum cholesterol, leisure-time physical activity, and diet in a Mediterranean Southern-Europe population. Br.J.Nutr. 2003 Aug;90(2):431-9.

25. Rennie KL, McCarthy N, Yazdgerdi S, Marmot M, Brunner E. Association of the metabolic syndrome with both vigorous and moderate physical activity. Int.J.Epidemiol. 2003 Aug;32(4):600-6.

26. Jakes RW, Day NE, Khaw KT, Luben R, Oakes S, Welch A, Bingham S, Wareham NJ. Television viewing and low participation in vigorous recreation are independently associated with obesity and markers of cardiovascular disease risk: EPIC-Norfolk population-based study. Eur.J.Clin.Nutr. 2003 Sep;57(9):1089-96.

27. Lawlor DA, Taylor M, Bedford C, Ebrahim S. Is housework good for health? Levels of physical activity and factors associated with activity in elderly women. Results from the British Women's Heart and Health Study. J.Epidemiol.Community Health 2002 Jun;56(6):473-8.

28. Ball K, Owen N, Salmon J, Bauman A, Gore CJ. Associations of physical activity with body weight and fat in men and women. Int.J.Obes.Relat Metab Disord. 2001 Jun;25(6):914-9.

29. Forrest KY, Bunker CH, Kriska AM, Ukoli FA, Huston SL, Markovic N. Physical activity and cardiovascular risk factors in a developing population. Med.Sci.Sports Exerc. 2001 Sep;33(9):1598-604.

30. Trichopoulou A, Gnardellis C, Lagiou A, Benetou V, Trichopoulos D. Body mass index in relation to energy intake and expenditure among adults in Greece. Epidemiology 2000 May;11(3):333-6.

31. Vaz de Almeida MD, Graca P, Afonso C, D'Amicis A, Lappalainen R, Damkjaer S. Physical activity levels and body weight in a nationally representative sample in the European Union. Public Health Nutr. 1999 Mar;2(1A):105-13.

32. Martinez JA, Kearney JM, Kafatos A, Paquet S, Martinez-Gonzalez MA. Variables independently associated with self-reported obesity in the European Union. Public Health Nutr. 1999 Mar;2(1A):125-33.

33. Slawta JN, McCubbin JA, Wilcox AR, Fox SD, Nalle DJ, Anderson G. Coronary heart disease risk between active and inactive women with multiple sclerosis. Med.Sci.Sports Exerc. 2002 Jun;34(6):905-12.

34. Slattery ML, Potter J, Caan B, Edwards S, Coates A, Ma KN, Berry TD. Energy balance and colon cancer--beyond physical activity. Cancer Res. 1997 Jan 1;57(1):75-80.

35. Schnohr P, Scharling H, Jensen JS. Intensity versus duration of walking, impact on mortality: the Copenhagen City Heart Study. Eur.J.Cardiovasc.Prev.Rehabil. 2007 Feb;14(1):72-8.

36. Balkau B, Vierron E, Vernay M, Born C, Arondel D, Petrella A, Ducimetiere P. The impact of 3-year changes in lifestyle habits on metabolic syndrome parameters: the D.E.S.I.R study. Eur.J.Cardiovasc.Prev.Rehabil. 2006 Jun;13(3):334-40.

37. Williams PT, Wood PD. The effects of changing exercise levels on weight and age-related weight gain. Int.J.Obes.(Lond) 2006 Mar;30(3):543-51.

38. Kyle UG, Melzer K, Kayser B, Picard-Kossovsky M, Gremion G, Pichard C. Eight-year longitudinal changes in body composition in healthy Swiss adults. J.Am.Coll.Nutr. 2006 Dec;25(6):493-501.

39. Kyle UG, Zhang FF, Morabia A, Pichard C. Longitudinal study of body composition changes associated with weight change and physical activity. Nutrition 2006 Nov;22(11-12):1103-11.

40. Schroeder TE, Hawkins SA, Hyslop D, Vallejo AF, Jensky NE, Wiswell RA. Longitudinal change in coronary heart disease risk factors in older runners. Age Ageing 2007 Jan;36(1):57-62.

41. Droyvold WB, Holmen J, Midthjell K, Lydersen S. BMI change and leisure time physical activity (LTPA): an 11-y follow-up study in apparently healthy men aged 20-69 y with normal weight at baseline. Int.J.Obes.Relat Metab Disord. 2004 Mar;28(3):410-7.

42. Wang BW, Ramey DR, Schettler JD, Hubert HB, Fries JF. Postponed development of disability in elderly runners: a 13-year longitudinal study. Arch.Intern.Med. 2002 Nov 11;162(20):2285-94.

43. Berk DR, Hubert HB, Fries JF. Associations of changes in exercise level with subsequent disability among seniors: a 16-year longitudinal study. J.Gerontol.A Biol.Sci.Med.Sci. 2006 Jan;61(1):97-102.

44. Murray LA, Reilly JJ, Choudhry M, Durnin JV. A longitudinal study of changes in body composition and basal metabolism in physically active elderly men. Eur.J.Appl.Physiol Occup.Physiol 1996;72(3):215-8.

45. Donnelly JE, Jacobsen DJ, Heelan KS, Seip R, Smith S. The effects of 18 months of intermittent vs. continuous exercise on aerobic capacity, body weight and composition, and metabolic fitness in previously sedentary, moderately obese females. Int.J.Obes.Relat Metab Disord. 2000 May;24(5):566-72.

46. Ross R, Pedwell H, Rissanen J. Effects of energy restriction and exercise on skeletal muscle and adipose tissue in women as measured by magnetic resonance imaging. Am.J.Clin.Nutr. 1995 Jun;61(6):1179-85.

47. Sykes K, Choo LL, Cotterrell M. Accumulating aerobic exercise for effective weight control. J.R.Soc.Health 2004 Jan;124(1):24-8.

48. Wilmore JH, Despres JP, Stanforth PR, Mandel S, Rice T, Gagnon J, Leon AS, Rao D, Skinner JS, Bouchard C. Alterations in body weight and composition consequent to 20 wk of endurance training: the HERITAGE Family Study. Am.J.Clin.Nutr. 1999 Sep;70(3):346-52.

49. Boudou P, Sobngwi E, Mauvais-Jarvis F, Vexiau P, Gautier JF. Absence of exercise-induced variations in adiponectin levels despite decreased abdominal adiposity and improved insulin sensitivity in type 2 diabetic men. Eur.J.Endocrinol. 2003 Nov;149(5):421-4.

50. Campbell KL, Westerlind KC, Harber VJ, Bell GJ, Mackey JR, Courneya KS. Effects of aerobic exercise training on estrogen metabolism in premenopausal women: a randomized controlled trial. Cancer Epidemiol.Biomarkers Prev. 2007 Apr;16(4):731-9.

51. Dengel DR, Galecki AT, Hagberg JM, Pratley RE. The independent and combined effects of weight loss and aerobic exercise on blood pressure and oral glucose tolerance in older men. Am.J.Hypertens. 1998 Dec;11(12):1405-12.

52. Murphy M, Nevill A, Neville C, Biddle S, Hardman A. Accumulating brisk walking for fitness, cardiovascular risk, and psychological health. Med.Sci.Sports Exerc. 2002 Sep;34(9):1468-74.

53. Nakamura Y, Tanaka K, Yabushita N, Sakai T, Shigematsu R. Effects of exercise frequency on functional fitness in older adult women. Arch.Gerontol.Geriatr. 2007 Mar;44(2):163-73.

54. Donnelly JE, Hill JO, Jacobsen DJ, Potteiger J, Sullivan DK, Johnson SL, Heelan K, Hise M, Fennessey PV, Sonko B, et al. Effects of a 16-month randomized controlled exercise trial on body weight and composition in young, overweight men and women: the Midwest Exercise Trial. Arch.Intern.Med. 2003 Jun 9;163(11):1343-50.

55. Schmitz KH, Jensen MD, Kugler KC, Jeffery RW, Leon AS. Strength training for obesity prevention in midlife women. Int.J.Obes.Relat Metab Disord. 2003 Mar;27(3):326-33.

56. Schmitz KH, Hannan PJ, Stovitz SD, Bryan CJ, Warren M, Jensen MD. Strength training and adiposity in premenopausal women: strong, healthy, and empowered study. Am.J.Clin.Nutr. 2007 Sep;86(3):566-72.

57. Kraemer WJ, Hakkinen K, Triplett-Mcbride NT, Fry AC, Koziris LP, Ratamess NA, Bauer JE, Volek JS, McConnell T, Newton RU, et al. Physiological changes with periodized resistance training in women tennis players. Med.Sci.Sports Exerc. 2003 Jan;35(1):157-68.

58. Maddalozzo GF, Snow CM. High intensity resistance training: effects on bone in older men and women. Calcif.Tissue Int. 2000 Jun;66(6):399-404.

59. Dionne IJ, Melancon MO, Brochu M, Ades PA, Poelhman ET. Age-related differences in metabolic adaptations following resistance training in women. Exp.Gerontol. 2004 Jan;39(1):133-8.

60. Joseph LJ, Davey SL, Evans WJ, Campbell WW. Differential effect of resistance training on the body composition and lipoprotein-lipid profile in older men and women. Metabolism 1999 Nov;48(11):1474-80.

61. Shaw I, Shaw BS. Consequence of resistance training on body composition and coronary artery disease risk. Cardiovasc.J.S.Afr. 2006 May;17(3):111-6.

62. Teixeira PJ, Going SB, Houtkooper LB, Metcalfe LL, Blew RM, Flint-Wagner HG, Cussler EC, Sardinha LB, Lohman TG. Resistance training in postmenopausal women with and without hormone therapy. Med.Sci.Sports Exerc. 2003 Apr;35(4):555-62.

63. Taaffe DR, Duret C, Wheeler S, Marcus R. Once-weekly resistance exercise improves muscle strength and neuromuscular performance in older adults. J.Am.Geriatr.Soc. 1999 Oct;47(10):1208-14.

64. Keeler LK, Finkelstein LH, Miller W, Fernhall B. Early-phase adaptations of traditional-speed vs. superslow resistance training on strength and aerobic capacity in sedentary individuals. J.Strength.Cond.Res. 2001 Aug;15(3):309-14.

65. Donnelly JE, Jakicic JM, Pronk MP, Smith BK, Kirk EP, Jacobsen DJ, Washburn R. Is resistance exercise effective for weight management? Evid.Based Prev.Med. 2004;1(2):21-9.

66. Engels HJ, Drouin J, Zhu W, Kazmierski JF. Effects of low-impact, moderate-intensity exercise training with and without wrist weights on functional capacities and mood states in older adults. Gerontology 1998;44(4):239-44.

67. Ishikawa K, Ohta T, Zhang J, Hashimoto S, Tanaka H. Influence of age and gender on exercise training-induced blood pressure reduction in systemic hypertension. Am.J.Cardiol. 1999 Jul 15;84(2):192-6.

68. Maiorana A, O'Driscoll G, Dembo L, Goodman C, Taylor R, Green D. Exercise training, vascular function, and functional capacity in middle-aged subjects. Med.Sci.Sports Exerc. 2001 Dec;33(12):2022-8.

69. Cheema BS, Gaul CA. Full-body exercise training improves fitness and quality of life in survivors of breast cancer. J.Strength.Cond.Res. 2006 Feb;20(1):14-21.

70. Annesi JJ, Gann S, Westcott WW. Preliminary evaluation of a 10-wk. resistance and cardiovascular exercise protocol on physiological and psychological measures for a sample of older women. Percept.Mot.Skills 2004 Feb;98(1):163-70.

71. Wing RR. Physical activity in the treatment of the adulthood overweight and obesity: current evidence and research issues. Med.Sci.Sports Exerc. 1999 Nov;31(11 Suppl):S547-S552.

72. Ewbank PP, Darga LL, Lucas CP. Physical activity as a predictor of weight maintenance in previously obese subjects. Obes.Res. 1995 May;3(3):257-63.

73. Jakicic JM, Winters C, Lang W, Wing RR. Effects of intermittent exercise and use of home exercise equipment on adherence, weight loss, and fitness in overweight women: a randomized trial. JAMA 1999 Oct 27;282(16):1554-60.

74. Schoeller DA, Shay K, Kushner RF. How much physical activity is needed to minimize weight gain in previously obese women? Am.J.Clin.Nutr. 1997 Sep;66(3):551-6.

75. Jakicic JM, Clark K, Coleman E, Donnelly JE, Foreyt J, Melanson E, Volek J, Volpe SL. American College of Sports Medicine position stand. Appropriate intervention strategies for weight loss and prevention of weight regain for adults. Med.Sci.Sports Exerc. 2001 Dec;33(12):2145-56.

76. Trumbo P, Schlicker S, Yates AA, Poos M. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. J.Am.Diet.Assoc. 2002 Nov;102(11):1621-30.

77. Klem ML, Wing RR, McGuire MT, Seagle HM, Hill JO. A descriptive study of individuals successful at long-term maintenance of substantial weight loss. Am.J.Clin.Nutr. 1997 Aug;66(2):239-46.

78. Tate DF, Jeffery RW, Sherwood NE, Wing RR. Long-term weight losses associated with prescription of higher physical activity goals. Are higher levels of physical activity protective against weight regain? Am.J.Clin.Nutr. 2007 Apr;85(4):954-9.

79. Fogelholm M, Kukkonen-Harjula K. Does physical activity prevent weight gain--a systematic review. Obes.Rev. 2000 Oct;1(2):95-111.

80. Perri MG, McAllister DA, Gange JJ, Jordan RC, McAdoo G, Nezu AM. Effects of four maintenance programs on the long-term management of obesity. J.Consult Clin.Psychol. 1988 Aug;56(4):529-34.

81. Leermakers EA, Perri MG, Shigaki CL, Fuller PR. Effects of exercise-focused versus weight-focused maintenance programs on the management of obesity. Addict.Behav. 1999 Mar;24(2):219-27.

82. Fogelholm M, Kukkonen-Harjula K, Nenonen A, Pasanen M. Effects of walking training on weight maintenance after a very-low-energy diet in premenopausal obese women: a randomized controlled trial. Arch.Intern.Med. 2000 Jul 24;160(14):2177-84.

83. Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, Buchner D, Ettinger W, Heath GW, King AC, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA 1995 Feb 1;273(5):402-7.

84. Jakicic JM, Marcus BH, Gallagher KI, Napolitano M, Lang W. Effect of exercise duration and intensity on weight loss in overweight, sedentary women: a randomized trial. JAMA 2003 Sep 10;290(10):1323-30.

85. Andersen RE, Wadden TA, Bartlett SJ, Zemel B, Verde TJ, Franckowiak SC. Effects of lifestyle activity vs structured aerobic exercise in obese women: a randomized trial. JAMA 1999 Jan 27;281(4):335-40.

86. Jeffery RW, Wing RR, Sherwood NE, Tate DF. Physical activity and weight loss: does prescribing higher physical activity goals improve outcome? Am.J.Clin.Nutr. 2003 Oct;78(4):684-9.

87. DiPietro L. Physical activity in the prevention of obesity: current evidence and research issues. Med.Sci.Sports Exerc. 1999 Nov;31(11 Suppl):S542-S546.

88. DiPietro L. Physical activity in aging: changes in patterns and their relationship to health and function. J.Gerontol.A Biol.Sci.Med.Sci. 2001 Oct;56 Spec No 2:13-22.

89. Tsuzuku S, Kajioka T, Endo H, Abbott RD, Curb JD, Yano K. Favorable effects of non-instrumental resistance training on fat distribution and metabolic profiles in healthy elderly people. Eur.J.Appl.Physiol 2007 Mar;99(5):549-55.

90. Dunstan DW, Daly RM, Owen N, Jolley D, De Court, Shaw J, Zimmet P. High-intensity resistance training improves glycemic control in older patients with type 2 diabetes. Diabetes Care 2002 Oct;25(10):1729-36.

91. Evans EM, Van Pelt RE, Binder EF, Williams DB, Ehsani AA, Kohrt WM. Effects of HRT and exercise training on insulin action, glucose tolerance, and body composition in older women. J.Appl.Physiol 2001 Jun;90(6):2033-40.

92. Gan SK, Kriketos AD, Ellis BA, Thompson CH, Kraegen EW, Chisholm DJ. Changes in aerobic capacity and visceral fat but not myocyte lipid levels predict increased insulin action after exercise in overweight and obese men. Diabetes Care 2003 Jun;26(6):1706-13.

93. Ross R, Janssen I, Dawson J, Kungl AM, Kuk JL, Wong SL, Nguyen-Duy TB, Lee S, Kilpatrick K, Hudson R. Exercise-induced reduction in obesity and insulin resistance in women: a randomized controlled trial. Obes.Res. 2004 May;12(5):789-98.

94. DiPietro L, Dziura J, Yeckel CW, Neufer PD. Exercise and improved insulin sensitivity in older women: evidence of the enduring benefits of higher intensity training. J.Appl.Physiol 2006 Jan;100(1):142-9.

95. Ryan AS, Hurlbut DE, Lott ME, Ivey FM, Fleg J, Hurley BF, Goldberg AP. Insulin action after resistive training in insulin resistant older men and women. J.Am.Geriatr.Soc. 2001 Mar;49(3):247-53.

96. Poehlman ET, Dvorak RV, DeNino WF, Brochu M, Ades PA. Effects of resistance training and endurance training on insulin sensitivity in nonobese, young women: a controlled randomized trial. J.Clin.Endocrinol.Metab 2000 Jul;85(7):2463-8.

97. United States.Public Health Service.Office of the Surgeon General., United States.Office of Disease Prevention and Health Promotion., Centers for Disease Control and Prevention (, National Institutes of Health (. The Surgeon General's call to action to prevent and decrease overweight and obesity. Rockville, MD; Washington, DC: U.S. Dept. of Health and Human Services, Public Health Service, Office of the Surgeon General ; For sale by the Supt. of Docs., U.S. G.P.O.; 2001.

98. DiPietro L. Physical activity, body weight, and adiposity: an epidemiologic perspective. Exerc.Sport Sci.Rev. 1995;23:275-303.

99. Prevalence of fruit and vegetable consumption and physical activity by race/ethnicity--United States, 2005. MMWR Morb.Mortal.Wkly.Rep. 2007 Apr 6;56(13):301-4.

100. Haapanen N, Miilunpalo S, Pasanen M, Oja P, Vuori I. Association between leisure time physical activity and 10-year body mass change among working-aged men and women. Int.J.Obes.Relat Metab Disord. 1997 Apr;21(4):288-96.

101. Thune I, Njolstad I, Lochen ML, Forde OH. Physical activity improves the metabolic risk profiles in men and women: the Tromso Study. Arch.Intern.Med. 1998 Aug 10;158(15):1633-40.

102. Wier LT, Ayers GW, Jackson AS, Rossum AC, Poston WS, Foreyt JP. Determining the amount of physical activity needed for long-term weight control. Int.J.Obes.Relat Metab Disord. 2001 May;25(5):613-21.

103. Barcenas CH, Wilkinson AV, Strom SS, Cao Y, Saunders KC, Mahabir S, Hernandez-Valero MA, Forman MR, Spitz MR, Bondy ML. Birthplace, years of residence in the United States, and obesity among Mexican-American adults. Obesity.(Silver.Spring) 2007 Apr;15(4):1043-52.

104. DiPietro L, Kohl HW, III, Barlow CE, Blair SN. Improvements in cardiorespiratory fitness attenuate age-related weight gain in healthy men and women: the Aerobics Center Longitudinal Study. Int.J.Obes.Relat Metab Disord. 1998 Jan;22(1):55-62.

105. DiPietro L., Dziura J, Blair SN. Estimated change in physical activity level (PAL) and prediction of 5-year weight change in men: the Aerobics Center Longitudinal Study. Int.J.Obes.Relat Metab Disord. 2004 Dec;28(12):1541-7.

106. Lamonte MJ, Ainsworth BE. Quantifying energy expenditure and physical activity in the context of dose response. Med.Sci.Sports Exerc. 2001 Jun;33(6 Suppl):S370-S378.

107. Saris WH, Blair SN, van Baak MA, Eaton SB, Davies PS, Di PL, Fogelholm M, Rissanen A, Schoeller D, Swinburn B, et al. How much physical activity is enough to prevent unhealthy weight gain? Outcome of the IASO 1st Stock Conference and consensus statement. Obes.Rev. 2003 May;4(2):101-14.

108. Singh MA. Exercise comes of age: rationale and recommendations for a geriatric exercise prescription. J.Gerontol.A Biol.Sci.Med.Sci. 2002 May;57(5):M262-M282.

109. Wieser M, Haber P. The effects of systematic resistance training in the elderly. Int.J.Sports Med. 2007 Jan;28(1):59-65.

110. Woods SC, Gotoh K, Clegg DJ. Gender differences in the control of energy homeostasis. Exp.Biol.Med.(Maywood.) 2003 Nov;228(10):1175-80.

111. Sainsbury A, Schwarzer C, Couzens M, Fetissov S, Furtinger S, Jenkins A, Cox HM, Sperk G, Hokfelt T, Herzog H. Important role of hypothalamic Y2 receptors in body weight regulation revealed in conditional knockout mice. Proc.Natl.Acad.Sci.U.S.A 2002 Jun 25;99(13):8938-43.

112. Guo SS, Zeller C, Chumlea WC, Siervogel RM. Aging, body composition, and lifestyle: the Fels Longitudinal Study. Am.J.Clin.Nutr. 1999 Sep;70(3):405-11.

113. Sternfeld B, Wang H, Quesenberry CP, Jr., Abrams B, Everson-Rose SA, Greendale GA, Matthews KA, Torrens JI, Sowers M. Physical activity and changes in weight and waist circumference in midlife women: findings from the Study of Women's Health Across the Nation. Am.J.Epidemiol. 2004 Nov 1;160(9):912-22.

114. Lee KJ, Inoue M, Otani T, Iwasaki M, Sasazuki S, Tsugane S. Physical activity and risk of colorectal cancer in Japanese men and women: the Japan Public Health Center-based prospective study. Cancer Causes Control 2007 Mar;18(2):199-209.

115. Lewis CE, Smith DE, Wallace DD, Williams OD, Bild DE, Jacobs DR, Jr. Seven-year trends in body weight and associations with lifestyle and behavioral characteristics in black and white young adults: the CARDIA study. Am.J.Public Health 1997 Apr;87(4):635-42.

116. Suominen H. Changes in physical characteristics and body composition during 5-year follow-up in 75- and 80-year-old men and women. Scand.J.Soc.Med.Suppl 1997;53:19-24.

117. Dziura J, Mendes de LC, Kasl S, DiPietro L. Can physical activity attenuate aging-related weight loss in older people? The Yale Health and Aging Study, 1982-1994. Am.J.Epidemiol. 2004 Apr 15;159(8):759-67.

118. Ekelund U, Brage S, Franks PW, Hennings S, Emms S, Wong MY, Wareham NJ. Physical activity energy expenditure predicts changes in body composition in middle-aged healthy whites: effect modification by age. Am.J.Clin.Nutr. 2005 May;81(5):964-9.

119. Kumanyika S. Obesity in black women. Epidemiol.Rev. 1987;9:31-50.

120. Williams DR. Racial/ethnic variations in women's health: the social embeddedness of health. Am.J.Public Health 2002 Apr;92(4):588-97.

121. Chang VW, Lauderdale DS. Income disparities in body mass index and obesity in the United States, 1971-2002. Arch.Intern.Med. 2005 Oct 10;165(18):2122-8.

122. Adams PF, Schoenborn CA. Health behaviors of adults: United States, 2002-04. Vital Health Stat.10 2006 Sep;(230):1-140.

123. Ravussin E, Lillioja S, Knowler WC, Christin L, Freymond D, Abbott WG, Boyce V, Howard BV, Bogardus C. Reduced rate of energy expenditure as a risk factor for body-weight gain. N.Engl.J.Med. 1988 Feb 25;318(8):467-72.

124. Kumanyika SK, Obarzanek E, Stevens VJ, Hebert PR, Whelton PK. Weight-loss experience of black and white participants in NHLBI-sponsored clinical trials. Am.J.Clin.Nutr. 1991 Jun;53(6 Suppl):1631S-8S.

125. Chitwood LF, Brown SP, Lundy MJ, Dupper MA. Metabolic propensity toward obesity in black vs white females: responses during rest, exercise and recovery. Int.J.Obes.Relat Metab Disord. 1996 May;20(5):455-62.

126. Allison DB, Edlen-Nezin L, Clay-Williams G. Obesity among African American women: prevalence, consequences, causes, and developing research. Womens Health 1997;3(3-4):243-74.

127. Heimburger DC, Allison DB, Goran MI, Heini AF, Hensrud DD, Hunter GR, Klein S, Kumanyika SK, Kushner RF, Rolls BJ, et al. A festschrift for Roland L. Weinsier: nutrition scientist, educator, and clinician. Obes.Res. 2003 Oct;11(10):1246-62.

128. Byrne NM, Weinsier RL, Hunter GR, Desmond R, Patterson MA, Darnell BE, Zuckerman PA. Influence of distribution of lean body mass on resting metabolic rate after weight loss and weight regain: comparison of responses in white and black women. Am.J.Clin.Nutr. 2003 Jun;77(6):1368-73.

129. Luke A, Dugas L, Kramer H. Ethnicity, energy expenditure and obesity: are the observed black/white differences meaningful? Curr.Opin.Endocrinol.Diabetes Obes. 2007 Oct;14(5):370-3.

130. Redman LM, Heilbronn LK, Martin CK, Alfonso A, Smith SR, Ravussin E. Effect of calorie restriction with or without exercise on body composition and fat distribution. J.Clin.Endocrinol.Metab 2007 Mar;92(3):865-72.

131. Weiss EP, Holloszy JO. Improvements in body composition, glucose tolerance, and insulin action induced by increasing energy expenditure or decreasing energy intake. J.Nutr. 2007 Apr;137(4):1087-90.

132. Banks-Wallace J, Conn V. Interventions to promote physical activity among African American women. Public Health Nurs. 2002 Sep;19(5):321-35.

133. Kumanyika S. Obesity treatment in minorities. In: Wadden TA, Stunkard AJ, editors. Obesity: theory and therapy. 3rd ed. New York: Guilford Publications Inc.; 2002. p. xiii,377.

134. Yancey AK, Kumanyika SK, Ponce NA, McCarthy WJ, Fielding JE, Leslie JP, Akbar J. Population-based interventions engaging communities of color in healthy eating and active living: a review. Prev.Chronic.Dis. 2004 Jan;1(1):A09.

135. Gibson CA, Kirk EP, LeCheminant JD, Bailey BW, Jr., Huang G, Donnelly JE. Reporting quality of randomized trials in the diet and exercise literature for weight loss. BMC.Med.Res.Methodol. 2005 Feb 23;5(1):9.

136. Ghosh A, Das Chaudhuri AB. Explaining body composition by some covariate factors among the elderly Bengalee Hindu women of Calcutta, India. J.Nutr.Health Aging 2005 Nov;9(6):403-6.

137. Slattery ML, Sweeney C, Edwards S, Herrick J, Murtaugh M, Baumgartner K, Guiliano A, Byers T. Physical activity patterns and obesity in Hispanic and non-Hispanic white women. Med.Sci.Sports Exerc. 2006 Jan;38(1):33-41.

138. Yancey AK, Wold CM, McCarthy WJ, Weber MD, Lee B, Simon PA, Fielding JE. Physical inactivity and overweight among Los Angeles County adults. Am.J.Prev.Med. 2004 Aug;27(2):146-52.

139. Hornbuckle LM, Bassett DR, Jr., Thompson DL. Pedometer-determined walking and body composition variables in African-American women. Med.Sci.Sports Exerc. 2005 Jun;37(6):1069-74.

140. Mack KA, Anderson L, Galuska D, Zablotsky D, Holtzman D, Ahluwalia I. Health and sociodemographic factors associated with body weight and weight objectives for women: 2000 behavioral risk factor surveillance system. J.Womens Health (Larchmt.) 2004 Nov;13(9):1019-32.

141. Kruger HS, Venter CS, Vorster HH, Margetts BM. Physical inactivity is the major determinant of obesity in black women in the North West Province, South Africa: the THUSA study. Transition and Health During Urbanisation of South Africa. Nutrition 2002 May;18(5):422-7.

142. Fitzgerald SJ, Kriska AM, Pereira MA, De Court. Associations among physical activity, television watching, and obesity in adult Pima Indians. Med.Sci.Sports Exerc. 1997 Jul;29(7):910-5.

143. Sternfeld B, Cauley J, Harlow S, Liu G, Lee M. Assessment of physical activity with a single global question in a large, multiethnic sample of midlife women. Am.J.Epidemiol. 2000 Oct 1;152(7):678-87.

144. Hui SSC, Thomas N, Tomlinson B. Relationship between physical activity, fitness and CHD risk factors in middle-age Chinese. J.Phys.Act.Health 2005;2(3):307-23.

145. Yu TY, Pei YC, Lau YC, Chen CK, Hsu HC, Wong AM. Comparison of the effects of swimming and Tai Chi Chuan on body fat composition in elderly people. Chang Gung.Med.J. 2007 Mar;30(2):128-34.

146. Crane PB, Wallace DC. Cardiovascular risks and physical activity in middle-aged and elderly African American women. J.Cardiovasc.Nurs. 2007 Jul;22(4):297-303.

147. Phelan S, Butryn M, Wing RR. Obesity prevention during adulthood. In: Kumanyika S, Brownson RC, editors. Handbook of Obesity Prevention. New York: Springer; 2007. p. 485-514.

148. He XZ, Baker DW. Changes in weight among a nationally representative cohort of adults aged 51 to 61, 1992 to 2000. Am.J.Prev.Med. 2004 Jul;27(1):8-15.

149. Iwane M, Arita M, Tomimoto S, Satani O, Matsumoto M, Miyashita K, Nishio I. Walking 10,000 steps/day or more reduces blood pressure and sympathetic nerve activity in mild essential hypertension. Hypertens.Res. 2000 Nov;23(6):573-80.

150. Witmer JM, Hensel MR, Holck PS, Ammerman AS, Will JC. Heart disease prevention for Alaska Native women: a review of pilot study findings. J.Womens Health (Larchmt.) 2004 Jun;13(5):569-78.

151. Yancey AK, Ortega AN, Kumanyika SK. Effective recruitment and retention of minority research participants. Annu.Rev.Public Health 2006;27:1-28.

152. Lara A, Yancey AK, Tapia-Conye R, Flores Y, Kuri-Morales P, Mistry R, Subirats E, McCarthy WJ. Pausa para tu Salud: reduction of weight and waistlines by integrating exercise breaks into workplace organizational routine. Prev.Chronic.Dis. 2008 Jan;5(1):A12.

153. Wilcox S, Parra-Medina D, Thompson-Robinson M, Will J. Nutrition and physical activity interventions to reduce cardiovascular disease risk in health care settings: a quantitative review with a focus on women. Nutr.Rev. 2001 Jul;59(7):197-214.

154. Kumanyika SK. Minisymposium on obesity: overview and some strategic considerations. Annu.Rev.Public Health 2001;22:293-308.

155. McNeill LH, Kreuter MW, Subramanian SV. Social environment and physical activity: a review of concepts and evidence. Soc.Sci.Med. 2006 Aug;63(4):1011-22.

156. Marcus BH, Williams DM, Dubbert PM, Sallis JF, King AC, Yancey AK, Franklin BA, Buchner D, Daniels SR, Claytor RP. Physical activity intervention studies: what

we know and what we need to know: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity); Council on Cardiovascular Disease in the Young; and the Interdisciplinary Working Group on Quality of Care and Outcomes Research. Circulation 2006 Dec 12;114(24):2739-52.

157. Yancey AK, McCarthy WJ, Harrison GG, Wong WK, Siegel JM, Leslie J. Challenges in improving fitness: results of a community-based, randomized, controlled lifestyle change intervention. J.Womens Health (Larchmt.) 2006 May;15(4):412-29.

158. Yancey AK, Ory MG, Davis SM. Dissemination of physical activity promotion interventions in underserved populations. Am.J.Prev.Med. 2006 Oct;31(4 Suppl):S82-S91.

159. Van Duyn MA, McCrae T, Wingrove BK, Henderson KM, Boyd JK, Kagawa-Singer M, Ramirez AG, Scarinci-Searles I, Wolff LS, Penalosa TL, et al. Adapting evidence-based strategies to increase physical activity among African Americans, Hispanics, Hmong, and Native Hawaiians: a social marketing approach. Prev.Chronic.Dis. 2007 Oct;4(4):A102.

160. Kumanyika S, Bell R, Field A, Fortmann S, Franklin B, Gillman M. Population based prevention of obesity: comprehensive promotion of healthful eating, physical activity and energy balance - AHA scientific statement. Circulation.In Press 2008.