

EXERCISE TREATMENT OF OBESITY

Tori Stone, PhD, John B. Pierce Laboratory, Yale School of Medicine, 290 Congress Avenue, New Haven, CT 06519. tstone@jbpierce.org

Loretta DiPietro, PhD, MPH, Department of Exercise & Nutrition Sciences, Milken Institute School of Public Health, The George Washington University, 950 New Hampshire Ave. NW, Washington DC 20052.

ldp1@gwu.edu

Nina S. Stachenfeld, PhD, John B. Pierce Laboratory, Yale School of Medicine, 290 Congress Avenue, New Haven, CT 06519. nstach@jbpierce.org

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ABSTRACT

Surveillance data from the general US population indicate a continued increase in the prevalence of overweight and obesity that is consistent with weight gain trends observed globally among industrialized countries. Physical inactivity and obesity are closely linked conditions and they account for a large burden of chronic disease and impaired function. The underlying agent in the etiology of obesity is a long-term positive energy balance; however, the pathways determining the rate and extent of weight gain due to a positive energy are complex. Engaging in regular, moderate-intensity physical activity for at least 150 min/week can help maintain energy balance and prevent excessive weight gain; however, this minimum requirement may not be sufficient for reversing already-existing obesity and chronic disease. In fact, physical activity closer to 300 min/week may be necessary for successful weight loss and weight loss maintenance. Regimented exercise programs alone may not be the most effective treatment for people with obesity, however. Rather, lifestyle changes that increase total daily energy expenditure need to be accompanied by dietary counseling for reducing daily caloric intake. Also, accumulating the necessary exercise and lifestyle physical activity in intermittent bouts, rather than one long continuous bout, can

improve adherence and the success of weight loss regimens. It is also important for both clinicians and patients to understand that a simple solution to obesity treatment does not exist due to the constellation of underlying mechanisms that drive energy balance. Indeed, physiological, behavioral, environmental, and genetic factors play both independent and interrelated roles that contribute to the complex etiology of obesity. Research from numerous scientific disciplines has shaped our understanding of obesity. While the relative contributions of insufficient energy expenditure versus excessive energy intake to obesity development continue to be debated, there is general agreement that exercise is a key element for both prevention and treatment. Future research should focus on the prevention of excess weight gain over the life course. In addition to the behavioral and intervention studies of the past several decades, an understanding of the regulatory processes governing energy intake, energy storage, and energy expenditure and how the reinstatement of exercise can correct the disruption of neural pathways is vital to the future of obesity research. Finally, public health science needs to link with public health practice to better enable the translation of this knowledge into policies that can alter the environment in a way that promotes an active lifestyle for all.

INTRODUCTION

Surveillance data from the general US population indicate a continued increase in the prevalence of overweight and obesity that is consistent with weight gain trends observed globally among industrialized countries (1-3). Myriad environmental, behavioral, physiological, and genetic factors contribute to the development of human obesity. However, the common underlying feature leading to these conditions is a positive energy balance. Attenuated metabolic responses to environmental exposures combined with predisposing factors and overall low energy expenditure may contribute to this positive energy balance. Although exercise is most effective in the prevention of obesity (4, 5), it can also contribute to weight loss and to weight maintenance over the long-term. Numerous intervention studies have evaluated the role of exercise training of various modes and intensities on the reduction of body weight and adiposity (6), and there is little doubt about the established benefits of increasing physical activity to the attainment and the maintenance of healthy body weight throughout the life span. Moreover, since exercise itself improves metabolic, respiratory, and cardiovascular function independent of weight loss (6), it has special significance for people with obesity who are at increased risk for obesity-related chronic conditions. In this chapter, we will describe the importance of exercise for the prevention and treatment of obesity, as well as to the prevention of

weight regain following weight-loss therapy. In addition, this chapter will address the contributions of the built environment to the onset and possible reversal of obesity at the population level.

THE ETIOLOGY OF OBESITY

Inactivity and obesity are closely linked conditions accounting for a large burden of chronic disease and impaired function. Over the past several decades, ever-decreasing levels of daily energy expenditure, along with a ready supply of calorie-dense foods, have resulted in a marked disruption to energy regulatory systems, which are still genetically programmed for the subsistence efficiency of our late-Paleolithic ancestors (7, 8). As stated previously, the underlying agent in the etiology of obesity is a long-term positive energy balance. However, the relative importance of excess energy intake over low energy expenditure to this imbalance is controversial. Ultimately, the pathways determining the rate and extent of a positive energy balance with weight gain are complex, and the unique and combined contributions of heredity, physiology, and behavior, to the development of obesity are not understood completely—especially since the influence of any one of these primary factors is usually modified by a constellation of other secondary factors endemic to our current *obesogenic* environment (Figure 1).

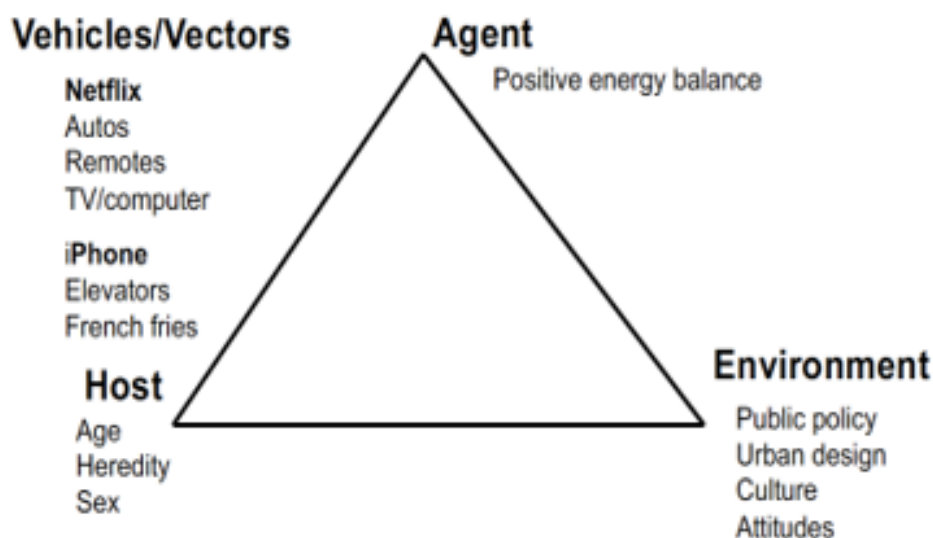


Figure 1. Public health model illustrating the multifactorial model etiology of obesity. The traditional public health of disease transmission applied to obesity etiology. In this model, the impact of the agent (positive energy balance) can be modified by a number of host (specific to the individual) and environment (specific to collective behaviors or conditions) factors. In addition, a variety of vehicles/vectors are responsible for transmitting the causal agent.

The 2018 *Physical Activity Guidelines for Americans*, 2nd Edition (6), along with the 2020 World Health Organization (WHO) Physical Activity and Sedentary Behavior Guidelines (9) recommend for all adults 150-300 min/week of moderate-intensity physical activity (e.g., brisk walking) or 75-150 min/week of vigorous-intensity activity for the prevention of excessive weight gain, cardiovascular and metabolic diseases, and functional decline. These recommendations also include muscle strengthening exercises on two days/week. Although specific recommendations pertaining to sedentary behavior have not been made thus far, the evidence linking extended sedentary time to morbidity and all-cause mortality is growing (6). Indeed, both the 2018 Guidelines for Americans and the WHO Guidelines stress that everyone should

"move more and sit less" (6) and "every move counts" (9). Importantly, current guidelines now stress the joint association between physical activity and sedentary time. For example, the health impact of sedentary behavior (particularly television viewing) becomes especially detrimental when combined with low levels of physical activity (6, 10). People can compensate for large amounts of sedentary time during the day (i.e., 8–14 h) by increasing their physical activity to achieve at least 30 min of accumulated moderate-intensity activity throughout the day. However, the more sedentary one is, the more accumulated activity is necessary to compensate (**Figure 2**).

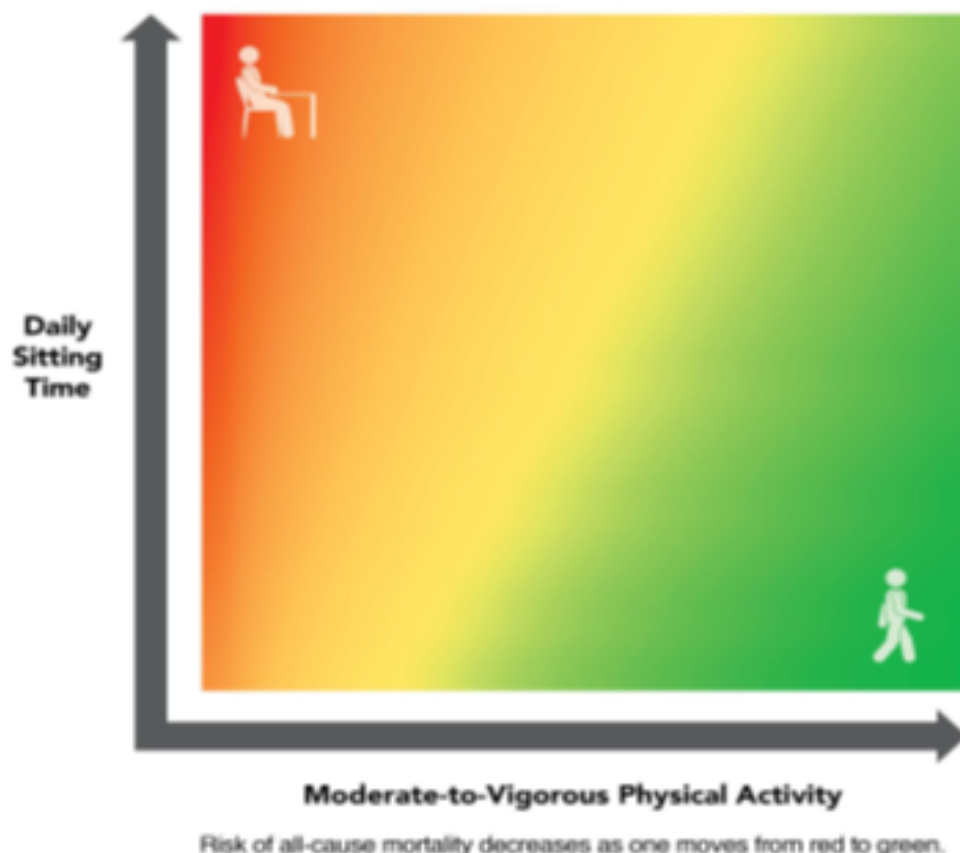


Figure 2. The joint effects of physical activity on health and function. The red zone is harmful, while the green zone is healthful, suggesting that the more sedentary one is, the more accumulated physical activity they need to compensate.

The Role of Exercise in Weight Loss and Weight Maintenance

Population physical activity guidelines may be more effective for health promotion and the primary prevention of chronic disease risk factors than they are for the reversal of already established chronic conditions. Although increasing physical activity and reducing sedentary time has demonstrated benefits to improved health and function, even among people with chronic disease or with disabilities (6, 9), *it is important to note that the minimum recommendation of 150 min/week of moderate-intensity physical*

activity, may not be sufficient to reverse these chronic conditions. Indeed, the treatment or reversal of some established conditions may require a dose of physical activity closer to 300 min/week. This may be especially true for the reversal of obesity and for weight loss maintenance. Although population- and laboratory-based data are limited, it appears that about 45–60 min/day of moderate-intensity activity is necessary to *transition from overweight to normal weight*, and ≥ 60 min/day may be necessary to *transition from obesity* (11–14), at least for a large part of the population with overweight and obesity who spend considerable time sitting throughout the day. In addition, there is

substantial individual heterogeneity regarding a person's weight loss responsiveness to an exercise regimen, and this responsiveness may vary by age, sex, degree of obesity, adipose tissue distribution, and even adipocyte size (15-17). Thus, the benefits of increased physical activity to cardiovascular and metabolic health notwithstanding, its effectiveness *per se* for substantial weight loss and in the reversal of obesity may be less so.

Weight loss of 1–2 pounds (0.5–1 kg) per week is generally recognized as safe and effective (18). Weight loss at this recommended rate, however, would require a negative energy balance of ~ 500–1000 kcal/day over an extended period of time. Such an energy deficit is difficult to achieve by lowering energy intake (dieting) alone. More importantly, such drastic decreases in caloric intake could result in nutritional deficiencies and the loss of lean mass, thereby lowering the metabolic rate (19). Also, adherence to such a degree of caloric restriction is difficult to maintain over long periods of time and, therefore, increases the likelihood of relapse and compensatory weight re-gain.

On the other hand, whether exercise alone (without coincident caloric restriction) significantly alters body weight in people with obesity is debatable. Assuming that 60 min/day of moderate-intensity activity is necessary for meaningful weight loss for people with obesity, a man would need to perform 68–136 min/day of moderate-intensity walking (7.9 kcal/min), and a woman may have to perform 72–145 min/day of the same activity (6.4 kcal/min) to achieve 500-1000 kcal/day deficit necessary for a weight loss of 1–2

pounds (0.5–1 kg)/week (20). Further, although this walking pace (3.5 mph or 3.8 METs) may be comfortable for most people, sustaining it for over 60 min on 7 days/week may not be feasible for people with obesity. Indeed, it may be quite difficult for people with obesity to perform the volume (i.e., intensity, frequency and duration) of exercise necessary for meaningful weight loss in the absence of caloric restriction. Therefore, most evidence currently indicates that both exercise and caloric restriction are necessary components of a successful weight loss program.

People who are successful in losing substantial amounts of body weight through diet alone often quickly regain it. Weight regain is often seen following exercise-, medication-, and even surgery-induced weight loss, indicating that adaptations to a negative energy balance contribute to the obesity epidemic. Laboratory findings report that the level of daily energy expenditure necessary to *prevent the re-gain* of body weight following obesity is also quite high relative to the modern-day lifestyle (17). This challenge may be the result of changes in body composition or the body's overall adaptive energy expenditure and metabolic response to exercise that limits weight loss to activity alone (8, 21) (Figure 3). The 2003 consensus statement from the International Association for the Study of Obesity (14) recommended 60–90 min/day of moderate-intensity activity or about 35 min/day of vigorous activity for successful weight maintenance following the reversal of obesity, which, again, exceeds the upper threshold of current physical activity recommendations (6, 9).

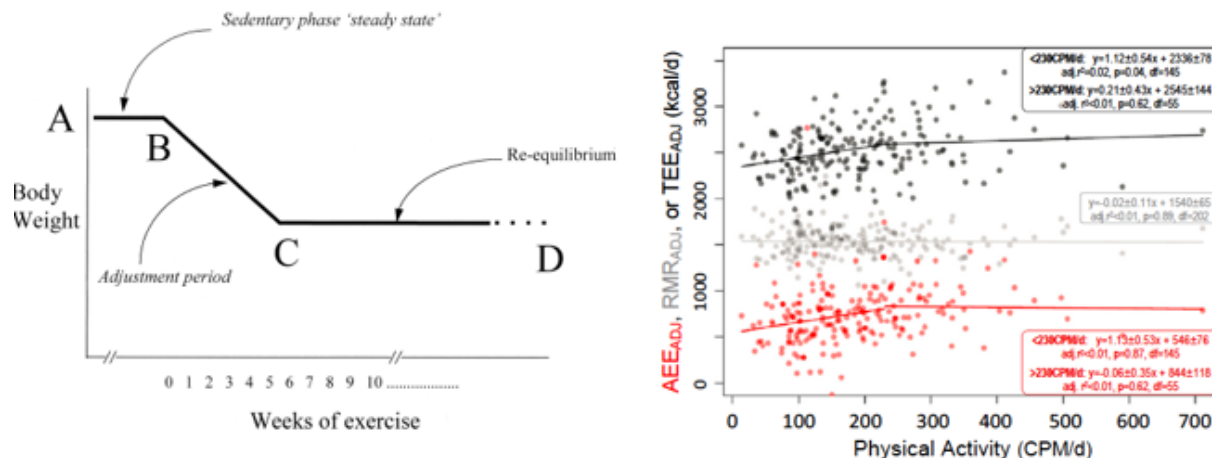


Figure 3. Changes in Total energy expenditure ADJ, resting metabolic rate ADJ, and activity energy (CPM/d), (right, Pontzer (8), with permission are consistent with the findings shown in the schematic of exercise impact on body weight demonstrating a new equilibrium after an initial weight loss (left (21)), with permission

In sum, caloric restriction without exercise may result in a loss of lean mass along with adipose tissue, thereby resulting in a drop in the metabolic rate and setting the stage for weight re-gain. The amount of daily exercise that is necessary to achieve a healthy weight loss without caloric restriction may not be feasible over time for people with obesity, thus again resulting in relapse. Most research now supports the conclusion that exercise combined with caloric restriction increases the net caloric deficit induced by a weight loss program and markedly attenuates the loss of both fat-free and total body mass (19). Finally, as is the case through the period of dynamic weight loss, those who combine caloric restriction with exercise are more successful in maintaining that weight loss over time, compared with those relying on either diet or exercise alone.

THE ROLE OF RESISTANCE TRAINING FOR WEIGHT LOSS AND MAINTENANCE

Both aerobic and resistance exercise will preserve lean tissue during the period of dynamic weight loss, and this is primarily a function of the volume of exercise performed over the weight-loss period (i.e., dose-response). Resistance training is especially

effective at preserving lean body mass during dynamic weight loss, although the amount of protein in the diet may impact this effectiveness (22). A program that combines caloric restriction with both aerobic and resistance training generally leads to greater weight loss and improved overall health, compared to a program combining caloric restriction with only aerobic exercise (11, 13). Of note is that the benefits of strength training to health and function can be independent of weight loss. For example, one 5-month study in older men and women with obesity that used both caloric restriction and resistance training led to reduced abdominal obesity, reduced hypertension, and improved metabolic syndrome without any changes in body weight (23). This is likely due to the increase in lean mass with resistance training, as well as the resulting quantitative and qualitative improvements in vascular and muscle function. Another study of older adults with obesity combined caloric restriction with one of three other exercise interventions: 1) aerobic exercise alone; 2) resistance training alone and 3) aerobic exercise and resistance training. Total body weight loss was similar across the three different exercise groups. However, the greatest improvements in measures of physical function were observed in the combined aerobic exercise with resistance training group (24). Thus, the benefits of

resistance training extend beyond fat loss to include improved metabolic and physical function—and this may be especially so for older people.

THE ROLE OF TOTAL DAILY ACTIVITY IN WEIGHT MAINTENANCE

Evidence suggests that *total daily accumulated energy expenditure* is the strongest predictor of weight loss in people with obesity (25-27). Therefore, an alternative to the typical recommendation of large continuous bouts of exercise may be intermittent exercise, which can result in a similar weight loss but with improved adherence over the long-term. Also, the integration of increased physical activity as part of an overall lifestyle change (e.g., more walking and stair climbing as part of the daily routine) may be as successful in promoting weight loss as is a structured exercise program. Given the high degree of negative energy balance required for weight loss, however, high levels of lifestyle activity

combined with caloric restriction are now prescribed for both initial and long-term weight loss for people with overweight and obesity.

The Physical Activity Level (PAL) has become a method of expressing total daily energy expenditure (TEE) in multiples of the resting metabolic rate (RMR: $PAL = TEE/RMR$), and thus far, few studies have examined its relation to weight regulation at the population level. Data from men in the Aerobics Center Longitudinal Study cohort indicate that a daily $PAL > 1.60 \text{ METs} \cdot 24 \text{ h}^{-1}$ (i.e., an average daily TEE 60% above RMR) is optimal for preventing meaningful weight gain ($\sim 0.82\text{--}0.91 \text{ kg} \cdot \text{y}^{-1}$ (13)) through middle-age (4). Moreover, increasing daily activity from the *low* PAL category ($<1.46 \text{ METs} \cdot 24 \text{ h}^{-1}$) to the *moderate* ($1.46\text{--}1.60 \text{ METs} \cdot 24 \text{ h}^{-1}$) or *high* ($>1.60 \text{ METs} \cdot 24 \text{ h}^{-1}$) categories resulted in a slight weight loss over time in this cohort (Figure 4).

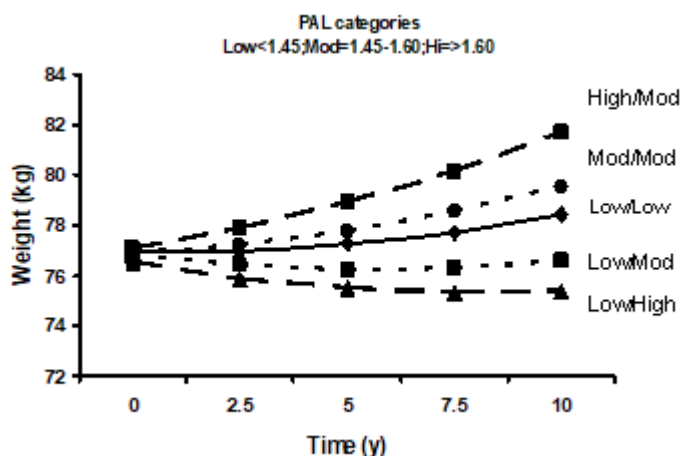


Figure 4. Predicted weight change over time by PAL change category among men in the Aerobic Center Longitudinal Study (ACLS) cohort. PAL=average daily physical activity level expressed as the ratio of total energy expenditure to the resting metabolic rate (TEE/RMR). Models adjusted for age, sex, height, baseline weight, and smoking. DiPietro, et al. *Int J Obesity*. 28:1541-1547,2004 (4)

The most useful strategy for accomplishing this average level of daily physical activity is exchanging passive or very low intensity activities (i.e., those involving sitting) for moderate-intensity activities that have energy requirements of about 3–6 METs. Moderate-intensity activities may have a substantially greater impact on the PAL than vigorous activities since vigorous activity is usually performed for very short periods of time and then can be compensated for by reduced volitional activity throughout the remainder of the day (28). Therefore, the best way to increase the average daily PAL from sedentary ($1.5 \text{ METs} \cdot 24 \text{ h}^{-1}$) to active ($>1.6 \text{ METs} \cdot 24 \text{ h}^{-1}$) is to add about 45–60 minutes of moderate-intensity activity to the daily routine. As described above, using either a continuous or intermittent exercise routine is equally effective in increasing overall TEE.

THE IMPACT OF WEARABLE DEVICES

In 2014, 10% of adult Americans over the age of 18 years reported owning an activity tracking device, and by 2016, the Worldwide Survey of Fitness Trends identified wearable technology as the most popular growing fitness trend, estimating the market to be around \$6 billion (29). This survey was recently updated, reporting that wearable technology remained the number one trend for 2020, and the market reached an estimated \$95 billion (30). Most large technology companies have incorporated activity monitoring technology into cellular phones, while larger corporations, including Apple and Google, have continued to expand their product lines to feature new models of watches, wristbands and other clothing devices with activity tracking capabilities. The most popular and affordable devices remain somewhat restricted to measuring step count and distance traveled.

New products are constantly in development given the high demand. Even though technological

advancements have reportedly improved these devices, debate among product engineers, research scientists and others involved in this industry regarding their accuracy still persists. Data indicate that these devices are less consistent with the measurement of overall activity duration, energy expenditure, and sleep quality, so they may require further testing and more advanced algorithms before being used in research (31). Advanced devices are in development that are capable of measuring biometric signs, such as stress, strain, impact forces, in addition to metabolic parameters (e.g., glucose and lactic acid) and the tracking of physical activity (32).

Despite some limitations, such devices are quite useful in helping people to monitor their own daily caloric intake, energy expenditure, sleep patterns, and overall health profile. These devices may also serve to increase motivation among those starting an exercise program because they can help to set goals and provide immediate feedback, although whether or not this is so for long-term weight loss programs is questionable (32). Ideally, such devices can sync with the electronic health record (EHR), thereby allowing health care providers a chance to objectively monitor a patient's lifestyle behaviors.

PERSONAL AND ONLINE TRAINING

Personal training has remained in the top 10 fitness trends reported since 2006, and popularity has increased as online training has become more accessible (30), especially during the strict quarantine policies imposed during the COVID-19 pandemic in 2020. It is reasonable to suspect that there will be a continued use of online training programs in 2021 and beyond. Unfortunately, like wearable devices, training fees and internet access may be luxuries not available to low-income households, and although some communities have facilities that provide free web access to the public (e.g., public libraries), they may

not be feasible locations for virtual exercise training. Thus, virtual exercise solutions that consider the financial limitations of current fitness trends are needed.

PROMOTING AN ACTIVE LIFESTYLE THROUGH THE BUILT ENVIRONMENT

There are few surveillance data on physical activity patterns over many years in representative populations that use consistent methods of data collection. Data from consumer groups and national monitoring and surveillance systems among persons living in the United States generally show a stable pattern of both leisure time and sport activity (33) but a decrease in work-related activity starting in the 1950s (34). These types of data are useful at the ecologic level in order to describe lifestyle trends among the population and to provide background data for community-based interventions that eventually affect public policy. Environmental interventions that promote change in *risk conditions* at the community level have a greater public health impact than attempting to change *risk factors* at the individual level. Environmental strategies more directly related to promoting an active lifestyle involve altering the built environment in which people spend much of their time—the community, the workplace, and the school.

A report from the Transportation Research Board (TRB) and the Institute of Medicine (IOM) outlines a number of recommendations pertaining to physical activity and the built environment (35). These recommendations state the primary need for multidisciplinary and inter-agency research (particularly longitudinal research and "natural experiments") linking specific aspects of the built environment with different types of physical activity. Ecological studies that can geocode physical activity and health data from surveillance systems such as the Behavioral Risk Factor Surveillance System (BRFSS) or from the National Health and Nutrition Examination Survey (NHANES) could provide useful information on

the environment and the specific locations where low activity and/or high prevalence of overweight is occurring. Similarly, statistical tools such as Geographical Information Systems (GIS) can provide more detailed information on the built environment (land use, sidewalks, green space) to link with surveillance data on physical activity patterns and various health indicators like obesity within a community. These data are also quite useful in tracking how changes to the environment affect changes in behavior and in subsequent health outcomes.

The Health Impact Statement historically has been used in environmental risk assessment to inform the public of the health consequences of various actions (e.g., the building of a new manufacturing plant in the community) and generally, they are effective at involving inter-agency action and public consensus. Since available evidence suggests that the built environment plays a major facilitating role in promoting an active lifestyle, urban planners, local zoning officials, those responsible for the construction of residences, developments, and supporting transportation systems, and members of the community must work together in the design of more activity-friendly environments.

SUMMARY

Most research to date suggests that exercise is more effective in the prevention of overweight and obesity than it is in its reversal. Weight loss programs that combine exercise with caloric restriction can maximize the net caloric deficit while reducing the loss of fat-free mass. Adding resistance training to aerobic exercise will enhance muscle quantity and quality, thereby providing health benefits independent of weight loss. Accumulating the necessary exercise and lifestyle physical activity in intermittent bouts, rather than one long continuous bout, can improve adherence and the success of weight loss and maintenance regimens.

Future research should focus on the prevention of excess weight gain over the life course. In addition to the behavioral and intervention studies of the past several decades, an understanding of the regulatory processes governing energy intake, energy storage, and energy expenditure and how the reinstatement of exercise can correct the disruption of neural pathways is vital to the future of obesity research. Molecular and clinical studies that can identify candidate genes and other biomarkers of energy regulation responding to exercise should link with large epidemiologic studies to determine the relations among these biological markers, physical activity patterns and long-term weight gain among various populations. Controlled intervention trials should continue to test the dose-

response relation between physical activity duration (min/week), volume (kcal/week), and/or intensity and various functional endpoints as rigorously as do pharmacological trials. Finally, public health science needs to link with public health practice to better enable the translation of this knowledge into policies that can alter the environment in a way that promotes an active lifestyle for all.

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