

The importance of physical activity in the prevention of overweight and obesity in childhood: a review and an opinion

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Summary

The prevalence of childhood obesity is increasing and there are a number of theoretical reasons as to why intervention may be more effective in childhood. There are certain risk times for the development of obesity in childhood, which provide a basis for targeted intervention. In addition, tracking data supports the persistence of obesity, at least in later childhood, as well as cardiovascular risk factors. Physical activity is the discretionary component of energy expenditure and there is evidence that falling levels of physical activity are contributing to the obesity epidemic. Physical activity in children is related to developmental stage, is reduced with increasing age and is influenced by parental physical activity. While there is debate about the immediate health benefits of physical activity to children, there are data to support that lower physical activity levels and sedentary behaviours are associated with a higher prevalence of obesity in children. Physical activity is an accepted strategy in the treatment of established obesity (tertiary prevention). The role of physical activity in the prevention of obesity (primary and secondary prevention) is less clear. However a number of recent school-based interventions directed at either increasing physical activity and/or decreasing sedentary behaviours, have shown encouraging results. On balance, increasing physical activity in children is an attractive and non-restrictive approach to obesity prevention. To adopt this approach requires the support and involvement of many community sectors other than health.

Keywords: children, physical activity, obesity, prevention.

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Introduction

What if there was a chronic childhood condition that affected at least 20% of children and was increasing in prevalence, had no defined cure, had high relapse rates, limited remission and which was associated with significant adult morbidity and mortality. Would the health sector expect strong support to find a cure and, more importantly, a prevention strategy? The answer could reasonably be expected to be a resounding yes, but unfortunately there seem to be difficulties. The problem is obesity and its prevention is a complex issue.

Obesity has been declared an epidemic (1) and the need is there to identify a solution to an ever-increasing problem. This increasing prevalence of both obesity and overweight is against a background of health messages that have exhorted populations to eat less fat and become more frequently and more consistently active. The long-term efficacy of adult weight management has not altered much since the report of Stunkard & McLaren-Hume, where 20% of individuals were identified as being able to achieve weight loss, and of that 20%, only 20% were able to maintain that weight loss in the long term (2). Klem *et al.* have identified the characteristics of successful weight

loss in the adult – namely adherence to a restrictive and carefully monitored eating plan and regular physical activity, equivalent to at least 60 min daily (3). This observation suggests that those who change lifestyle can be successful, but that an extremely consistent effort is required. Given the poor outcomes of treating established adult obesity and overweight, it is not surprising that attention has been directed to intervention and prevention in children.

Theoretical, but unproven, reasons as to why prevention of, and early intervention in, obesity might be more effective in children

Children are the population group in whom the effects of a strategic obesity intervention might be expected to be apparent. Children have height growth potential and so have an opportunity to return to healthy growth parameters in the normal course of growth if weight is controlled. Moreover, children learn lifestyle behaviours from an early age and may be more flexible in their ability to change behaviours than adults.

Childhood-onset obesity tends to be more severe and is associated with more extreme psychosocial and physical morbidity, which may contribute disproportionately to the cost of adult obesity.

Levels of prevention

In a public health model, primary, secondary and tertiary levels of prevention exist (1). In childhood obesity, primary prevention would be an intervention to prevent children becoming overweight. This approach might work well if there was a method to identify the child at risk of obesity and if a recognized and efficacious intervention existed. Secondary intervention is the prevention of the overweight child from becoming an obese child. This intervention should be strongly supported if the tracking data indicate that childhood obesity persists, and identifies a group of the population already targeted by their peers for bullying and teasing (4). Tertiary prevention is the treatment of established obesity, including the comorbidities of obesity. The lowest percentage of the affected population is included in this approach. Emphasis on tertiary prevention runs the risk of redirection of resources into health that may be better used at a lower prevention level.

Risk times for the development of obesity

There are defined periods during the growth cycle where there is an increased risk of obesity – early infancy, the adiposity rebound in prepuberty, and adolescence – which need to be taken into account. The latter two periods are particularly relevant to intervention. Low birth weight is a

risk for adult obesity and/or the metabolic syndrome. If low birth weight is the result of early gestational deprivation, then adiposity, hypertension and diabetes are more prevalent (5). If the calorific deprivation has occurred during late gestation, then hypertension and diabetes are more prevalent, but not necessarily obesity (6). The earlier the adiposity rebound occurs, which is a universal phenomenon in mid-childhood, the greater the degree of adiposity in adolescence and adulthood (7,8). Adolescence is a further risk time, particularly in females where increased body fat deposition is normal, with already obese adolescents experiencing a body fat gain which is threefold greater than that of lean adolescents (9).

Tracking of body weight in childhood

Not all tracking studies use the same definition of obesity and some commenced well before the obesity epidemic, confounding interpretation. No study has demonstrated an absence of relationship between childhood and adult obesity. Persistence of overweight is accepted, but what varies between studies is the degree of effect and the age from which the prediction is valid (10–16). The study of Kelly *et al.* (13), of over 1000 New Zealand children, revealed that the stability of tracking is particularly strong in the high and low body mass index (BMI) ranges. Guo *et al.* (14), in 500 children from the Fels study, demonstrated that increasing BMI percentile and increasing age strengthened the prediction of adult BMI. Stronger correlations appeared earlier in females than in males. Even though the risk for an obese child becoming an obese adult is considered to be high in these studies, in absolute terms less than 50% of obese children progressed to become obese adults. Less than one-third of obese adults were obese in childhood. Up to 50% of obese adolescents remain obese in adulthood. Late-adolescent obesity and greater degrees of adolescent obesity both make this persistence more probable.

Morbidity and mortality risks of childhood obesity

Childhood obesity is not a benign condition. Tracking of cardiovascular risk factors in childhood was best demonstrated in the Bogalusa study. Bao *et al.* (17) found that the offspring of parents with early coronary artery disease were overweight in childhood and developed an adverse cardiovascular risk profile at a faster rate than children whose parents were not so affected. In addition to the data confirming tracking of cardiovascular risk factors, the Bogalusa group have correlated cardiovascular risk with atherosclerotic change in an autopsy study of 204 children and young adults, who died predominantly from trauma (18). The recently reported increases in type II diabetes

occurring early in adolescence are probably related to the increase in obesity prevalence in this age group (19). Furthermore, obesity in childhood is associated with increased adult cardiovascular morbidity and mortality, irrespective of the adult weight. Mosberg demonstrated increased mortality in adult life in children whose standard deviation score (SDS) weight score was >3 in puberty (20). Must *et al.*, in a review of the Third Harvard Growth Study, demonstrated for males only that the relative risk for all-cause mortality and coronary heart disease mortality were 1.8 and 2.3, respectively, for males who were overweight in adolescence, compared to those who were not (21). Nieto *et al.* found similar relative risks of mortality for children in the top weight versus bottom weight quintiles (22).

The significant genetic component to obesity

The genetic component to obesity has been well demonstrated in multigenerational family studies (23,24) and in twin and adoptee studies (25,26). The offspring of two obese parents have an 80% chance of becoming obese compared to a less than 10% chance of the offspring of two lean parents (27). Based on Whitaker *et al.*'s (10) longitudinal data from children and parents, the odds ratio for adult obesity associated with childhood obesity was 1.3 up to 2 years of age but rose to 17.5 at 17 years of age. Conversely, the odds ratio for obesity in adulthood with one obese parent changed from 2.2 at 17 years to 3.2 at 2 years. Early intervention might thus target family, and later intervention the child.

Other predictors of excess weight gain in childhood include breast feeding practice (28), physical activity (29,30) and leptin and insulin (31,32).

Community concerns

For those who work in the clinical management of obesity, it is apparent that there is a community resistance to intervention in established obesity, which might have an effect on prevention measures. There is the unfounded belief that adiposity in childhood is 'puppy fat' and will disappear during puberty. Second, there is the unfounded concern that any restrictive food practices in childhood will induce an eating disorder. Concerns which relate to the induction of eating disorders emphasize the importance of physical activity as a strategy, because attention is deflected from food and eating.

The definition of obesity and overweight in children

A universally accepted definition of childhood obesity is essential to the intervention process, but may not be easy to determine. A number of definitions exist, including

percentage of ideal body weight and body fatness, as determined by skin-fold thickness or other body composition techniques, as well as BMI. Children change height, weight and body composition as a result of physical growth and development, so that any reference standard must take these changes into account, as well as secular trends towards earlier maturation. The comorbidities of obesity, on which the definitions of adult obesity are based, do not consistently appear in childhood and it is thus difficult to define what percentage of body fat is unhealthy at any age and stage of development. It is most practical to use the measure that is also used in adults, BMI. The BMI in childhood is lower than in adults, and each BMI must be interpreted in light of the age and gender of the child. For this reason, BMI values are often quoted as a percentile or as a standard deviation (SD) score. These measures, provided that there is a relevant reference standard, are useful for research and epidemiological purposes. However, they are not as useful for individual clinical practice unless the appropriate charts are available and understood. The International Obesity Taskforce (IOTF) has recently published a large international data set of BMI cut-off points for children and adolescents from 2 to 18 years of age, which pass through a BMI of 18.5, 25 and 30 for adults (33). Childhood BMIs can now be related to adult BMIs in a useful manner, and the percentile line that finishes at a BMI of 30 at 18 years of age correlates reasonably well with the 95th percentile for current BMI standards (34).

Prevalence of obesity in childhood

There is evidence, particularly from the American National Health and Nutrition Examination Survey (NHANES), to show that the prevalence of obesity has increased in children (35,36). The prevalence of overweight has more than doubled between NHANES II and III (37). At the lower end of the BMI distribution there is very little difference, with the increases occurring at the higher end of the BMI distribution. There is a positive skewness occurring in the heavier children, and the heavier children are becoming heavier. This observation has also been reported in an Australian data set of 2277 primary school children aged between 7 and 12 years who took part in the Health of Young Victorians Study (38). An increase in slightly over one unit of BMI in a 12-year interval was recorded, with again the greatest change at the heavier end of the distribution. A Spanish group has also reported a similar finding over a similar time period (39).

These findings could be interpreted as a general environmental effect that is having a more pronounced effect on a certain group of the population. As at a single time point an individual risk cannot be identified, the concept of universal intervention must be considered.

Energy expenditure in childhood

If physical activity is to be used as a means of preventing obesity, the meaning of physical activity, in terms of energy expenditure, is relevant. The components of energy expenditure comprise the resting metabolic rate or resting energy expenditure (REE), the thermic effect of food and the thermic effect of exercise. The REE accounts for the greatest part of total energy expenditure and is proportional to lean body mass (LBM) (40). Therefore, as LBM increases with growth, so does absolute total energy expenditure. Overweight children will have a greater total energy expenditure than their leaner peers as a result of their greater LBM. The requirements for growth on a daily basis are modest: 1–2% of total energy expenditure during childhood (excluding the neonatal period where energy requirements for growth are considerably greater) and 2–4% during the adolescent growth spurt (41). The discretionary part of the energy expenditure equation is thus physical activity, but children's discretionary physical activity time is often out of their direct control.

The doubly labelled water (DLW) technique, a safe, non-invasive method for measuring total (daily) energy expenditure (TEE) (42,43), has increased the knowledge of energy expenditure in children. Our group has shown in 6–8-year olds that current dietary recommendations (44) overestimate TEE by approximately 11% (45). This figure has been found to be even higher in younger children (46,47). The DLW technique, combined with a measure of REE, can be used to calculate the physical activity component of energy expenditure. The mean TEE for both boys and girls in our study was significantly lower than the published recommendations for energy intake. Measures of physical activity in the total group were found to be inversely correlated with measures of body fatness. However, there was a gender difference in the relationship between physical activity level ($PAL = TEE/REE$) and body fatness. In boys, but not in girls, there were significant inverse correlations between PAL and weight, weight SD score, BMI, BMI SD score, fat mass and percentage body fat, similar to or a little lower than values that have been reported in other studies of children of similar age (48,49). These gender-different results are in agreement with those of Ku *et al.* who found that moderate and strenuous activity scores in 8-year old boys had significant inverse correlations with percentage body fat, whereas there was no significant correlation of activity with body fatness in 8-year old girls. Gender differences between physical activity-related energy expenditure and body composition have also been previously reported in adults (51). Therefore, in prepubertal boys, either physical activity level could have a primary influence on body fat, or body fatness significantly affects the level of physical activity, whereas dietary energy, dietary fat intake or nutrient partitioning may be

more relevant in girls. Such observations need to be both better understood in physiological terms, as do the metabolic effects *per se* of physical activity in childhood, and taken into account when planning and evaluating intervention and prevention strategies.

Physical activity in childhood

Physical activity is taken to mean any time that the child is not asleep or completely sedentary. Sedentariness is an important concept, and will be discussed below. Physical activity in children can be planned or incidental – observation would suggest that in a 'time poor' society the emphasis is placed on planned activity for children.

Secular trends in physical activity in children, many of which are related also to safety of play, where freedom of activity is curtailed because of perceived or real danger, are not documented in traditional scientific literature. Such trend data may well be available, but not accessible. For example, the Transport Department of Western Australia has performed detailed transport studies of school car trips (52).

Limited episodes of vigorous activity may produce increased fitness, increased skill and increased strength, but will not produce a consistent increase in more general physical activity, which has been termed lifestyle or incidental activity. Incidental activity also includes spontaneous physical activity (SPA) or non-exercise activity. This type of activity, which includes wriggling and fidgeting, has a demonstrated heritability (53). It is also the type of behaviour that is often actively discouraged in children. This discouragement might be a less than desirable and modifiable adult behaviour.

Children's activity varies in type, duration and intensity. Unlike adults there is no established grading system of intensity (METs) for various activities. Children's play is one category (54) but may represent varied energy expenditure. Vigorous play will increase with age, strength and skill development (55). Small children spend up to 50% of their time in sedentary play and much of more active play is stop-start in nature (56) and difficult to characterize. There is a decline in physical activity during adolescence, with the decline more apparent in females than in males and with a significant proportion of adolescents inactive (57–59). The 1997 NSW Schools Fitness and Physical Activity survey (57) showed that 25% of Year 6 boys and 30% of Year 8 and 10 boys had low aerobic capacity, with 5% and 30% the corresponding figures for girls.

Measurement of physical activity in childhood (Table 1)

If physical activity was to be measured as part of a prevention strategy, what techniques are available? There are

Table 1 Influences on physical activity in children and adolescents

Age
Developmental stage
Gender
Socioeconomic status
Ethnicity
Parental activity
Parental inactivity
Prompts to be active
Aerobic fitness
Obesity
Genetic

a number, but many of these do not lend themselves to population studies. These methods include diary, observation, heart rate monitors and motion monitors. Diaries, at least in young children, are dependent on parental report. Our group has shown, using a modified Bouchard questionnaire (60), that parental report correlates well with a triaxial motion monitor recording using the Tritrac monitor (61). In adults, the Tritrac accelerometer has been shown to be a reliable measure of physical activity (62). Heart rate monitors in children have a linear relationship to oxygen consumption as a measure of physical activity and can be used in the field (63,64). While these measures allow assessment of physical activity, they are not sufficiently sensitive to discriminate between types of sedentary behaviours or low-grade physical activity that might be relevant in altering energy expenditure over time. Therefore, measures have less value as a prescription than as an epidemiological tool. If methods of motion recording could be made sufficiently small, robust and inexpensive, then these could be used in prescription and prevention. There are indirect measures of physical activity that have been used in large populations. These measures include fitness based on aerobic activity (65). In at least one Australian study, aerobic capacity has been shown to relate to body fat. Dwyer *et al.* demonstrated in 10-year-old children that girls had lower physical work capacity than boys and greater body fat, and that children from Italian and Greek cultural backgrounds had lower aerobic capacity and greater skin-fold thickness than children of Australian or UK parentage (66). High physical fitness scores in children are associated with increased levels of physical activity (67), but it is incorrect to equate physical activity with physical fitness. Fitness is a narrow definition and may be difficult to measure accurately in younger children. A training effect is greatest in the least fit (68). Training, at least in the adolescent, increases muscle bulk (68). In summary, there is no one validated practical, inexpensive and reliable method, which covers all the nuances of body movement, suitable for defining physical activity in children and adolescents.

The physical activity and capabilities of children change during growth and development, and their play is much harder to define than physical activity in adults because of its less structured nature. The refining of measurement tools for adults will not necessarily produce an acceptable measurement tool for children, just as it cannot be assumed that activity guidelines for adults can be extrapolated for use in children.

In adults there exists an inverse relationship between measure of physical and/or cardiorespiratory fitness and cardiovascular and/or other morbidity and mortality (69–71), with a dose–response (72,73). Just as measurement of overweight and obesity in children is limited by the lack of immediate morbidity/mortality, so is the ability to achieve consensus statements and guidelines on physical activity that are backed by a strong evidence base related to positive health outcomes.

To recommend physical activity as a prevention modality in obesity in childhood, there are some evidential requirements:

1. Evidence that physical activity *tracks* from childhood to adulthood.
2. An understanding of *what influences physical activity* in childhood so that these components could be built into a prevention framework.
3. That there is *some physical health benefit* in childhood.
4. Prospective data on a *correlation between activity and fitness*.
5. An understanding of the role of physical activity in the *treatment of established obesity*.
6. *Community interventions* which have fitness as an outcome indicator.

Physical activity tracking in childhood

Dennison *et al.* 1988 (74) identified a cohort of 740 men who were 23–25 years of age at re-evaluation and who had participated as schoolchildren in standardized fitness tests. Current physical activity was described by questionnaire, and initial analysis grouped the adults into physically active or inactive. The physically active adults were characterized by better fitness scores in childhood (particularly the run tests), as well as by higher rates of participation in activity since high school, greater parental encouragement in sport and greater spousal encouragement in sport. There were no differences between groups for BMI. The risk of adult physical inactivity versus childhood run score was significantly increased for those adults who as children had scored in the lowest quintile of the run test compared to those in the highest quintile.

There is short-term variability of activity throughout the day for children (75). The evidence for longer term tracking is not strong, but some studies do support it (76–78).

Studies are medium term, and the measures (heart rate, observation) infrequent, but these did show correlations over the time period, particularly for home-based activity. It would be important to confirm persistent tracking into later childhood and at the time of transition from adolescence to adulthood. Unfortunately tracking is dependent on both the assessment tools used (poor) and the stability of the trait that is tracked (probably low) (79). Tracking studies are unable to distinguish between the influences of genes, environment and social behaviours on tracking. It is unclear whether the tracking of physical activity parallels the tracking of cardiovascular risk.

Influences on physical activity in children (Table 2)

Physical activity is a behaviour. Children learn behaviours from parents and there is general agreement from studies that parental physical activity has an influence on their children's activity (80–82). Children are more active than their parents. Children of active mothers are twice as likely to be active as children of inactive mothers, and this was

increased over threefold for active fathers. There was a sixfold increase in the activity of children if both parents were active. Maternal education level is also inversely associated with inactivity (83), and simply perception of a mother's activity was an influence in African-American children (84). Interventions directed at families and/or parents have a potential for benefit in children, without necessarily targeting the child. The mechanism(s) for the influence of parental activity on childhood activity are probably multiple and include role modelling, shared physical activity, genetic influences and increased access. Genetic influences in physical activity are supported by twin studies (85). There is evidence that reminding young children to be active influences play (86), and thus prompting to be active is a potential intervention technique both at home and at school.

Recently, Fogelholm *et al.* (87) suggested that the parent–child relationship for inactivity is stronger than the relationship for more vigorous activity, both for obese and control children in the study. Both the parent–child and mother–father correlations of inactivity were stronger than correlations for vigorous activity or overall physical activity level. Socioeconomic status (SES) in a non-selected group of adolescents failed to demonstrate a relationship between level of activity and socioeconomic stratum or ethnicity (88). This is different to the studies in adults that have found effects of both these factors, although the absolute contribution of both is hard to determine (89,90). On the other hand, objectively measured physical activity in children correlated with SES (91–93). These observations have implications for the planning of any physical activity intervention. Children may be primarily influenced by parents and hence the SES effect; as adolescents, peer practices and current fashion may be more influential.

Physical activity in obese children

There is some disagreement as to whether obese children are less active overall (94,95), but obese children monitored directly appear to spend less time in motion than leaner peers – they are conservatory of activity (96). Prepubertal Pima Indian children, a group with a strong genetic tendency to obesity, already display reduced physical activity in comparison to lighter, same-age Caucasian peers (97). Pima girls were particularly inactive. There is general agreement in the literature that children with established obesity have a number of characteristics around physical activity, being less likely to participate in vigorous or moderate exercise. They are less fit than their leaner peers or siblings. Using an objective measure of activity, heart rate monitors, Maffei *et al.* (98) showed a relationship between fat mass and time spent in sedentary activity in a day. While clearly not demonstrating causality, there is the suggestion that adiposity may be maintained or supported by inactivity.

Table 2 Measurement of physical activity in children and adolescents

Measure	Description
Direct observation	Accurate, resource intensive, effect of physical presence of observer, not suitable for population studies
Diary	Parental completion for children <10 years of age, reporter bias (including over-reporting), reliance on recall, allows representative coverage
Questionnaire	Qualitative or part quantitative, useful for population studies, requires validation in a specific study group, children's activities not easily defined for direct questioning
Heart rate monitor	Validated method using variation in heart rate, practical in free-living state, activity in young children may not create much increase in heart rate
Motion monitor	Bi- or tridirectional monitors of motion, current models not as small or robust as would be ideal, excellent for free-living state, need diary record of vehicular travel (which will record as motion)
DLW	Combined with REE measure allows calculation of activity energy expenditure, accurate, excellent free-living measure, high cost prohibits use in large populations
Fitness test	<i>De facto</i> measure of activity, can be used in the field, often combined with skills and strength testing, younger children particularly need understanding/encouragement to perform maximally

DLW, doubly labelled water; REE, resting energy expenditure.

Huttenen *et al.* (99) were unable to find any differences in the time that the lean and obese spent in active and inactive pursuits or in the number of pastimes involving physical activity. However, obese children were less involved in formal sports clubs than lean children and were identified as having lower sports grades in school. After 12 months of obesity intervention, the children in the study of Huttenen *et al.* had reduced their relative weight and body fat, and aerobic fitness was improved, despite no formal training intervention. Obese children are inclined to have increased upper body power and static strength as a result of their increased LBM (which is required for their greater fat mass), whereas greater difficulties might be experienced in walking, running and flexibility. There are also changes in plantar pressures, which may negatively affect their capability (100). The energy cost of walking or running is greater for obese children than their lean peers as a raw score, but normalizes when adjusted for their greater LBM (101). While adiposity itself is probably the greatest influence, mechanical factors may also be important in the differences described in the obese child.

The health benefits of physical activity in childhood

Physical activity has been shown to positively affect cardiovascular risk factors in adults (102,103). Whilst beyond the scope of this review, the effect of physical activity on cardiovascular risk is related to its effect on both body fatness (including abdominal fat) and insulin action. Trained muscles exhibit greater capillarization and increased sensitivity to insulin (104,105). Generally, the correlation with physical activity and body fatness has been stronger in children than physical activity effects on cardiovascular risk factors. In the Young Finns Study, high levels of physical activity appeared to be especially beneficial for males (106). In younger children, the effects of physical activity on the cardiovascular risk profile are less clear, and overall the results are not strong, with cross-sectional data reporting both some effect and no effect of childhood activity on cardiovascular risk factors (possibly because the prevalence of abnormality is low and absolute range of risk factor narrow in this age group). It has been suggested that the intensity of physical activity may be important, even in the prepubertal age group (107). Some studies demonstrate poor fitness in children associated with unfavourable blood pressure and lipid profiles (108,109), but not all studies have found this (110). The Bogalusa group has data on its school-based Heart Smart programme participants suggesting that cardiovascular risk factors remain better correlated with fatness rather than with fitness (111). There is also evidence that cardiovascular risk factors cluster, with inactivity included as a risk factor (112,113). A significant proportion of children and

adolescents are inactive (114), and that a modest increase in activity will increase health benefit is important. There is thus evidence of a health benefit from regular physical activity in children, but there are no guidelines as to what might be an appropriate activity prescription. Guidelines will be difficult to obtain: risk factors cluster; methodologies required to demonstrate physiological improvement are generally not performed in children; the least fit will probably benefit more physiologically than the fitter, as modest increases in physical fitness will increase health benefit [extrapolating from adult data] (115).

Prospective studies on physical activity and fatness in children

There is evidence that adolescent activity influences fatness in adulthood (116). There is also evidence that childhood physical activity may have a protective effect on the development of accelerated weight gain in childhood, an important observation for prevention and early-intervention strategies. Klesges *et al.* observed that dietary intake and physical activity were more influential on subsequent weight gain than parental overweight (29). Moore *et al.* studied a subset of the Framingham Children's study monitored by Caltrac motion monitors and triceps skin-fold (30). Children with activity counts greater than the median gained fewer millimetres over 12 months; in addition, the leaner children who were in the low-activity group were less likely to increase fatness than were the heavier children of low activity. Using DLW, Goran *et al.* (117) were unable to demonstrate (in a group of 75 children observed over 5 years) that reduction in energy expenditure accounted for accelerated fatness gain, but because 2 weeks of every year only were considered, subtle TEE variation may have been missed. The main predictors of a relative increase in fatness were gender, the initial degree of fatness and parental adiposity. Analysis of data from the Child and Adolescent Trial for Cardiovascular Health (CATCH) study (118), which will be reviewed in some detail below, demonstrated that in the older prepubertal child, over-fatness at baseline was a strong predictor of fatness at follow-up, echoing the observation of risk of the heavier child (119). This group also demonstrated a greater number of cardiovascular risk factors in the heavier children and lower performance on 9-min run – not unexpected, but not predictive of a change in fatness. The study of Berkey *et al.* (120), of over 10 000 subjects, found larger increases in BMI in both males and females who reported higher levels of small screen entertainment use. Physical activity appeared only as a significant predictor for girls. In a recent Cretan cohort study, primary schoolchildren were assessed at 6, 9 and 12 years of age (121). Fifty per cent were already obese, as judged by BMI percentiles at baseline, indicating the difficulty of defining predictors of

future obesity, as opposed to predictors of further excess weight gain. At 6 years of age, 6% of variability of BMI was accounted for by an endurance shuttle run, which proceeded to predict a proportion of fatness, as judged by skin-folds at 9 and 12 years of age. Fatness was the best predictor of future fatness. Physical activity by self-report did not predict fatness.

Television and childhood obesity have been a topic of great interest and some debate since the publication of a seminal paper by Dietz & Gortmaker in 1985 (122). Using data from the NHANES surveys, the prevalence of obesity in 12–17-year olds increased as the number of hours of television watched per day increased. These authors, plus others, subsequently reported on further television and obesity data, spanning 1986–90 (123). A dose–response relationship to television hours and overweight was demonstrated, together with television hours and increased appearance of and decreased remission of overweight. These findings were not reproduced by Robinson *et al.* (124). The NHANES data also allowed the investigation of vigorous activity and television viewing (125). Boys were more vigorously active than girls and the physical activity rates of boys dropped less steeply than girls with increasing age. Television watching was more closely related to BMI or skin-folds than was reported vigorous activity. There were no significant statistical relationships between vigorous activity and television viewing. Neither did television appear to influence children's requests for sports items and physical activities (126).

Television might influence body fatness in a number of ways. Television induces stillness that is more still than other nominated sedentary activities such as reading or drawing (127). Klesges *et al.* demonstrated the effectiveness of this medium to allow stillness, with children having measurably lower REE watching TV than when just sitting still (128). Television influences food choice (126). Television time, for many, is snack time and the diversion of television will reduce the capacity to monitor total energy intake. For many families, meals are taken in front of the television. Television as a childminder may reduce access to active play time. Television has been more extensively investigated than other small screen leisure activities, such as computers, videos and video games, all of which may be expected to have subtly different impacts on energy expenditure.

There is some evidence in infants, children and adults that reduced spontaneous activity may be associated with risk of weight gain over time (53,129,130). There are no simple measures of such activity. While spontaneous physical activity is both a characteristic of many children and sometimes discouraged, there are no specific studies that have measured the energy expenditure of 'wriggling' in children. There is one adult study that considers spontaneous physical activity (131). Non-obese adult subjects

were overfed by 1000 kilocalories per day for 8 weeks, and by quite stringent, but not physically restrictive, procedures kept volitional activity at low level. Using DLW and REE, a measure of non-exercise activity was obtained and this inversely and significantly correlated with total fat gain over time, with the implication that non-exercise activity may have a role in the maintenance of energy balance.

Physical activity in the treatment of established obesity in children

Many studies are relatively short-term and most do not measure the composition of the weight lost, which is particularly important for physical activity intervention where fatness may be lost and LBM maintained. While the enhancement of physical activity is a component part of weight-management programmes, no study has sought to define the relative contribution of activity. Only recently has this been performed in adults (132), where if the calorific deficit induced by exercise was identical to the calorific deficit induced by dietary intervention, then weight loss was identical. Therefore, the enhanced activity prescriptions in weight management overall, and in childhood specifically, will probably be inadequate to induce such a large degree of calorific deficit. Most reports of childhood weight management have not made any consistent attempt to quantify activity compliance, other than if activity was supervised, and even then attendance (rather than performance) was quantified (133,134). The work of Epstein and co-workers provides useful direction. A family-based approach, incorporating the standard elements of dietary change, enhanced physical activity and behavioural change, will probably be more effective in the long term in overweight children than in their overweight parents (135). Children at 10 years of follow-up maintained their percentage overweight change at –5%. This loss is both the degree of weight loss that might be expected to achieve metabolic benefit and the degree of change that would have a profound effect at a population level. Epstein *et al.* have also published a study to test the hypothesis that decreasing sedentary behaviours is as effective in weight management in children as increasing active behaviours (136). While this study does not have a control diet-only group, it does provide results for 24 months. The activity prescriptions were the reduction of sedentary behaviour or increased physical activity, for a similar length of time. Compliance was assessed by accelerometer and self-report, and targeted sedentary behaviours were those most inclined to persist. The change in percentage overweight was similar for both reduced sedentary and increased physical activity groups. This study suggests that targeting inactivity may be as useful as targeting increased physical activity in weight management, and is an attractive concept for population interventions. Another weight-management

strategy in the obese child by Golan *et al.* (137,138) is worthy of mention for its potential to inform regarding the prevention of obesity and overweight. Their intervention group was parent-only participation in the group weight-management sessions. The concept of using basic effective parenting strategies to produce microenvironmental change is appealing and has the advantage of not stigmatizing the obese child. Activity level was one of the targeted behaviours, but an increase failed to occur – including for the parents. This finding suggests that eating behaviours were easier for parents to modify than were activity behaviours, and the reasons for such would be fruitful research.

Community interventions designed to increase physical activity in children

Finally, this review will consider interventions based on physical activity that are directed towards weight change. In a Cochrane review where any interventional study based on physical activity, dietary change, or both, and which had anthropometric change as a primary outcome, only seven studies were identified that fitted the randomized control trial criterion (139). Four of these studies related to physical activity and will be considered in greater detail below.

While there are many descriptive studies of community intervention, these tend to have common difficulties, including that of no control group. Often these studies were directed at cardiovascular risk, and change in body fatness was not an identified outcome indicator. Many of these studies are based on self-report, with no quantifiable measure of change. Some are without formal evaluation, and many have short intervention or follow-up.

Mo-Suwan *et al.* (140) described a 30-week intervention in nearly 300 preschool children, with the stated aim of determining the effect of a structured aerobic programme on adiposity indices. Children in the treatment group took part in a 15-min walk before the beginning of school and a 20-min dance session three times a week, after their afternoon sleep. Using triceps skin-folds there was a near-significant decrease over time in the percentage of subjects who exceeded the 95th centile. The interest in these findings is the very modest amount of physical activity in the intervention.

Flores used a 'Dance for Health' program for 110 Afro-American and Hispanic 10–13-year olds as part of a cardiovascular risk-intervention strategy (141). One-hundred and fifty minutes of dance per week over three sessions for 12 weeks resulted in a decrease in BMI in girls only. Dance was chosen as being culturally appropriate and highlights that any general community-intervention strategies will need to be tailored to specific groups at the local level.

Robinson's study is specific for this review's age group (142). This trial aimed to reduce sedentary behaviours and

video game use and to correlate these changes with changes in physical activity, adiposity (BMI, skin-fold and waist and hip measurements) and dietary behaviours. Parents also reported on their child's eating and activity behaviours. Cardiorespiratory fitness was assessed by shuttle run. The six-month intervention was school-based in 200 children who had a mean age of 8.9 years. Parents were informed of the intervention through newsletter. In the intervention group BMI, triceps skin-fold, waist and waist to hip ratio all fell significantly. Children reported watching significantly fewer hours of television and video games and eating less meals in front of the television, a finding confirmed by parents. Snacking, other sedentary behaviours, physical activity and fitness did not change. The study highlights the difficulty of selecting intervention and outcome indicators. This group identified a broad range of outcome indicators – 15 – of which 40% achieved significance.

Gortmaker's 2-year study involved nearly 1300 students who were aged 11.5 years at study commencement (143). This was a randomized, controlled field trial. The primary end-point was obesity using BMI and triceps skin-fold. Food, activity and television and video were assessed by questionnaire, which included food frequency. Nineteen variables were selected at baseline. The intervention was school-based, interdisciplinary and embedded in the existing curricula. The focus was on decreasing the incidence of television viewing, decreasing consumption of high-fat foods, increasing fruit and vegetable intake and increasing moderate-to-vigorous physical activity. The prevalence of obesity was reduced and remission of obesity increased in girls, but not in boys. Both genders reduced the incidence of television viewing significantly in the intervention group. There was no demonstrable change in activity, and intervention girls showed an increase in intake of fruit and vegetables. Compared to the previous study there was no parental involvement.

Two regularly referenced studies will be briefly critiqued to demonstrate that a similar design with dissimilar outcome indicators may not achieve similar results, despite appearing to have many of the elements in the previous two interventions. The first is an Australian study (144). This was a randomized, controlled trial, with over 1000 children. There were five intervention groups – school-based nutrition, home-based nutrition, school physical fitness, school and home nutrition, and school nutrition and physical fitness – studied for 12 months. Triceps skin-fold change was significant in only one of the intervention groups – school nutrition and physical fitness – and in both genders. In contrast, the CATCH study (118) was unable to demonstrate fatness change in a randomized, control trial involving over 5000 students, over 3 years, with a mean entry age of 8.8 years. The intervention was food service modification and enhanced physical education at school. The primary end-point was serum cholesterol,

which did not significantly change in the intervention group. Neither did blood pressure or measures of body fatness, although students reported statistically significant increase in dietary knowledge, a change in dietary intention and food choice, and improved diet and physical activity self-efficacy.

How certain is it that reduced physical activity is a contributor to increasing obesity in children?

There are no studies to confirm that physical activity has fallen in children over the decades that obesity and overweight have increased. Epidemiological cross-sectional population studies in adults have used measures of non-sedentary activity, which have demonstrated a high prevalence of inactivity and have specified groups particularly at risk of inactivity (145,146). What is not assessed in such studies is the component of lifestyle activity that intuitively is the falling component. Inactivity has been engineered into the environment very effectively. In the Prentice & Jebb review (147) *de facto* measures of inactivity, including hours of television watched by adults and household car ownership, appear to be related to the second and greater postwar increase in overweight and obesity. It would be probable that the lifestyle activity of children has fallen because they share the environment with adults. Ours has become a time-poor society, fatigued by non-physical demands and trying to compartmentalize daily living tasks. It is small wonder that physical activity is discarded in this environment.

Conclusion

Overweight and obesity in children are socially engineered problems. Physiology is responding appropriately to the conditions of plentiful food supply and reduced activity by storing fat. An evolutionary stage has been reached where energy expenditure is a requisite to deal with energy excess, rather than a requisite to deal with energy deficiency. The community has responded to obesity and overweight as primarily a medical problem, whereas obesity should be viewed in the prevention context as a social issue with health sequelae. As no one factor is to blame, it is difficult for any one group or institution to take responsibility for the prevention of obesity. There is a more than lingering view that being overweight is the individual's fault and should be fixed by the individual.

Health professionals should support physical activity as a prevention for overweight in children. The scientific evidence for this approach is not strong, but neither is it absent. It would be unwise to await further evidence before any action is taken, but production of further evidence should be undertaken in parallel to action. A complex con-

dition such as obesity is unlikely to be resolved by relatively simple solutions.

Any evidence collection on the effect of physical activity in obesity intervention and prevention should, in the medium-to-longer term, be able to be evaluated, sustainable, transferable and have community involvement. Such research should be viewed as a 'living laboratory'. Families, schools, community, government and the legislative process at all levels, social welfare, transport and industry all have a role in the prevention of obesity in children, but many such groups will need to be convinced that this is part of their business.

The following strategies are suggested:

1. A reduction of childhood sedentary activities should be promoted, with a focus on television (for which there is evidence) and on other forms of sedentary, small screen entertainment such as computers, video games, etc. (for which there is not as much evidence). Such an intervention would require a family and school alliance, parental commitment to behavioural change and provision of alternative leisure activity. This intervention could also be incorporated into positive parenting strategies and early childhood centre education.
2. Schools should promote physical activity and the learning of skills that allow lifelong physical activity. In order to sustain any change, a family/school alliance would be required. Adolescent females and certain ethnic groups may need special consideration.
3. Local environmental review and change needs to occur to allow children and families to be more physically active outside school hours. This strategy implies active community involvement in such change – communities must see that increasing physical activity is important and actively lobby for it to occur in a form that is relevant and sustainable for their community. This strategy would involve alliances with services that may not view obesity as their core business and is the least evidence based.
4. Targeted strategy of increased physical activity and decreased sedentary behaviour directed at families who are concerned about generational health risk, including but not only concerned with, obesity. Children of obese parents and particularly children of obese parents with early-onset morbidities, including cardiovascular disease and type II diabetes, irrespective of the child's current weight, are the target group. Such an approach requires an increase in health professional skills in, and knowledge of, intervention prescription. Direct intervention should be increased in children from late primary school age, but prior to this a family focus maintained.
5. Strategies should always include an evaluation of the tools used for the assessment of physical activity and an appreciation of potential gender differences.

Whatever physical activity approach is employed it should be along the lines of fun, fitness and well-being. Fun is an essential factor, as the environment that needs to be altered for children is often a fun environment – exciting, interactive and consuming.

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