Chapter 3

Preventing weight gain and promoting physical activity

Preventing weight gain and changing the physical activity habits of individuals and populations present a formidable set of challenges. Patterns of food intake and physical activity in individuals and populations are subject to a plethora of influences at several levels (see Chapter 1). What people eat and how active or inactive they are can be influenced by genetic and biological factors; by psychological states, traits and learned habit patterns; by family, community and other proximal social influences; by organizational structures at work and other formal and informal social systems; by barriers and opportunities in people's physical environments; by economic factors that influence access to private and public resources; and by the broad political, economic and social processes that ultimately shape the patterns of behavioural choice in whole populations. It is therefore not surprising that even the best planned and most carefully implemented efforts to prevent weight gain and promote physical activity have shown only modest results.

As the body of scientific evidence in this Handbook makes clear, preventing weight gain and promoting physical activity should be central to the cancer-preventive agendas of all countries. Thus, we have a strong imperative for preventive action, but still only limited knowledge of the likely effectiveness of different types of intervention. Most interventions for weight gain prevention or for promotion of physical activity have shown only modest changes that usually were not well maintained over time after the intensive intervention phase. The way forward for cancer-prevention initiatives based on weight gain prevention and physical activity promotion must be guided by both realism and by the best use of the available scientific information.

Diet and prevention of weight gain

This Handbook has a primary focus on prevention of weight gain and promotion of physical activity. However, energy balance can also be maintained by limiting energy intake. Optimal ways to prevent weight gain by dietary modification are largely unknown. Epidemiological studies tend to suffer from increasing underreporting of food intake with increasing body weight (Seidell, 1998). Intervention studies usually have too limited duration and too few participants to allow proper evaluation of the long-term effects on body weight in populations. There are also many dimensions of food intake other than just energy intake that may play a role (Table 14). These include macronutrient composition, energy density, food palatability and pleasure of eating, portion sizes and meal patterns (e.g., nibbling versus gorging) (Table 15).

Physical, economic and sociocultural factors also influence dietary intakes at the levels of populations, households and individuals (Egger & Swinburn, 1997).

Influences of diet on weight gain always interact with that of physical activity. For example, regular physical activity influences fat and substrate balance. This effect is considerable when an activity is maintained over a long period; physically trained individuals metabolize more fat at equivalent levels of energy expenditure than untrained individuals (Hurley *et al.*, 1986). Stubbs *et al.* (1995) showed that volunteers who were moderately active were able to

Table 14. Energy content of macronutrients

Macronutrient	Energy content	
	kJ/g	kcal/g
Carbohydrate	16	4
Fat	37	9
Protein	17	4
Alcohol	29	7

Table 15. Characteristics of consumption of the major macronutrients: fat is easy to eat, but difficult to shift

	Protein	Carbohydrate	Fat
Ability to end eating	High	Moderate	Low
Ability to suppress hunger	High	High	Low
Storage capacity	Low	Low	High
Pathway to transfer excess to alternative compartment	Yes	Yes	No
Ability to stimulate own oxidation	Excellent	Excellent	Poor

consume *ad libitum* diets with 40% energy from fat, whereas the same individuals when sedentary gained weight on the same diet. It is therefore thought that people who sustain moderate or high levels of physical activity are less likely to gain weight when they eat diets with a high fat content (35–40% of energy). Because fat is a major contributor to overall energy intake, lower fat intake (e.g., 20–25% of energy) may be needed to minimize energy imbalance and weight gain in sedentary individuals. Physical activity not only influences food metabolism. It also interacts with food choice and may also affect energy balance through its effects on food intake and preferences. Information on this is rather limited.

Prevention of weight gain through physical activity

Because both weight gain and weight loss are functions of energy balance, prevention of weight gain could theoretically be achieved by changes in either dietary energy intake or physical activity (energy expenditure). Weight reduction resulting from increased physical activity without restricted energy intake is only modest (Garrow & Summerbell, 1995; National Institutes of Health and National Heart, Lung, and Blood Institute, 1998 (Figure 22). In contrast, many recent reviews have underscored the importance of physical activity in prevention of weight gain (Saris, 1998; Ravussin & Gautier, 1999; Wing, 1999; Jeffery *et al.*, 2000). However, because of the narrative and non-systematic nature of most available reviews, a systematic review was undertaken to evaluate all research reports with data on physical activity and weight gain, published between 1980 and early 2000 (Fogelholm & Kukkonen-Harjula, 2000). The following section is based on that review. It is important to note that the review was restricted to Caucasian (white) adults, because comprehensive data were available only for this group.

The following criteria were applied in selecting prospective, observational studies for inclusion in the review:

- data on physical activity and change of weight (or BMI) were provided;
- duration of follow-up was at least two years;
- no intervention was performed;
- studies on weight change during special circumstances, e.g., after smoking cessation or during pregnancy, were excluded.

Seventeen prospective observational studies (Rissanen *et al.*, 1991; Klesges *et al.*, 1992; Owens *et al.*, 1992; Williamson *et al.*, 1993; Taylor *et al.*, 1994; Bild *et al.*, 1996; Haapanen *et al.*, 1997a; Heitmann *et al.*, 1997; Kahn *et al.*, 1997; Parker *et al.*, 1997; Barefoot *et al.*, 1998; Coakley *et al.*, 1998; Thune *et al.*, 1998; French *et al.*, 1999a; Guo *et al.*, 1999; Crawford *et al.*, 1999; Fogelholm *et al.*, 2000a) fulfilled these criteria (Table 16). The mean duration of follow-up was approximately seven years, with a range from 2 to 21 years. All studies used a retrospective questionnaire to assess the habitual (usually over the past year) level of physical activity. Three studies (Rissanen *et al.*, 1991; Parker *et al.*, 1997; Thune *et al.*, 1998) used a rough, subjective classification into 2–4 activity classes. Most studies assessed physical activity of both moderate intensity and more intense activities. Two studies focused on vigorous exercise activities (Barefoot *et al.*, 1998; Coakley *et al.*, 1998). Three studies also assessed occupational (or non-recreational) activity (Klesges *et al.*, 1992; Williamson *et al.*, 1993; Guo *et al.*, 1999). Finally, Coakley *et al.* (1998) and Crawford *et al.* (1999) asked specifically about television and video use.

The outcomes of the studies may be grouped according to when physical activity data were collected, that is, whether baseline, follow-up or change (from baseline to follow-up) in physical activity was compared against change in weight. The studies using baseline physical activity data yielded inconsistent results. In three (Klesges *et al.*, 1992; Owens *et al.*, 1992; Haapanen *et al.*, 1997a), an inverse relationship between baseline physical activity and weight change was seen, i.e., a large amount of physical activity was associated with smaller weight change. However, Haapanen *et al.* (1997a) reported this inverse relationship for men, but not for women. High baseline activity at work was associated with less weight gain in the study by Klesges *et al.* (1992). In contrast, two studies reported that a large amount of vigorous physical activity at baseline was associated with greater weight gain (Klesges *et al.*, 1992; Bild *et al.*, 1996). Finally, three studies did not find a significant association between baseline total physical activity (Williamson *et al.*, 1993; Parker *et al.*, 1997) or television and video watching (Crawford *et al.*, 1999) and the magnitude of weight change.

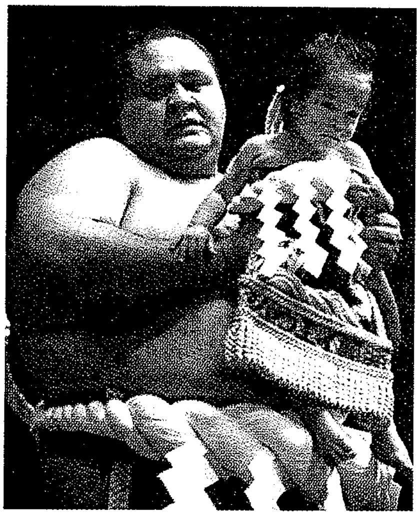

Figure 22 Difference in weight: The body weight of a person doing physical activity also affects the amount of energy used. A person weighing 220 kg will expend more energy walking for 30 minutes than a 90-kg person (Sumo wrestler Akebono and his son Hiroshi)

Table 16. Physical activity and weight gain: a summary of prospective, observational studies

Reference	Subjects, sex (age at entry)	Follow-up	Assessment of physical activity	Statistical adjustments	Main effects of PA	Results
Rissanen *et al.*, 1991	6165 M, 6504 W (25–64 y)	5.7 y (median)	Leisure PA at follow-up (questionnaire, 3 categories: frequent, occasional, rare)	Age, BMI, education, marital status, parity, smoking, alcohol, coffee, health status	+	PA at follow-up was inversely associated with wt gain in men and women
Klesges *et al.*, 1992	142 M, 152 W (mean 34 y)	2 y	Leisure sports activity and occupational PA score (Baecke PA scale) (data collected annually)	Baseline wt, diet, pregnancy, smoking, alcohol, family risk of obesity	+/ns/–	Baseline work ($\beta = -3.5$) and leisure ($\beta = -6.2$) activity predicted wt loss in W, but not in M. Baseline sports activity predicted wt gain in W ($\beta = 3.0$) and M ($\beta = 1.9$).
Owens *et al.*, 1992	500 W (42–50 y)	3 y	Leisure habitual PA (Paffenbarger questionnaire; kcal/wk)	Sex-hormone use, smoking, change in menopausal status	+	Both baseline PA and increased PA were associated with less wt gain
Williamson *et al.*, 1993	3515 M, 5810 W (mean 47 y)	10 y	Non-recreational and recreational PA (three-point scale)	Age, BMI, race, education, smoking status, alcohol, physician-diagnosed health conditions, parity	+	Wt change was inversely associated with PA at follow-up. Decreased PA was associated with wt gain. Baseline PA was not associated with wt change.
Taylor *et al.*, 1994	568 M, 668 W (20–60 y)	7 y	Moderate and heavy PA. TV watching (h/day)	Age, smoking, sex	+	Increased PA (compared to stable or decreased PA) was associated with less wt gain
Bild *et al.*, 1996	1100 M, 1096 W (18–36 y)	2 y	PA score (intensity and duration of PA at leisure and work)	Age, BMI, perception of fatness, physical fitness, education, smoking, diet, alcohol	ns/–	Low baseline PA predicted wt loss (OR = 0.05) in M. Change in PA was not associated with wt change.
Haapanen *et al.*, 1997a	2564 M, 2695 W (19–63 y)	10 y	Leisure PA (scores, grouped into tertiles) and single-item self-assessment of total PA (4 classes)	Age, perceived health status, smoking status and socioeconomic status	+/ns	No regular PA at baseline was associated with ≥ 5 kg wt gain in W (OR = 1.6), but not in M (vigorous activity twice a wk was used as reference). Inactivity at follow-up was inversely associated with wt gain in both genders (OR = 2.6–2.7). Becoming physically inactive was also asssociated with wt gain (OR = 2.0–2.5).
Heitmann *et al.*, 1997	2110 M, 2490 W (twin pairs) (18–39 y)	6 y.	PA during leisure (classified into 3 classes by tertiles of total MET values) at follow-up	Age, smoking, zygosity, BMI at entry, change in BMI of the twin pair	ns	PA at follow-up was not associated with wt change (multiple regression)

Table 16 (contd)

Reference	Subjects, sex, (age at entry)	Follow-up	Assessment of physical activity	Statistical adjustments	Main effects of PA	Results
Kahn *et al.*, 1997	35156 M, W 44080 (mean 40 y)	10 y	Jogging, aerobics, tennis, gardening and walking (h/wk). Both baseline and follow-up data were queried at follow-up.	Age, education, region of the country, BMI at age 18 y, marital status, diet, alcohol, smoking, menopausal status, estrogen use, parity	+	Compared with no activity, jogging > 1 h/wk (M,W), aerobics > 1 h/wk (M) or > 4 h/wk (W), tennis 1–3 h/wk (W) gardening > 1 /wk (W) or >4 h/wk (M) and walking > > 4 h/wk were associated with significant BMI loss (mean –0.08 to –0.49 kg/m^2).
Parker *et al.*, 1997	176 M, 289 W (mean 47 y)	4 y	Participation in aerobic activity (dichotomous) at baseline.		ns	No association between baseline aerobic exercise and subsequent weight change (tertiles)
Barefoot *et al.*, 1998	3885 M, 841 W (mean 19 y)	21 y	h/wk (questionnaire) at follow-up	BMI at entry, smoking, gender, depression	+	Exercise was negatively correlated with wt gain (β = –0.88).
Coakley *et al.*, 1998	10 272 M (44–54 y)	4 y	Vigorous PA (min/wk), TV/VCR watching (h/wk) (questionnaire)	Age, diet, smoking, baseline values (including PA and TV/VCR use)	+	Vigorous PA (β = –0.16) and TV/VCR use (β = 0.02) at follow-up (adjusted to baseline values) were associated with wt change.
Thune *et al.*, 1998	5220 M, 5869 W (20–49 y)	7 y	Leisure PA at baseline and follow-up (questionnaire, PA graded in four groups)	Age, smoking, coffee, dietary fat, menopausal status	+	Sustained high or increased PA was associated with less weight gain during the follow-up period.
French *et al.*, 1999a	228 M, 892 W (mean 35 y)	4 y	Leisure PA score (annual questionnaire)	Age, diet, baseline values	ns	The cumulative duration of increased PA was not significantly associated (β = –0.035) with wt loss.
Guo *et al.*, 1999	102 M, 108 W (mean 44 y)	9.1 y (mean)	Leisure and occupational PA score; individuals divided into three PA groups (biannual questionnaires)	Age, menopausal status, duration of estrogen use	+/ns	Compared with high PA (throughout the entire study period), low and medium PA were associated with wt increase (2.8 and 1.8 kg, respectively) in M, but not in W.
Crawford *et al.*, 1999	176 M, 705 W (20–45 y)	3 y	TV watching (h/day)	Baseline BMI, obesity prevention treatment, age, education, baseline smoking, diet (multiple regression)	ns	TV viewing at baseline, average TV viewing and change in TV viewing were not associated with wt change.
Fogelholm *et al.*, 2000a	442 M (36–49 y)	10 y	Leisure PA score (intensity x duration x frequency)	Age, weight at age 20, weight at entry, chronic diseases, smoking, occupational class, diet, alcohol, marital status, former sports training	+/ns	Increased PA was negatively associated (β = – 2.23) with wt change. No association for decreased PA, continuous high PA or continuous low PA vs. wt change.

Abbreviations: β, beta coefficient in multiple regression; BMI, body mass index; h, hour(s); M, men; MET, metabolic equivalents; ns, = no association between physical activity and weight maintenance; OR, odds ratio; PA, physical activity; W, women; wk, week(s); wt, weight; y, year(s); +, physical activity associated with better weight maintenance; –, physical activity associated with poorer weight maintenance.

The results using data on physical activity at follow-up were more consistent. Four studies found that a large amount of physical activity or exercise (Rissanen *et al.*, 1991; Williamson *et al.*, 1993; Haapanen *et al.*, 1997a; Barefoot *et al.*, 1998) at follow-up was associated with less weight gain. Only Heitmann *et al.* (1997) did not find such an association.

Many studies used data on physical activity from both baseline and follow-up. An increase in physical activity was associated with less weight gain in seven studies (Owens *et al.*, 1992; Williamson *et al.*, 1993; Taylor *et al.*, 1994; Haapanen *et al.*, 1997a; Coakley *et al.*, 1998; Thune *et al.*, 1998; Guo *et al.*, 1999; Fogelholm *et al.*, 2000a). Two studies did not find any association between changes in physical activity (Bild *et al.*, 1996) or in television and video watching (Crawford *et al.*, 1999) and weight change. In one study (Fogelholm *et al.*, 2000a), increased but not decreased physical activity was associated with weight change. French *et al.* (1999a) did not find an association between the cumulative duration of increased physical activity (annual recording) and weight change.

Both studies with data on only vigorous exercise (Barefoot *et al.*, 1998; Coakley *et al.*, 1998) found an inverse association between exercise and weight change. However, the different types and intensities of physical activity cannot be compared from these data. The two studies using data on television watching yielded contradictory results (Coakley *et al.*, 1998; Crawford *et al.*, 1999).

The findings that a larger amount of physical activity, assessed at the end of follow-up, was associated with less weight gain may be interpreted in three different ways: first, physical activity may really prevent weight gain; second, less weight gain may lead to better exercise adherence; third, participation in physical activity may be a proxy for a generally healthier lifestyle or psychological profile (e.g., better self-regulation).

The studies cited above did not generally include data that would allow calculation of the level of energy expenditure associated with prevention of weight gain. Data from studies examining prevention of weight relapse after prior weight reduction suggest that an increase in weekly energy expenditure of approximately 6300 to 8400 kJ/week (1500–2000 kcal/week, corresponding to about 1 h of brisk walking daily) is associated with improved weight maintenance (Fogelholm & Kukkonen-Harjula, 2000). This would correspond to an increase in daily energy expenditure of approximately 10%. However, the increase in energy expenditure needed for primary prevention of weight gain may be slightly lower.

Community interventions for prevention of weight gain

Only a few controlled community interventions have had physical activity as a central behavioural component and BMI as an outcome (Fortmann *et al.*, 1990; Murray *et al.*, 1990; Brownson *et al.*, 1996; Tudor-Smith *et al.*, 1998). These interventions were designed to decrease mortality and morbidity of cardiovascular heart diseases, but all had increased physical activity and decreased prevalence of obesity as means to achieve this main objective. Three projects (Heartbeat Wales (Tudor-Smith *et al.*, 1998), the Minnesota Heart Health Program (Murray *et al.*, 1990; Kelder *et al.*, 1993; Luepker *et al.*, 1994; Jeffery *et al.*, 1995) and the Stanford Five City Project (Fortmann *et al.*, 1990; Taylor *et al.*, 1991; Young *et al.*, 1996)) included both intervention and control communities, whereas the Bootheel Heart Health Project (Brownson *et al.*, 1996) had the state as a comparison area. The duration in the interventions was 4–7 years. The subjects were obtained by random cross-sectional sampling at the beginning and the end of the follow-up (Brownson *et al.*, 1996; Tudor-Smith *et al.*, 1998) or through a combination of cohort and independent cross-sectional surveys (Fortmann *et al.*, 1990; Murray *et al.*, 1990).

These projects based their intervention on widespread educational approaches, that is, face-to-face counselling by health professionals and peers, and use of mass media (television, radio, newspapers, print materials). Moreover, the use of social support (organized groups, such as walking clubs), physical activity contests, opinion leaders and models, and risk-factor screening were common to these interventions. Changes in the physical environment (e.g., building of walking and fitness paths) were reported in one project only (Brownson *et al.*, 1996), whereas policy changes, with special labelling of foods in grocery stores and restaurants, were described in two interventions (Kelder *et al.*, 1993; Tudor-Smith *et al.*, 1998).

Out of the four projects, two (Brownson *et al.*, 1996; Tudor-Smith *et al.*, 1998) did not detect any significant effect of intervention on physical activity, although there was a tendency for increased physical activity in the intervention areas of the Bootheel Heart Health Project (Brownson *et al.*, 1996). The residents of the intervention communities of the Minnesota Heart Health Study were somewhat more physically active (self-reported) at the end of the follow-up (Kelder *et al.*, 1993), an increase apparently due to an increase in activities of low intensity. In the Stanford Five-City Project, the intervention had a positive effect on physical activity in the independent, cross-sectional samples, but not in the cohort survey (Fortmann *et al.*, 1990; Young *et al.*, 1996). The observed increase was seemingly due to increased amounts of daily usual activities, rather than to vigorous exercise (Young *et al.*, 1996).

Although the results on physical activity were somewhat positive in most projects, the effects on body weight change were disappointing. Three projects did not find any effect of intervention on BMI (Jeffery *et al.*, 1995; Brownson *et al.*, 1996; Tudor-Smith *et al.*, 1998). In the Stanford Five-City Project, BMI increased less in the treatment than the control communities, but this effect was observed only by using cross-sectional, independent surveys (Taylor *et al.*, 1991).

Despite the fact that a majority of cross-sectional and observational studies have shown that high physical activity is associated with smaller weight gain, the success of community studies in preventing weight gain was not very good. The failure to show clear intervention effects could be due to methodological problems. Multifaceted interventions are difficult to evaluate in general and methods of assessing physical activity in large groups are quite crude and imprecise (Wareham & Rennie, 1998). Moreover, favourable secular trends in dietary choices as well as in smoking cessation may not only dilute intervention effects but also confound the effect of physical activity in prevention of weight gain.

Another obvious reason for the above discrepancy is that physical activity and energy expenditure in the intervention communities did not increase enough to counterbalance secular changes in food intake and daily activity (Fogelholm *et al.*, 1996a). In the most successful intervention (The Stanford Five-City project; Taylor *et al.*, 1991) the difference in estimated daily energy expenditure between the intervention and control communities was 250 kJ/day (60 kcal/day), a weekly difference of 1750 kJ (420 kcal). This is much less than has been associated with prevention of weight regain (Fogelholm & Kukkonen-Harjula, 2000). Moreover, it is probable that the three other community interventions were even less successful in increasing total energy expenditure. There are several potential explanations for the difficulty in increasing physical activity in intervention communities:

- The focus has been too much on traditional physical activity, rather than usual daily activities (lifestyle activity). The same problem is also seen in controlled obesity treatment trials. It is likely that large population segments may more readily accept increased lifestyle activity than more structured exercise training.
- There was too little priority for physical activity in the interventions. All interventions cited above had a decrease in cardiovascular disease mortality and morbidity as primary objective. This meant that the approaches were very broad and physical activity was just one focus of the intervention plan.
- The interventions were too general and hence important subgroups were lost. For instance, Jeffery *et al.* (1995) noted that the intervention effects were more clearly seen in residents with elevated serum cholesterol concentration or a history of obesity-related disease. Other potential subgroup targets for physical activity interventions could be people of lower social status, minority groups and older adults.
- A high-profile health promotion programme extended even to the control area (Luepker *et al.*, 1994; Tudor-Smith *et al.*, 1998). The intervention and control communities were not isolated, both areas being targets of health promotion through mass media and from physicians and other health professionals. If the educational environment is already saturated with health promotion material, any additional efforts may have only marginal effects (Jeffery *et al.*, 1995).
- All interventions had a strong emphasis on education, their basic assumption being that increasing the level of knowledge about obesity-related risks, dietary choices and exercise behaviour would enable people to improve weight maintenance (Jeffery *et al.*, 1995). Only the Bootheel Heart Health Project reported deliberate efforts to change the physical environment by construction of walking and fitness paths (Tudor-Smith *et al.*, 1998).

Prevention of weight regain after prior weight reduction

The challenge in weight reduction is not really to lose enough weight, but rather to maintain the reduced weight. Most studies show very poor weight maintenance, regardless of the technique used to reduce body weight (Glenny *et al.*, 1997). The role of physical activity in prevention of weight regain was studied in the review by Fogelholm and Kukkonen-Harjula (2000) of both observational studies and randomized clinical interventions. The main results are summarized below.

A total of 19 non-randomized weight-reduction interventions with an observational follow-up were reviewed. The duration of the follow-up was typically between one and three years. Most of the studies used a retrospective questionnaire or an interview to assess physical activity. Only Schoeller *et al.* (1997) measured total activity level by the doubly labelled water technique, focusing on vigorous exercise, rather than total physical activity.

The results from the above studies were quite consistent: a total of 12 studies found that a large amount of physical activity at the follow-up measurement was associated with less weight regain after weight reduction. Four studies used the change in physical activity from baseline (immediately after weight reduction) to the end of the follow-up: they all reported that increased physical activity was associated with a smaller weight regain. Using only baseline (after weight reduction) data on physical activity, however, gave less consistent results: Schoeller *et al.* (1997) found that more physical activity was associated with better weight maintenance,

Figure 23 Bike to Work Day: promotion of physical activity at the National Institute of Environmental Health Sciences (NIEHS) in the United States

although McGuire *et al.* (1999) did not find such an association. Jeffery *et al.* (1984) reported that physical activity immediately after weight reduction, but not one year later, was associated with less weight regain at two years' follow-up.

Eight randomized interventions with exercise and control groups and a prospective follow-up of at least one year's duration (Perri *et al.*, 1986; Sikand *et al.*, 1988; King *et al.*, 1989; Pavlou *et al.*, 1989; van Dale *et al.*, 1990; Skender *et al.*, 1996; Wadden *et al.*, 1998; Wing *et al.*, 1998) were reviewed (Table 17). The duration of weight reduction varied between eight weeks and 12 months. Three studies used a very low-energy diet (Sikand *et al.*, 1988; Pavlou *et al.*, 1989; van Dale *et al.*, 1990) during the weight-reduction phase, while the other studies used a more conventional diet with restricted energy intake. Only Perri *et al.* (1986) reported use of behaviour therapy. All studies used aerobic exercise (walking or ergometer cycling) with a target duration of approximately 1.5 to 3 h/week. In addition, Wadden *et al.* (1998) had one group with strength training.

Only one study (Pavlou *et al.*, 1989) found clearly that exercise training during weight reduction led to less weight gain during the follow-up than in non-exercising groups. Sikand *et al.* (1988) reported a similar but non-significant difference. King *et al.* (1989) found that weight regain was smallest in exercising subjects randomized to supportive telephone contacts during the follow-up. However, those exercising subjects who were randomized to no extended support showed a tendency to regain even more weight than the diet-only subjects. van Dale *et al.* (1990) reported better weight maintenance in one physical exercise group ($N = 5$), but the finding was apparently caused by one outlier. In contrast to the above results, four studies did not find exercise training to improve maintenance of reduced body weight (Perri *et al.*, 1986; Sikand *et al.*, 1988; Wadden *et al.*, 1998; Wing *et al.*, 1998).

Very few studies (Perri *et al.*, 1988; Leermakers *et al.*, 1999; Fogelholm *et al.*, 2000b) have used a design with randomization to exercise and control groups after weight reduction (Table 18). Perri *et al.* (1988) used several weight-maintenance techniques, including aerobic exercise in two groups (men and women). All groups participating in the six-month weight-maintenance intervention had less weight gain compared with the controls, who were not contacted after the weight reduction. Nevertheless, the exercise groups did not succeed any better or worse than the other weight-maintenance groups. Leermakers *et al.* (1999) randomized 67 subjects (men and women) into exercise-focused and weight-focused groups after a six-month weight-reduction period. The exercising subjects met bi-weekly in supervised exercise session and were also trained in relapse prevention strategies to avoid or cope with lapses in exercise. The weight-focused group learned problem-solving for weight-related difficulties, without emphasis on physical activity. During the unsupervised follow-up (six months), the exercise-group gained more weight than the weight-focused group. Finally, in the study of Fogelholm *et al.* (2000b), weight-reduced, but still overweight or obese, premenopausal women were randomized into control, moderate walking (target activity energy expenditure 4.2 MJ/week (1000 kcal/week)) and heavy walking (8.4 MJ/week (2000 kcal/week)). All groups received diet counselling. Compared with the end of weight reduction, weight regain at the two-year follow-up was 3.5 (95% confidence interval 0.2–6.8) kg less in the moderate walking group than in control subjects. The heavy walking group did not differ from the controls.

Inadequate amounts of physical activity may help to explain why it has been so difficult to find an effect of physical activity on weight maintenance in clinical trials. The weekly amount of prescribed exercise in the randomized trials varied from 80 min to 300 min, which corresponds to an increase in weekly energy expenditure by 2300 to 8800 kJ (560 to 2100 kcal). However, adherence to the exercise prescription is much less than 100%, and in particular long-term adherence may be poor.

According to four studies (Hartman *et al.*, 1993; Ewbank *et al.*, 1995; Schoeller *et al.*, 1997; Jakicic *et al.*, 1999), the estimated difference in energy expenditure from physical activity between the highest and the lowest exercise group was more than 5500 kJ/week (1300

Table 17. Physical activity and weight regain: a summary of randomized controlled trials with or without exercise during weight reduction. All subjects were overweight or obese initially

Reference	Subjects	Weight reduction trial design (method, amount)	Exercise prescription	Follow-up	Results
Perri *et al.*, 1986	14 M, 76 W	20 wk. BT only, BT + EX. Mean wt loss 9.4 kg.	4 x 20 min aerobic EX weekly	18 mo, including 6 mo maintenance support by mail and phone. 67 measured (74%)	Wt regain was similar in BT (3.1 kg) and BT + EX (3.3 kg) groups
Sikand *et al.*, 1988	30 W	4 mo. VLED only, VLED + EX. Mean wt loss 19.8 kg.	Aerobic EX, 2 supervised weekly sessions (about 60–90 min/wk)	24 mo. 21 measured (70%).	Wt regain tended to be less in EX subjects (58% vs. 96%)
King *et al.*, 1989	103 M	12 mo. Diet only, EX only. Mean wt loss 6.0 kg.	3 x 40–50 min brisk walking weekly + encouragement to increase lifestyle activity (120–150 min/wk)	12 mo. Randomized into support contacts by mail and phone vs no contact. 72 measured (70%); 48 in maintenance support.	2-y wt regain was smallest (17%) in EX subjects with maintenance support. EX without support gained 71% and the diet groups 41–42% of wt loss.
Pavlou *et al.*, 1989	160 M	8 wk. 4 different VLEDs (420–1000 kcal/d). Diet only, diet + EX (4 x 2 groups). Mean wt loss 13.3 kg.	3 x 90 min EX weekly, including 35–60 min aerobic EX per session (270 min/wk)	18 mo. 110 measured (69%).	EX groups regained about 10% of the wt loss, whereas the diet groups regained 92%
van Dale *et al.*, 1990	15 M, 39 W	Duration 12–14 wk. VLED only, VLED + EX. Mean wt loss 12.2 kg.	Aerobic (2–3 h/wk) and fitness (2 h/wk) training (240–300 min/wk)	18–42 mo. 36 measured (67%).	In one study, EX improved wt maintenance at 42 mo, but the difference was apparently caused by one outlier. No other effects of EX were reported for the other two studies.
Skender *et al.*, 1996	66 M, 61 W	12 mo. Diet only, EX only, diet + EX. Mean wt losses 6.8, 2.9, 8.9 kg.	Walking; target goal 5 x 45 min/wk (225 min/wk)	12 mo. 61 measured (48%).	Wt regain was similar in diet + EX vs. diet only groups. EX only lost and regained less.
Wadden *et al.*, 1998	99 W	48 wk. Aerobic EX + diet, strength training + diet, aerobic EX + strength training + diet, diet only. Mean wt loss 15.6 kg.	2–3 weekly sessions. Aerobic = step aerobics; strength = Universal Gym or Cybex equipment; combination = 40% aerobic, 60% strength (120–180 min/wk).	12 mo. 77 measured (78%).	EX did not affect maintenance of wt loss.
Wing *et al.*, 1998	32 M, 122 W	6 mo. CON, diet only, EX only, diet + EX. Mean wt losses 1.5, 9.1, 2.1, 10.3 kg.	Brisk walking etc., 5 days/wk, target energy expenditure 6.3 MJ (1500 kcal) per wk.	18 mo. 129 measured (84%).	EX did not affect maintenance of wt loss.

Abbreviations: BT, behavioural therapy; CON, control subjects (no treatment); EX, exercise; M, men; mo, month(s); PA, physical activity; VLED, very-low-energy diet; W, women; wk, week(s) wt, weight

Table 18. Physical activity and weight regain: randomized controlled trials with or without exercise training after weight reduction

Reference	Subjects	Weight reduction	Maintenance intervention	Follow-up (method, amount)	Results
Perri *et al.*, 1988	26 M, 97 W	BT. 12.4 kg in 20 wks	6 mo. Extended therapist contact (C) vs C and social influence (S) vs C and 4 x 20 min aerobic EX weekly vs C, S and EX vs no maintenance support	12 mo. 91 measured (74%)	All 4 conditions with maintenance support yielded better long-term wt loss than BT alone. EX did not significantly affect the results
Leermakers *et al.*, 1999	13 M, 54 W	Diet + BT, 8.8 kg in 6 mo.	6 mo. EX vs wt-focused. EX = 150 min/wk, biweekly sessions, contingencies, relapse prevention training. 57 (85%) completed	6 mo. 48 completed (72%)	EX subjects gained more (4.4 kg) than the wt-focused subjects (0.8 kg) during mo 6 to 12.
Fogelholm *et al.*, 2000	85 W	VLED, 13.1 kg in 3 mo.	9 mo. Randomized into walking (2 groups, EX-1 = target energy expenditure 4.2 MJ/wk, EX-2 = 84 MJ/wk) and CON. All received diet instruction.	24 mo. 74 measured (87%)	The mean wt regain after WR was 8.3 kg. Compared with the end of WR, wt regain at the end of follow-up was 3.5 (95% CI 0.2–6.8) kg less in EX-1 vs CON.

Abbreviations: BT, behavioural therapy; CI, confidence intervals; CON, control subjects (no treatment); EE, energy expenditure; EX, exercise; M, men; mo, month(s); VLED, very-low-energy diet; W, women; WR, weight reduction intervention; wt, weight

kcal/week), but less than 8400 kJ/week (2000 kcal/week). The difference in yearly weight regain (high versus low exercise groups) in the above studies was 5 to 8 kg. Hence, it seemed that an increase in energy expenditure of physical activity of approximately 6300 to 8400 kJ/week (1500–2000 kcal/week, corresponding to 1 h of brisk walking daily) was associated with improved weight maintenance. This is more than most randomized trials aimed at, and certainly more than the exercisers actually achieved. Keeping up increased regular exercise is believed to be particularly problematic among obese subjects, who may have both physiological and psychological barriers to physical activity (Fogelholm & Kukkonen-Harjula, 2000).

All randomized trials used traditional structured training prescription with walking, jogging or ergometer cycling as the modes of exercise. Only King *et al.* (1989) encouraged subjects also to increase daily lifestyle activity. Since the introduction of health-related exercise (Pate *et al.*, 1995), interest in lifestyle activity (with several short bouts of exercise daily) has increased, but few groups have studied the effects of lifestyle activity (Andersen *et al.*, 1999; Dunn *et al.*, 1999) or of multiple short-bout exercise (Jakicic *et al.*, 1999) on weight change in overweight persons. None of these studies found any statistically significant difference between the effects of different kinds of activity on weight.

Some groups have studied different strategies to improve adherence to exercise programmes. Three papers have reported that adherence to a home-based exercise programme is at least as good as a supervised group programme among overweight persons (King *et al.*, 1991; Perri *et al.*, 1997; Jakicic *et al.*, 1999). Exercise prescribed in multiple short bouts rather than as one continuous daily bout may or may not improve exercise adherence (Jakicic *et al.*, 1995, 1999). Although one might suppose that adherence would be easier for a lifestyle activity than for a more fixed exercise regimen, two studies (Andersen *et al.*, 1999; Robinson, 1999) found adherence to be equal for both approaches.

How to increase physical activity

The first US Surgeon General's Report on Physical Activity and Health (United States Department of Health and Human Services, 1996) has established the importance of the overall physical activity and health agenda. It is not known to what extent it will be feasible to integrate systematic and cost-effective exercise

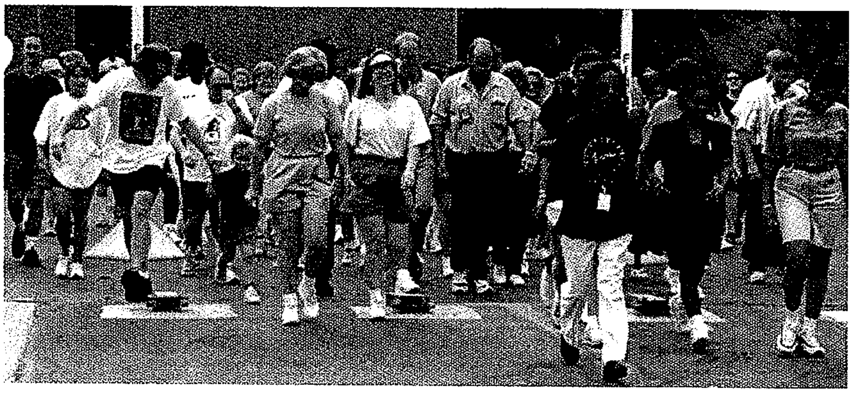

Figure 24 Organized walking day for NIEHS staff members and family

counselling into routine primary care and other health services. It is also not yet clear what effects might be achieved by mass-reach, ubiquitous public health strategies that offer 'passive' protection to populations by creating (or recreating) environments in which physical activity is a natural and enjoyable part of people's lives.

Trials of interventions to increase physical activity typically lead to modest initial changes in behaviour and any changes tend not to be maintained after the intensive initial intervention phase.

Controlled intervention trials in healthcare settings that yielded the strongest and best-maintained effects on behaviour have revealed several important elements, including multiple and continuing contacts with participants and multiple behavioural intervention components (Simons-Morton *et al.*, 1998). For such individual or small-group interventions, the most effective programme elements appear to be the use of structured behaviour-change techniques; educational, health-risk appraisal and verbal persuasion methods have been found to be far less effective (Dishman & Buckworth, 1996).

Workplace, community and mass-media intervention studies have typically found modest or no actual effects on behaviour and, where it has been assessed, poor maintenance of behavioural changes (Dishman *et al.*, 1998; Marcus *et al.*, 1998).

The conduct of physical activity intervention trials on which to base large-scale, comprehensive strategies has inherent scientific difficulties. Meta-analyses and qualitative reviews of published studies have identified several areas of methodological limitation. These include lack of standardized outcome measures, lack of rigorous experimental controls and compromises in the implementation of interventions (Dishman *et al.*, 1998). Studies that meet rigorous methodological criteria and that demonstrate strong and sustained effects on physical activity behaviour are few. However, behavioural scientists, epidemiologists, exercise and sport scientists and others are developing improved, standardized and objectively validated measures of physical activity behaviours and are applying these in population studies (Sallis & Saelens, 2000). New studies of physical activity determinants, including environmental influences, are being developed (Baker *et al.*, 2000; Owen *et al.*, 2000). Particular issues for higher-risk or traditionally neglected groups are being identified and addressed systematically (Taylor *et al.*, 1998; Ainsworth, 2000; Ainsworth *et al.*, 2000). Trials of innovative approaches to increasing energy expenditure through incidental and lifestyle activities are under development (Dunn *et al.*, 1998).

The major need is to develop evidence-based mass-reach interventions, along with environmental and policy changes that can be demonstrated to have a positive impact on rates of participation in physical activity (Jebb & Moore, 1999; Sallis *et al.*, 1998). For example, there are now opportunities to conduct trials of mass-reach behavioural-change services that use combinations of traditional broadcast media with the new capacities provided by the Internet and other information technology innovations. Such strategies can potentially provide automated, individually tailored physical activity assessments and structured, interactive advice to large numbers of people at very low cost (Marcus *et al.*, 1998).

It may be helpful for interventions to focus on sedentary behaviour as an entity in its own right (Jebb & Moore, 1999; Owen *et al.*, 2000). Prolonged periods of sedentary behaviour at work may in future be regarded as an occupational health risk.

Trials of interventions to influence physical activity have focused on individuals. The challenge is to influence whole populations effectively. The extensive social changes and strategies needed to promote physical activity will require strong interactions between science, advocacy and public health policy. Environmental and policy initiatives require research on new ways to assess putative macro-level influences on physical activity. Such environmental and policy interventions include, for example, the provision of walking and cycling paths, restrictions on automobile access to city centres and provision of showers and changing facilities at workplaces. Systematic trials are needed to demonstrate the extent to which such changes can influence people's choice to be more active (Sallis *et al.*, 1998).

Lessons to be learned from other successful public health campaigns

Campaigns that have been successful in dealing with public health problems include those to discourage smoking and drink-driving or to promote immunization and the wearing of seatbelts. Analyses of these campaigns have helped to identify features that can be applied in public health interventions to control obesity (Egger & Swinburn, 1997). For example, it appears that programmes which involve government, the community, the food industry and the media, and which are of long duration, lead to positive and sustainable change (WHO Consultation on Obesity, 1998).

Public health programmes to prevent weight gain are unlikely to achieve the same spectacular rates of success as those associated with the control of infectious disease. Unlike the case of pathogens, it is not feasible to remove totally the causes of obesity. Nor is it a simple process to isolate and manage exposure to major disease-promoting factors in the way that the control of smoking and hypertension has contributed to the reduction in rates of chronic heart disease. Overweight, the consequence of energy imbalance, is more tightly controlled physiologically than other risk factors are and is subject to many environmental influences that shape food choices and physical activity behaviours (Figure 25). Nevertheless, with concentrated efforts, particularly along the lines recommended in Chapter 10, successes in weight gain prevention and in physical activity promotion can be achieved.

There are good reasons to believe that well conducted preventive initiatives with adequate resources will succeed. For example, large numbers of people in many populations do maintain habits of regular physical activity and maintain a healthy body weight. While this is more likely in higher socioeconomic groups, it should nevertheless be seen as realistic and achievable. Regular physical activity and maintaining a healthy body weight will be more possible if people have supportive environments. Where governments and community bodies provide facilities and settings for physical activity, or where there are well organized programmes with adequate resources, people are better able to maintain regular activity. For societies to provide such support and services, significant commitments of funding and well developed policies and organizational systems are required. Given the extent of cancer-related risk and other health risks associated with overweight and inactivity including heart disease and diabetes, such serious commitments should be made.

Figure 25 Keep on moving! A person loses 25% of his or her lean body mass and 75% of his or her fat when losing weight through reduction of energy intake alone. Weight loss that is achieved with a combination of dietary restriction and physical activity is more effective !
For maintenance of desirable body weight a maintenance level of energy intake alone with physical activity is recommended to preserve lean body mass and muscle tone.