Task 4.1: Critical narrative review of educational strategies and psychological approaches explaining young children's acquisition and formation of energy-balance related behaviours, and facilitating their management

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Declarations:

None of the authors has any conflicts of interests to declare.

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4.1.1. Conduct a literature search of evidence underlying psychological approaches on how young children acquire their eating and activity habits, including meal sizes and food likes and dislikes and the implications for the development of individual risk factors for obesity.

Executive summary and recommendations

This part of the review is primarily concerned with understanding the psychological and behavioural processes that underlie the development of eating and physical activity behaviour in young children, and the implications for risk of obesity.

Eating Behaviour

- Eating behaviour can be measured in several ways, including as amount eaten of a meal (or meals) or of particular foods, or choice of and preference for foods, eating rate, or appetitive ratings - as general states or for specific foods - or responsiveness to food and its consequences.
- A child's eating behaviour reflects gene-environment interactions: specific eating tendencies linked to obesity risk have been shown to have strong heritability, including sensitivity to satiety, eating rate, and enjoyment of food. Preschool children's likings for food groups also show moderate to strong heritability, especially for meat and fish. Other heritable influences on eating include temperamental aspects such as food neophobia (unwillingness to try new foods, especially fruit, vegetables and meat) and impulsivity. Nevertheless, environmental influences are very important, and probably more so the younger the child and the more varied the environment. Indeed, food neophobia is mitigated by breastfeeding, and peaks during preschool years. Successful interventions should include awareness of such inherited vulnerabilities and their environmental interactions.
- Maternal prepartum diet and preweaning infant feeding practices may influence obesity risk, and there is limited evidence that mothers' (specifically) prepartum protein and fat intakes predict those of their children. Stronger evidence suggests that both maternal prepartum diet and breastfeeding may encourage early acceptance of novel foods such as fruits and vegetables through exposing the foetus and neonate to flavours from such foods in the maternal diet.
- Children are born with an innate liking for sweetness, and disliking for sour and bitter tastes. Genetic polymorphisms influence taste sensitivities, and enhanced sensitivity to bitter taste may inhibit acceptance of bitter vegetables. Nevertheless, these innate influences are not strongly related to diet in adults, and are clearly modifiable by experience.

- The role of experience, or learning, is critical in the development of young children's eating behaviour. Examples vary from encouraging food acceptance through simple taste exposure, reinforcement of liking for a new flavour through pairing with an already liked flavour, to quickly learning to prefer food flavours predicting greater energy delivery (an example of 'Pavlovian' or classical conditioning). Moreover, learned flavour-energy associations also help to control meal size in advance of actual energy absorption. Instrumental or 'operant' learning, whereby actions such as eating a particular food are rewarded, e.g. by verbal praise or treats, are often used as attempts to improve the healthiness of children's eating: however, the results can be counterproductive, and care is needed in choosing an effective strategy.
- Observational learning, or modelling, is another key aspect of experience for moderating children's eating. Modelling of healthy eating by respected (slightly older) peers or adult carers is likely to be beneficial in encouraging healthy eating, especially of younger children. However, healthful modelling competes with unhealthful modelling in children's environments, and sustained repetition may be necessary for longer term benefits.

  Parents are clearly an important influence on children's eating, not least through provision of healthy foods and modelling their eating. At least a moderately controlling parental style is likely to be more successful than either a neglectful or overindulgent one. Nevertheless, there is concern that too much control, or coercion, such as emphasising 'cleaning the plate', or encouraging consumption as a means to an end, may prevent a child from being sensitive to its own internal appetite cues, as well as associating that food with a negative social context or devaluing instrumental one. To a large extent, parental feeding practices may be driven by their child's own temperament and eating style. Interventions should encourage awareness of these issues in parents.

Physical Activity

- Physical activity is defined as "any bodily movement produced by skeletal muscles that results in a substantial increase in energy expenditure above resting metabolic rate and includes leisure time physical activity, exercise, sport, occupational work, and household and other chores".
- In children and adolescents, physical activity plays an important role for normal growth, maturation, and development. Understanding why a child is active or inactive is, therefore, essential.
- Preschool children's activity patterns differ from those of older children and adolescents in that young children's physical activity patterns do not usually occur as a planned,

structured activity, but rather as short bursts of vigorous activity that are followed by less-intense recovery periods.

- Current studies indicate that the inclination to be physically active or sedentary has a biological foundation. Twin and family studies confirm that physical activity-related traits are characterised by familial aggregation and influenced by genetic factors. Results from animal model studies indicate that single genes, and changes in gene function (e.g. by foetal programming) can markedly influence physical activity-related behaviour. Nevertheless, the genetic contribution to physical activity shows increasing expression with age. This strengthens the case for interventions in young children when the effects of the environment can be expected to be at their largest.
- Recent reviews of studies in pre-school children find that boys are more active than girls, children with active parents tend to be more active, and children who spend more time outdoors are more active than those who spend more time indoors.
- Parents need to be involved in their child's physical activity in a variety of ways if their child is to lead an active lifestyle. Overall physical activity support provided by parents predicts children's organised physical activity, and fathers' physical activity predicts overall physical activity in adolescents. Programmes designed to increase physical activity levels in children should promote the importance of physical activity to parents, especially to fathers, and encourage them to increase their own physical activity level.
- Peers are also important, especially for slightly older children: Youngsters who feel more accepted by their peers also take part in more physical activity with friends.
- Overweight and obese children (especially girls) are unlikely to be physically active if they experience low perceived self-efficacy and high body dissatisfaction. This finding, however, pertains more to older children (> 8 years).
- Perceived road safety and threat posed by strangers ("stranger danger") are major causes of parental anxiety in relation to their children's safety in the neighbourhood. Parent' views rather than children's are stronger influences on children's physical activity, including independent free play and active transport within the neighbourhood.
- Social interventions to improve perceived safety and physical interventions involving redesign of the built environment to improve actual safety may help to ease parental restriction of their children's active transport and physical activity in their neighbourhood.

1. Scope and methodology of the review: acquisition of eating behaviour and physical activity and risks for obesity

This review is primarily concerned with understanding the psychological and behavioural processes that underlie the development of eating and physical activity behaviour in young children, and the implications for risk of obesity. The review will concentrate on theories and evidence concerning eating behaviour and physical activity in young children, primarily pre-school children aged 4 to 6 years, in view of the target age group of Toybox. Nevertheless, where particularly relevant, or overlapping, evidence in older children will be considered, and even in adults where it is key to understanding relevant psychological theory. To provide sufficient understanding of the context of individual risk factors for obesity, genetic and non-genetic maternal influences, including *in utero* effects related to maternal diet, and influences of breastfeeding, will also be considered. However, interventions in infants will not be considered in detail here.

The bibliographic search strategy focused on articles published in peer-reviewed, English-language journals, published since 1980. A small number of papers published in French or German were also retrieved. The databases used included PubMed, Web of Knowledge, Scopus, and PsycINFO. Citations in reviews and citation paths within databases were also used.

Outcomes considered included: (i) eating: food (and caloric drink) choice/diet, other measures of preference such as liking ratings and rankings, facial expression responses, food/drink intake including meal size, obesity risk factors, e.g. eating rate, food ‘enjoyment’ or responsiveness, neophobia, picky-fussy eating, delay of gratification, self-regulation, obesity, overweight, BMI (z scores) (ii) physical activity: reported hours, number and frequency of leisure time activities, METs, pedometer, steps, exercise; sedentary activity time, e.g. sitting, television watching. Search terms were derived from these outcomes, also including ‘children’, ‘child’, ‘pre-school children’, ‘parenting style’, feeding, reward sensitivity.

1.1 Introduction

Recent reviews of interventions aimed at preventing childhood obesity have acknowledged that the majority of these interventions have taken place in school-based settings, and yet have had rather limited success (1). Schools are obviously convenient and practical settings to carry out such interventions; however, there are two major weaknesses to this approach that may explain the lack of success: first, engagement of parents, and consideration of the family environment, is often too limited; secondly, it has been argued that by school age (e.g. older than six), quite strong eating and activity habits may already have formed. By contrast, younger children are just starting to change from infant foods to more adult foods, eating culture and environment, and developing their own likes and dislikes: moreover, in the USA at least, some 20% of children are at risk from overweight or obesity before the age of six. Thus, it is this transitional preschool period, which may be a more effective stage for obesity prevention (1).

1.2 Eating Behaviour

1.2.1 Outcomes and operationalisations

Eating behaviour includes several different sorts of behavioural output; for example, acceptance or rejection of foods (essentially, swallowing a food or conversely spitting it out or not even attempting to eat it), amount eaten of a food or combinations of foods, at a meal or over more extended periods, or expression of a preference or aversion through a choice between foods or perhaps food groups, or as assessed by ratings of facial expression sequelae after tasting a food. Likes and dislikes are behavioural dispositions that can be reported without actually measuring eating behaviour directly; similarly, sensations such as hunger or other appetitive terms, e.g. craving, desire to eat, are reported states with expected impact on eating behaviour. Nevertheless, these dispositions and sensations are by no means perfect predictors of eating behaviour, especially when the context in which the assessments were made differs from that in which eating actually occurs; for example, there may be an unexpected choice of foods, or the presence of a novel food, or inhibitory or facilitatory social contexts. Thus eating is an outcome that can be influenced by a complex array of sensory, physiological, genetic, social (family, parental, peer), cultural, environmental and learned inputs.

In terms of young children's eating behaviour, Table 1 sets out the main influences and the developmental stages at which their influence can be seen. Without doubt, the first few years of life are critical to development of food preferences and eating habits (2). To understand how these influences contribute to development of a child's idiosyncratic eating behaviour, it is useful to consider these processes in approximately chronological order.

1.2.2 Genetic influences on childhood obesity and eating behaviour

As our understanding of genomics grows, there is increasing interest in genetic influences on health, and childhood obesity is no exception. A better understanding of the extent of genetic influence, and both its independence from and interactions with the environment, will help to shed light on mechanisms contributing to childhood obesity, and which sorts of intervention are likely to succeed. To this end, twin and adoption studies investigating gene-environment contributions to childhood obesity have recently been systematically reviewed: results from 5 adoption studies and 9 twin cohorts were included, for children up to 18 years old (3). From the twin studies, this review presents estimates of heritability, shared and unique environments by age. Overall heritability for BMI is about 75% but varies considerably with age: interestingly, the nadir of heritability was found at ages 4-5 years, albeit still at about 50%, whereas this age showed the strongest effect of shared environment (approaching 30%), though this influence becomes negligible in adolescence, presumably reflecting increasing independence of behaviour. Unique environment was relatively stable over age, at about 13% overall. Emphasising this strong genetic component, the adoption studies showed reliable correlations between biological parents and offspring, as well as between biological siblings, that were consistently stronger than those between adoptive parents and adoptee children. The authors point out that the genetic influence on obesity is just as likely to be mediated by behaviour as by, for example, metabolic effects: moreover, the more stable the childhood environment of a particular society is, the stronger the genetic component will appear to be.

In a longitudinal study of more than 7,000 twins, the heritability of adiposity increases with age, so that by age 11, the heritability of BMI was 78% (4). The authors suggest that this could reflect growing children increasingly selecting environments that allow adiposity-related expression of their genetic propensities.

Behavioural mediators of genetic influence on BMI could be either eating behaviour or physical activity; the latter is considered in section 1.3 (Physical Activity), so we turn now to evidence for genetic influences on children's eating behaviour (genetic influences on taste sensitivity are discussed in the later section on innate likes and dislikes).

Good evidence for genetic influences on children's eating behaviour is relatively recent. These include heritability or genes influencing taste and food preferences, reward sensitivity, and appetitive and satiation tendencies. Breen et al. (5) investigated heritability of food preferences using mothers' reports of food preferences in 103 monozygotic and 111 dizygotic 4-5 year-old same-sex twin pairs. For heritability modelling, the preferences were grouped into categories already established by factor analysis as describing food groups sharing preference patterns, i.e. desserts, fruits, vegetables and meat and fish (6). Heritability was modest for liking for dessert foods (0.20), moderate for vegetables (0.37) and fruits (0.51), and high for liking for meat and fish (0.78). Shared environmental effects were strong for desserts, fruits and vegetables, while non-shared environmental influences were low for all four food groups, suggesting little independent influence of idiosyncratic experience on food preferences in young children.

In another study, questionnaire measures of responsiveness to satiety together with slowness of eating (e.g. ‘My child gets full before his/her meal is finished’) and responsiveness to food cues plus enjoyment of eating (e.g. ‘Given the choice, my child would eat most of the time’) in 8- to 11-year-old twins (n = 5435 pairs) were completed by parents for both children. Heritability of satiety responsiveness averaged 63%, and 75% for food cue responsiveness/enjoyment. Shared and non-shared environmental influences were 21% and 16% for satiety responsiveness, and 10% and 15% for food cue responsiveness, respectively. In this twin cohort, heritability of both standardized BMI and waist circumference (abdominal adiposity) was 77%, although waist circumference also had an independent genetic effect (40%) (7). It is therefore not too surprising that both BMI and waist circumference were linearly related to the measures of heritable eating behavior: that is, from low-normal BMI or thin waist to obese levels, satiety responsiveness decreased whereas food cue responsiveness increased (8).

Further evidence for the strength of genetic influence on these facets of eating behaviour was found in twin babies up to 3 months old: mothers rated similar behaviours as above using the Baby Eating Behaviour Questionnaire (Gemini study: (9)). Satiety responsiveness/slowness of feeding was highly heritable, whereas food responsiveness was moderately heritable. In yet another twin cohort (TEDS study; 10-12 years old at measurement), this same group reported that eating rate, which was positively related to adiposity in these twins, showed 62% heritability (10).

The most common genetic locus reliably associated with obesity is the FTO gene (or a single nucleotide polymorphism [SNP] close to it), which probably exerts its effect mainly through energy intake rather than expenditure in humans (11). It is therefore intriguingly consistent that this FTO polymorphism is associated with eating in the absence of hunger in 4-5 year old children (12), and with lower satiety responsiveness in 8-11 year olds (13). However, for adiposity in adolescents, physical activity seems to moderate the effect of this SNP on adiposity, so developmental stage may be important (14). Another set of candidate polymorphisms, associated with the melanocortin-4 receptor, have been linked to obesity, satiety responsiveness and enjoyment of food in Chilean children (15).

There is experimental evidence for close correlations between parents and children in their responsiveness to food reward, which could be an indicator of genetic predispositions (16). That study also found that responsiveness to food reward was related to impulsivity in children, echoing earlier findings that obese children are less able to delay gratification from immediate food rewards (17). This may be related to evidence that impulsivity has been shown to be greater in obese than non-obese children (18). Furthermore, 8-12 year-old obese children who were higher in impulsivity, as measured by a behavioural task, were less able to lose weight when following a weight-loss programme (19).

This evidence for genetic influence on childhood obesity and eating behaviour should not be taken as lessening the importance of behavioural interventions, but rather as underlining the importance of individual vulnerabilities to obesity related eating, and how these predispositions might interact with their environment, both within and without the family. One case in point comes from analysis of a dopamine D2 receptor (DRD2) polymorphism: adolescents carrying the allele associated with fewer DRD2 in the brain were more likely to develop emotional eating behaviour in response to high parental control (20). Another example is evidence in adolescents that a polymorphism associated with the eating-suppressant peptide, neuromedin B, is more strongly associated with central adiposity in children with mothers having low educational attainment (21). Birch and Anzman (22) have argued for a developmental systems perspective in childhood obesity, in which phenotypic outcomes are seen as the result of multilevel actions whose effects depend on the environmental context experienced. An awareness of inherited vulnerabilities and their environmental interactions should allow more effective targeting of intervention strategies.

Nevertheless, it should be noted that some recent data on parent-child associations for obesity more easily invoke a social rather than genetic explanation. It is well established that having one or two obese parents substantially increases the risk of the child being obese (23). However, Perez-Pastor et al. (Early Bird Study of children followed from age 5 to 8 years; (24)) found that daughters' BMI were strongly associated with their mothers' BMI but not their fathers, whereas sons' BMI were strongly associated with their fathers' but not their mothers' BMI. These gender-assortative associations are hard to explain by Mendelian genetic transmission, so are more likely to need sociocultural explanations (25).

Finally, there is increasing evidence for gene polymorphisms in taste receptors that could differentially affect children's eating behaviour (26). This evidence is reviewed under innate likes and dislikes (Section 1.2.4).

1.2.3 Influences of maternal prepartum diet and infant feeding practices

There is now substantial evidence that maternal diet during pregnancy, including both under- and overnutrition, and its impact on foetal development and birth weight, can influence the child's risk for cardiovascular disease and metabolic syndrome in later life (27). Moreover, rapid 'catch-up' growth is also a risk factor for obesity (28), as is being overweight for length at birth (29). Nevertheless, there has been relatively little research on the relationship between maternal diet during pregnancy and the offspring's own diet. In rats, low protein maternal diet during pregnancy led to a preference for self-selecting a high-fat food over high-carbohydrate food in the offspring at 12 weeks postnatally (30). In sheep, overfeeding during pregnancy causes alterations in foetal neural appetite systems that could desensitise the brain to changes in fat deposition (31). In humans, a recent study found that maternal macronutrient intakes during pregnancy predicted the children's macronutrient intakes at 10 years of age, especially protein and fat, more strongly than either paternal intakes or mothers' postnatal intakes (32). This suggests that there is a nutrient-dependent intrauterine 'programming' mechanism that can influence children's' appetites and food choices to some extent independently of shared family food environment or other postnatal parental influences.

After birth, infant feeding practices are, not surprisingly, important for a child's growth and development; moreover, meta-analyses of published data suggest than an infant's risk of developing obesity by school age is significantly increased by about 20% for formula feeding rather than breastfeeding in the first few months (33). One hypothesis is that the high protein content of formula milk – a cost-effective way to achieve minimum amino acid requirements – leads to rapid weight gain and programming of appetite systems to promote overeating: supporting evidence comes from a randomised controlled trial (RCT) of high and low protein formula milks, where infant weights at 2 years of age were in line with WHO growth standards (based on breast-fed babies) for the low-protein version but not the high protein version (33). However, in many countries, uptake of breastfeeding is strongly confounded with other factors that influence childhood obesity risk, such as maternal education, socioeconomic status, smoking and other family health behaviours, and it has been argued that a protective effect of breastfeeding *per se* may be weak at best (34). A cluster-randomised trial intervention to promote breastfeeding in Belarus (Promotion of Breastfeeding Intervention Trial, PROBIT) followed up 13,889 children to age 6.5 years, but found no significant benefit of breastfeeding on BMI (35). Moreover, a recent longitudinal study of 307 Australian children followed up at age 10 years (36) found that risk of overweight or obesity was reduced by 10% for each week that introduction to solid foods was delayed: the mean age of introduction for the healthy weight group was 20.5 weeks, versus 18.7 weeks for the overweight group. This study did not find a significant relationship with breastfeeding, nor did it interact with solid food introduction. The reason for this finding is unclear, and might reflect parental response to greater expression of inherent appetite in earlier solid-fed infants. It might also be a marker for family attitudes to child feeding, including a wish to involve other members in the infant's feeding, or ignorance of recommendations (37). Even so, more fundamental mechanisms are possible, such as nutrient programming of developing gut hormones controlling appetite.

Additionally, both the maternal prepartum diet and breastfeeding can have an impact on infant food acceptance through exposure to flavours derived from the mother's diet (38). Evidence for this form of early learned influence on children's eating will be considered in Section 1.2.6.

1.2.4 Innate likes and dislikes

Many mammals are known to be born with innate reactions (ingestion/acceptance or egestion/rejection) to tastes that probably have evolved because the taste consistently predicts a consequence of eating something that has an impact on the animal's survival or reproductive success. Thus, many animals instinctively reject bitter (e.g. quinine) and astringent (e.g. tannin) tastes, presumably because these are associated with the presence of poisonous plant alkaloids. Sour tastes, which might indicate indigestibility, are also rejected by neonates. Conversely, animals commonly show an innate propensity to ingest sweet tasting food or fluids: these innate acceptance and rejection reactions have both been demonstrated in newborn human babies, including those born anencephalic, i.e. lacking intact cerebral hemispheres (39). Acceptance or rejection can be judged by naïve observers of films of the babies' facial expressions and oral movements. Sweetness might be a consistent cue for ripeness (and so high sugar content) of non-toxic fruit and roots, although ripeness also means loss of acidity, astringency and inedible toughness. Primate species that eat a wide-ranging diet have a low threshold for detection of sweetness, which encourages consumption even of low-sugar foods, whereas those with feeding strategies limited to high-energy foods have higher sweetness thresholds (40). However, Booth and Thibault (41) have suggested that a more convincing evolutionary role for sweet liking in mammals may be as an anti-bitterness device in nitrogen-rich mother's milk. That is, 'sweet' receptors respond to chemical groups on both sugars and amino acids, so there would be strong selection pressure to develop an ingestive reflex when such receptors are stimulated, ensuring that the protein-rich milk is not rejected.

This trade-off between sweetness and bitterness seems to be supported by findings for children with differing alleles of a gene for detection of the bitter taste of 6-n-propylthiouracil

(PROP), i.e. the TAS2R38 gene (42, 43). Children who were homo- or heterozygous for the bitter taste sensitivity allele preferred higher levels of sucrose in foods and drinks than those without this allele. Intriguingly, mothers who were non-tasters of the bitter PROP themselves rated children who were bitter tasters as more emotional than children who did not have bitter-sensitive alleles. Although ratings of child food neophobia did not differ here, it is notable that another study concluded that low-threshold PROP tasters may be inherently more neophobic, or at least more emotionally reactive to food (44) (see discussion of picky/fussy eating, Section 1.2.5). Moreover, Bell and Tepper (45) found that 'non-taster' preschool children more readily ate bitter vegetables than did taster children: this is in line with an earlier report that sensitivity to the bitterness of PROP predicts dislike of spinach in 3-6 year old children (46).

However, these different TAS2R38 genotypes did not show correspondence to sweet preferences in adults, suggesting that such genetic influences on children's eating behaviour are modifiable by experience (see above). Those with the heterozygous genotype (AVI/PAV) are more likely to show loss of bitter sensitivity with age than the homozygous phenotypes (47). Overall, these genotypes relating to bitter sensitivity are likely to be more relevant to eating behaviour in young children than in adults, and the evidence of a relationship to food preference is certainly stronger in children (48).

Salty taste seems to be innately liked by many animals, although human neonates appear indifferent to it; nevertheless, human infants start to express a preference for salty taste by about 4 months of age, i.e. pre-weaning (38). Interestingly, severe 'morning sickness' during pregnancy has been linked to greater liking for salty tastes in the offspring (49). Post-weaning, dietary experience is likely to be influential on children's liking for salty taste (50).

In general, the complex sensory experience of eating, from the combination of tastes, smells, chemical irritation, textures and latent heat of foods, cannot provide sufficiently consistent cues to postingestive consequences for many responses to be hard-wired by inheritance. Thus, adaptive food choice cannot rely solely on a battery of innate reactions of acceptance or rejection, particularly for omnivores such as rats and ourselves that require too many nutrients for optimal health, and have too many possible sources of them, to depend on innate appetites (51). Instead, as with other behaviours, we depend on learning processes to fine tune our eating: indeed, learning allows both innate likes and dislikes to be modified or even reversed (38).

1.2.5 Food neophobia, picky eating and child temperament

Neophobia is the fear of novelty, and food neophobia is defined as a reluctance to try new or unfamiliar foods: it is typically measured using brief questionnaires, which, for young children, are usually completed by parents (52). Most parents will be familiar with the concept of children being unwilling to try new foods; however, children clearly vary on a continuum in the extent to which they persist in this, and food neophobia is typically considered a form of personality trait. Indeed, high levels of food neophobia are associated with trait anxiety in adults (53) and children (54), and to the related domains of emotionality and shyness (55). Anxious children and adults show attentional biases to possibly threatening stimuli, so it is not surprising that neophobic children are sensitive to fears of food contamination, easily succumbing to feelings of disgust about novel foods.

In support of this, recent twin studies have shown strong heritability of food neophobia in both children (75%; (56) and adults (66-69%; (57). Interestingly, the twin study in 8-11 year-old children (56) also showed that the environmental contribution (22%) was entirely non-shared, i.e. unique to each child. By contrast, an earlier twin study of preschool children's temperament found no genetic contribution to 'food reactivity', which may be more related to picky eating (see below). Although one should be cautious about generalising from sibling twin findings to non-twin or singleton situations, the data suggest that parents may bring different strategies to feeding each child and/or each child seeks to influence parents' approaches to feeding differently. This is reflected in other evidence for little family resemblance in food neophobia (55).

The main concern for food neophobic children is that their diet will be unhealthily limited, due to avoidance of fruits, vegetables and protein-rich sources (58). Indeed, a key aspect of food neophobia in young children is that the reluctance to try foods is strongly biased to fruits, vegetables, meat and fish, whereas sweet and starchy staple foods are not affected (59). Although neophobic children may typically eat less energy while young (58), and so would be unlikely to be at early risk of obesity, a concern is that, with a diet dominated by energy-dense, sweet fatty staple and snack foods, they may develop an eating pattern that could put them at risk of weight gain later in life (60). Furthermore, interventions to improve their diet would need to take their neophobic tendencies into account: for example, children who are not at all neophobic are much more accepting of strong or novel tastes, including sourness (61).

Another important aspect of food neophobia is that it varies with age. A common experience of parents is that a child will happily accept a variety of vegetables in the first few months after weaning, but then abruptly become unwilling to try them, typically at around 18 to 24 months. Food neophobia is known to peak between ages 2 to 6 years (60), and it has been argued that reluctance to try new foods, especially of types that carry a risk of toxicity, may have adaptive value in children of this age, who are starting to explore the world with some independence (59, 62). This age sensitivity needs to be addressed by any trait based model of neophobia; it implies an interaction between genetic predisposition and developmental processes that encourage its expression, i.e. an epigenetic phenomenon. An important inference is that interventions in preschool children need to demonstrate awareness of this strong influence on children's dietary variety and food acceptance.

In contrast to food neophobic children, picky eaters are characterised not just by a limited diet, especially of vegetables, but also a reluctance to try quite familiar foods (60). Although pickiness can be quite extreme even in adults, picky eating has not been as extensively researched. Measures of picky eating are sure to overlap with those of food neophobia, and are probably almost opposite to 'enjoyment of food' (63), although there is debate as to their independence (60): nevertheless, there is some evidence for temperamental differences between them (53, 54, 64), and picky eating may be less affected by the age of the child. It seems plausible that picky eating is more related to developmental and temperamental interactions with parents over meals: for example, child temperament is known to be a mediating risk factor for obesity by age 9-10 years, including the persistence of food-related tantrums (65). Intriguingly, picky eating in preschoolers was predicted by reluctant suckling in early infancy as well as more negative affect (66). Moreover, there is evidence that fussy infants with more negative temperament may be fed more to mollify them (67). It may be relevant that high sensitivity to tastes and smells, rather than neophobia, was found to make children less likely to model the fruit and vegetable consumption of their parents (68).

1.2.6 The roles of learning in children's eating behaviour

There is a substantial literature on the roles of different forms of learning in eating behaviour which cannot be considered in detail here. Instead, this section will concentrate on the evidence that clearly applies to young children.

Non-associative learning: 'mere' exposure and learned safety

Evidence in both animals and human beings demonstrates that, whereas a novel food is usually treated cautiously (cp. neophobia), familiarity through repeated exposure leads to loss of caution and increased acceptance of the food (69). One implication of this learned acceptance with exposure is that familiar foods would be less likely to acquire aversive connotations, e.g. by association with illness, than more novel foods. This inhibition of learned aversion is known as 'learned safety' and is well described in animals (70, 71), and probably true for humans (72). However, a potential downside of this phenomenon is that prior associations with stimuli, or even exposure to a stimulus without reinforcement, can inhibit new learning (73).

Where the exposure to the food increases acceptance despite involving merely tasting, and not swallowing, the food, i.e. there is no obvious reinforcement from postingestive nutritional effects, then the learning could be non-associative, as in habituation to a stimulus (74). There are many claims for a role for this seemingly non-associative form of learning due to 'mere' exposure in acquired food acceptance in human beings (75). However, it may often be the case that there has been some form of reinforcement, particularly social or emotional, contingent with the exposure (75, 76), so that in fact the learning may be at least partly associative, for example a form of 'evaluative conditioning' (77).

Whether or not the learning is associative, a significant advance in understanding the contribution of passive flavour exposure was the finding that maternal diet affected the flavour of the mother's milk, which in turn altered flavour acceptance in their babies. However, the results were not entirely positive. For garlic and carrot flavour, prior exposure to the flavour in breast milk seemed, respectively, to suppress feeding on garlic-flavoured breast milk (78), or suppress eating of cereal mixed with carrot juice relative to infants exposed for the first time to those flavours (79). This was suggested to be a form of sensory-specific satiety (similar to habituation but for hedonic not sensory responses) to the recently exposed flavours. In a subsequent study, which included exposing foetuses, via their amniotic fluid, to carrot flavour from the pregnant mother's diet, infant acceptance of cereal mixed with carrot juice was judged to be enhanced relative to water (80). Another finding from this group was that early exposure to a particular infant formula milk determined subsequent liking for not only the same and similar formulas, but for related tastes in other drinks, such as sourness and bitterness, in infants fed on sour-tasting protein hydrolysate formula (81).

In infants just being weaned and naïve to vegetables, Sullivan and Birch (82) found that ten opportunities to eat a small amount of puréed peas or green beans led to increased intake of this vegetable, but this was only significant in breast-fed babies. It was suggested that breast-fed babies might more readily accept a novel vegetable, having experienced vegetable flavours in breast milk previously. Similarly, breastfed babies have been found to more readily accept peaches on first exposure, compared to formula-fed babies, perhaps due to fruit flavour exposure in breast milk (83). Nevertheless, Gerrish and Mennella (84) showed later that formula-fed infants given nine exposures to several different vegetables subsequently ate not only more carrot than a group fed only potato, but also more puréed chicken than a group fed only carrot. They also found that prior experience with fruit in these infants led to greater intake of carrot on first exposure. One explanation is that exposure to flavour variety reduces neophobia, and breastfed babies do appear to be less neophobic (54). However, improved acceptance of food flavours carried in breast milk could also involve a specific form of associative learning, i.e. flavour-flavour learning, while acceptance of related flavours could be due to 'generalisation' of acceptance of one flavour complex to another sharing related stimulus properties (see below).

Birch and colleagues have provided several demonstrations in preschool children of increased acceptance of foods following repeated tasting (85, 86) – usually requiring at least 5-10 exposures. Birch et al. (86) also showed that tasting was necessary to enhance rated taste preferences, not just visual exposure. This simple way of encouraging liking for foods has been used effectively in short-term interventions to enhance acceptance of vegetables in young children (87-89) (see Section 4.1.2), although again contingent social reinforcement was likely. Furthermore, in 4-7 month-old infants, substantial increases in intake of an exposed (eaten) food, including fruit, occur after just one feed, and this generalises to similar foods, such as other fruit (90). This suggests that liking for healthy foods can be enhanced much more quickly in infants than in young children aged two or more. However, it may also reflect a short-lived phase of easy acceptance, before neophobia starts (60). It is also notable that, when 4-5 year-old children were exposed to novel tofu flavoured with either sugar, salt or nothing, they developed a preference specifically for the exposed flavour, while liking for the unexposed flavours typically decreased (91). This suggests some resistance to generalisation to liking the food complex carrying the flavour, in its absence. Moreover, in 7-9 year-old children, exposure to palatable novel foods did not increase willingness to try other novel foods, unlike in infants (90) or older children (87).

Associative learning

Associative learning is a powerful mechanism by which an organism acquires knowledge about the relationship between events, and is thought to be the principal form of learning that influences eating (92, 93). In its simplest form, it is the establishment of a memory that a perceived 'cue' has a particular 'consequence', or that two events are linked. A cue might be an event perceived in the external or internal environment (a stimulus). If the association between the cue and the consequence is remembered, then the cue has been 'conditioned' (a conditioned stimulus, CS) or reinforced to the association. The reinforcing consequence is the unconditioned stimulus (US). In some cases, 'stimulus substitution' may occur, when the unconditioned response (UR) that would normally follow the US (e.g. saliva secretion in response to food) is now elicited by the CS (e.g. a sound previously paired with food presentation), so that salivation is now a conditioned response (CR). However, the CS-US contingency can also elicit an anticipatory CR that is quite different from any UR induced by the US. These are instances of classical or Pavlovian conditioning. Where the CS or US does not involve ingestion, tight temporal contiguity between CS and US is normally required to see such learning: however, for ingestive behaviour, associative learning has unique properties that allow much longer delays between, for example, a taste and its consequence, whether an aversion or a preference is being learned (92, 94).

Instrumental learning and reward

For ingestive behaviour, learning typically involves a two-stage process (95). The first is the form of stimulus-reinforcement association discussed above that teaches the animal the value of food-related stimuli. The second is learning what appropriate action is required to obtain the food reinforcer. In this type of action-outcome learning, known as instrumental or operant conditioning, internal or external stimuli can act as discriminative stimuli (S^D), predicting that the reinforcing outcome will follow the action, and strengthening the cue-consequence memory (96, 97). Also, classically conditioned CSs previously paired with a food can enhance instrumental responding for that food during food deprivation ("Pavlovian-instrumental transfer") (73). Reinforcement should not be confused with 'reward': it is the memory of the association between events that is reinforced, so that if a CS is perceived it will evoke a memory of the properties of the food-related US, and a CR is likely to follow. The reinforcing consequence may not necessarily be pleasurable, and could involve aversive motivational states.

Evidence that learning has occurred depends on measuring a change in behaviour in appropriate test conditions. In general, this involves demonstrating a CR to a CS, or an operant response to a S^D, in the absence of the reinforcing US. This is known as testing in *extinction*. The learnt response will usually be *extinguished* on repeated testing in this way, since the association of CS to US is no longer reinforced. However, some paradigms produce learned responses that appear to be very resistant to such extinction (98).

Using rewards (positive reinforcement) is of course a common means to encourage a behaviour, albeit there are various theoretical accounts as to the process (99). Several investigators have studied the impact of rewards, whether social or more tangible and edible, on encouraging healthy eating in children, although some approaches can actually have a counterproductive effect (22, 100). These studies are examined in more detail in Section 4.1.2.

The learnt appetite for energy

The physiological need for energy, and especially for sufficient availability of glucose to ensure a constant supply to the brain, probably provides the primary motivation to eat. Energy can be derived from any of the three macronutrients, carbohydrate, protein and fat, available in a multitude of physical forms. The extent to which a given macronutrient in a food is metabolised to energy, rather than stored or used for growth or other physiological function, depends on the current nutritional status of the eater, as well as the nutrient content of the food. Thus, humans and other animals cannot rely on some invariant sensory cue to decide how much to eat of what food, to satisfy their immediate needs.

Instead, we have to know about the consequences of eating a particular food in our current state, and how that state will change on eating. So, we must learn to associate the taste, texture and/or smell experienced while eating the food, with postingestive sensations or changes in state. Removal of an energy deficit as the food is absorbed will be a positive consequence (US) that will reinforce an appetite, or preference (CR), for flavours (CSs) in the eaten food. Thus, we do not strictly have an appetite for energy, but rather an associatively learnt appetite for food providing that energy.

There is now considerable evidence that just this sort of cue-consequence associative conditioning of flavour preferences (also called flavour-consequence learning; FCL) occurs in many animals (98, 101, 102), including people (Booth *et al.*., 1994; Birch, 1999) (69, 103, 104). Birch et al. (105) showed that, after 8 trials, young children learned to prefer flavours of drinks with extra energy from carbohydrate, compared to flavours in low-energy drinks (150 kcal difference). This was followed by evidence from the same group that 2-5 year-old children learned to like novel flavours paired with high-fat energy-rich yoghurts after 8 trials, but not flavours in low-fat yoghurts having 110 kcal less energy (106). Similarly, in 3-4-year-old children given 12 conditioning trials, high-fat yoghurt flavours came to be preferred over fat-free yoghurt flavours (energy difference, 162 kcal) (107). In this study, one group of children just tasted the yoghurts at each exposure (mere exposure control), and this resulted in a moderate increase in liking for both high- and low-energy flavours.

In general, a hungry animal will prefer flavours associated with rich sources of energy, and the hungrier the animal or person, the more sensitive to the caloric consequences of the food it becomes (108). Children are probably more sensitive to quite small differences in energy delivery than adults, but even among children, increasing age seems to be associated with a weakening of this sensitivity (109). One reason may be increasing dominance of cognitive strategies based on attitudes, and also cultural habits, that develop with aging (110), although parental practices that emphasise external controls of eating could also be to blame (1) (see Section 1.2.8).

This energy sensitivity in young children is illustrated by the finding that 4-5 year-old children's preferences for fruit and vegetables were strongly correlated (r=0.65) to the foods' energy densities (111). This is despite the fact that the most energy dense food in this study was the banana (4 kJ/g), which is one-fifth as energy dense as chocolate. The correlation was shown not to be due to sugar (for vegetables) or protein content. A similar finding across a range of foods was reported recently for 2-3 year-old children choosing their own food in a nursery canteen (112): children most often chose foods with greater energy per portion. It is most likely that these findings reflect learned preferences conditioned by post-ingestive energy absorption.

Flavour-flavour learning and evaluative conditioning

Another form of associative learning that can occur during eating is flavour-flavour learning, perhaps a form of evaluative conditioning, whereby acceptance of a previously 'neutral' (often novel) flavour is altered by pairing its consumption with a flavour that is reinforcing, i.e. either liked or disliked (74, 104, 113). For example, pairing a novel flavour with sweetness can increase liking for that novel flavour, at least if sweetness is considered a pleasurable and positively motivating taste (114, 115). Sweetness may become more rewarding and salient in the presence of hunger, and so more strongly (and subconsciously) able to reinforce such flavour-flavour learning (116). This suggests that sweetness reinforcement could be used as a strategy to encourage acceptance of healthy foods in children: just such strategies have been attempted and will be considered in Section 4.1.2.

Learnt control of meal size

It is one thing to acquire a liking for food flavours predicting a good source of energy, as described above. It is another to know how much of such food to eat, in order to satisfy our current energy needs. It might be supposed that we could rely on a physiological signal, such as a gut hormone, that is released, or reaches a critical level, when enough energy has been absorbed. However, the system needs to be more adaptable than that, and the reason is simple: consider first that a typical meal (say eaten at a school canteen rather than the occasional luxurious feast) is eaten within 20 minutes. Yet, the constraints of digestion, and physiological adaptation, mean that food is emptied from the stomach into the upper gut for absorption at a rate of only about 2-3 kcal/min (for a mainly solid meal) (117). In other words, a 600-kcal meal will take 3.5 to 5 hours to empty from the stomach. For most animals, it would not be adaptive to linger for hours over a meal, so the solution is to learn to anticipate how much energy a particular amount of a food will provide, so that a meal can be completed quickly and well in advance of absorption of all the energy (93).

Our brains provide a solution by learning to predict later energy repletion from experience of orosensory cues from what is eaten, in association with internal cues such as gastric distension, and afferent information about rate of absorption of nutrients, via the vagus nerve and hormonal signals (118). Thus, it has been argued that a large part of what ends a meal is a learnt rejection of food in the presence of particular internal states generated by eating food, such as gastric distension. Booth called this learnt control of meal size "conditioned satiety", and he and colleagues have provided substantial evidence for such learning in rats and primates (119-121).

Booth et al. (122) provided the first evidence for learnt satiation in man. In their study, participants drank 100 ml of starch solution prior to eating a lunch, which included a particular flavour of yoghurt-based dessert. On one occasion, the drink was 65% starch, which was paired with one flavour of the dessert, and on another the drink was 5% starch, which was paired with a different flavour of dessert. Initially, lunch intakes after each type of drink did not differ, but with a few repeated pairings, participants ate less after the high-energy drink than after the low-energy drink. Furthermore, when the energy of the drinks was subsequently equated at 35% (extinction testing), the participants still ate less of the meal with the flavour of dessert previously associated with the high-energy drink, and this difference was due to changes in the later stages of the meal.

In a later study, after 2-4 pairings of soup flavours and dessert flavours with starch-augmented high or low energy content (differences of 190-280 kcal), learnt starch-paired flavour-dependent suppression of intake was seen for energy-rich soup flavours, but not for dessert flavours (123). In a second experiment, using these same foods, rated appetite for the energy-rich flavours increased when eaten hungry, but decreased when eaten without hunger. A similar result was found for preschool children, in whom flavour preferences conditioned by 12 pairings of flavours with high-fat energy-rich yoghurt (relative to a fat-free low-energy yoghurt) were diminished when the children were satiated (107): by contrast, increased liking due to mere exposure did not vary with hunger state. Thus, in both adults and children, appetite for a food can depend on a learnt association between a food's flavour, its after-effects and the internal state in which it is eaten.

Booth (124) interprets these state-dependent effects as evidence that the internal state cues and food sensory cues are configured into a Gestalt stimulus complex governing the conditioned response, i.e. learnt appetite or satiation. The implication is that the learnt appetite is not fully expressed unless all components of the associated internal and external cues are present. An alternative model proposed by Davidson (125) holds that the internal state, during which sensory cues come to predict post-ingestional effects, acts as an 'occasion setter', i.e. a contiguous or contextual stimulus that modulates associative strength between a CS and US. Thus, the eater has learned that a particular meal has a particular reinforcing consequence when eaten in a particular state, e.g. a level of hunger, and any deviation from those circumstances alters the learned response. This is similar to the control of appetite that environmental contexts can acquire after repeated association with a particular eating experience (73, 126), so that desire for a food or drink might be elicited by a particular room or social gathering. Such cue-potentiated eating has been shown in preschool children, who were repeatedly asked to eat snacks in the presence of one set of visual and auditory stimuli, or even a location (CS+), and did not eat in the presence of another set of such stimuli (CS-) (127). To test for learnt control of appetite by the paired stimuli, children were first sated with a snack then exposed to either CS+ or CS- stimuli, on different days. Intake increased, and latency to eat decreased during exposure to CS+ vs. CS-, at least for children who were explicitly aware of the CS-snack pairing.

Related evidence for learned control of meal size comes from two studies in preschool children. In the first study, children were given repeated experience of consuming preloads with disguised differences in energy paired with particular flavours, followed by ad-libitum snack intake (128). In extinction testing, with no energy difference in the preloads, children consumed more of the snack foods following the low-energy-paired flavour than the high-energy-paired flavour. In the second study, there was similar evidence for differential intake following preloads with flavours previously paired with high or low energy content. However, in this case the learning trials occurred in one of two conditions: one focussing the children's attention on their internal cues for hunger and satiety, and the other focussing on external cues, including rewards for eating. These latter children showed no evidence of learned responsiveness to flavour cues predicting caloric differences (129). This effect of external, including social, contexts distracting from learned control of eating might underlie the decline with age in ability to compensate for recent energy consumed by reducing intake in a subsequent meal, especially if parental practices distract from attention to internal states (109, 129, 130).

1.2.7 Social cognitive theory: observational learning and modelling in eating

Not all learning requires direct reinforcement to alter behaviour: the offspring of both human beings and other animals may have innate tendencies to imitate conspecifics with whom they have some form of allegiance or respect. The impact of this sort of modelling, or observational learning, was dramatically illustrated by Bandura's classic experiments in which children watched adults beating an inflatable doll, and then subsequently imitated this behaviour, even if the adult actor was reprimanded (131). From such results, Bandura developed his theory of social learning, now expanded into social cognitive theory (132). A core facet of this theory is that for behaviour change to occur effectively, the person making the change must have good 'self-efficacy', i.e. a strong belief in their own ability to do something successfully (133). Clearly, modelling by respected peers, parents, teachers – i.e. 'important others' – is one potentially useful way to strengthen self-efficacy and encourage behaviour change, including healthy eating. However, both underlying motivation and a supportive environment that encourages initiation and success will also be key. Moreover, given their young age and lack of independence, it is not clear that self-efficacy has much relevance for changing eating behaviour in preschool children (134, 135). Even in eight year-olds, self-efficacy did not significantly predict fruit and vegetable consumption, although another aspect of the theory, outcome expectancies, as well as liking for fruits and vegetables, did have weak predictive effects (136). Although interventions may improve self-efficacy in children, the extent to which it is a prerequisite for success, or an epiphenomenon, is not clear (137).

Nevertheless, there is considerable evidence that modelling (observational learning) could be an important influence on young children's eating behaviour (138-141). Indeed, this form of learning will contribute to the strong correlations between parental and child diets and food preferences, especially for easily categorised foods such as fruits and vegetables (6, 142, 143), although simple availability and exposure could also contribute to such findings (144). Experimental evidence for the impact of modelling on improving eating behaviour in preschool children will be considered in detail in Section 4.1.2. However, it is worth noting here that effects of modelling need not be beneficial: for example, a child may model unhealthy eating from observing its parents or siblings. Modelling may also be weaker than other strategies, depending on the relationship between model and observer (145). Moreover, modelling is the basis of success for television advertising to children, and the large amount of advertising of relatively unhealthy energy-dense foods and drinks to children, particularly in the USA, could be contributing to childhood obesity (146). One study in 3-5 year-old children found that the presence of McDonald's branding on foods and drinks led children to report that the branded foods tasted better than identical non-branded foods, and the more so for those exposed to more television and who more often ate at McDonald's (147).

There are several other psychosocial or 'sociocognitive' theories relevant to motivation and behaviour change in adults (e.g. Theory of Planned Behaviour; Health Belief Model; Transtheoretical 'Stages of Change' model; Self-regulation Theory; PRIME theory); however, because these require a level of self-awareness, reflection and conceptual thinking, as well as behavioural control, that is unlikely to be present in preschool children (134), these models will not be considered further here.

1.2.8 Parenting, the family food environment and young children's eating behaviour

Parenting style

The concept of parenting style represents a collection of parents' attitudes and behaviours toward a child, reflecting especially the degrees of control and responsiveness expressed. Parenting styles are commonly classified as one of four types: authoritative (controlling but responsive), authoritarian (controlling and unresponsive), indulgent/permissive, or neglectful. These classifications have been applied to parenting styles in the context of feeding practices and diet-related parent-child interactions (148). However, the extent to which parental styles relate to healthy diets in children depends also on the children's own personalities and eating tendencies (149, 150), mediated by child-specific and responsive parenting practices (151). The findings are not always consistent, but overall, indulgent and neglectful parenting styles are associated with negative dietary health or child obesity outcomes (152-154). Even so, the studies are almost entirely cross-sectional, so causality cannot be determined for certain. Nevertheless, there is some experimental evidence relating to parental control, which is discussed again in 4.1.2.

Parental feeding practices and effects on children's eating

Parenting practices concerning approaches to feeding their children arise out of challenges to parents' goals as to how their child should eat, or the rate at which they are growing or putting on weight. As a result, their practices are not as invariant as parenting styles, but can respond to a particular child's behaviour and developmental stage (151) and so are more likely to be influential (150). Essentially, these are strategies designed to control how much of what foods, and when, a child will eat. Thus, parental feeding practices reflect parents' beliefs about how a child should be eating, or growing, as well as their reactions to the child's own behaviour. It should also be noted that this applies to any carer responsible for feeding the child. The practices are usually measured using validated questionnaires such as the Child Feeding Questionnaire (155) or the Parental Control Index (156). Typical practices include using food as a reward (either to encourage eating of another food, or for non-eating related behaviour), using food to pacify or control, pressuring a child to eat (more in general or of specific foods, or to finish the served portion), restricting certain foods or types of food, and modelling. A distinction has also been made between these generally overt strategies and more covert ones (not detectable by the child), such as not buying unhealthy food, keeping it out of a child's sight and reach, or serving smaller portions (157); however, the evidence that either overt or covert strategies are more effective for reducing risks of childhood obesity is weak (158).

Ventura and Birch (151) have proposed a conceptual mediation model in which parenting, child eating and child weight are all related by bidirectional paths, i.e. each is capable of influencing the other. However, their review of studies published in this area up to 2006 revealed only four that included measures of parenting, child eating and child weight, so that evidence for clear mediation in the full model remains weak. Nevertheless, there is good evidence for an association between parental practices and child eating, including some longitudinal studies. These findings are summarised here, and studies relevant to preschool children are described in section 4.1.2.

There is a consistent pattern of evidence that greater pressure to eat from parents is associated with children of lower weight (159-161) and being picky eaters (162, 163). Although it is possible (from largely cross-sectional data) that children become so as a reaction to parental pressure to eat (especially foods they dislike), it seems more likely that parents are reacting to underweight, picky eaters by encouraging greater consumption. Moreover, this is supported by longitudinal studies tracking child weight or eating over time: coercion to eat is associated with pickiness and poor diet (162). Nevertheless, an observational study of mealtime interactions for 77 3-year-old children and their mothers found that mothers who frequently prompted children to eat had children who ate more and faster, and this was related to a more controlling maternal style (164). In a cross-sectional study of 564 parents of preschool children, pressure to eat was measured by the Parental Control Index (156), and frequency of fruit and vegetable intakes of parents and children, and child neophobia were assessed by questionnaires. There was only a slight negative effect of parental control on fruit and vegetable intake, which became nonsignificant once neophobia (small negative association) was included in the regression model: the main predictor was parents' own fruit and vegetable consumption. It is also worth noting that not all studies have found a significant relationship between picky/neophobic eating and child weight, despite evidence of increased attempts at parental control with fussier children (165, 166).

Hendy and colleagues developed a self-report measure, the Parent Meal-time Action Scale (PMAS) to study parental practice predictors of child weight and diet, in 6-10 year-olds, in competition with genetic, exercise and television watching contributions (167). They found that children's healthy weight and diet was predicted by 7 practices: positively with daily fruit and vegetable availability, fat reduction, positive persuasion, and insistence on eating (fathers only); negatively with snack modelling, allowing many food choices and preparing special meals (differently from the family meal). In another study using the PMAS to predict weight gain in fussy eating children recruited from a feeding clinic, four subscales were examined for association with children's BMI: positive persuasion, insistence on eating, snack modelling, and special meals (168). Only preparation of special meals was independently associated with weight gain in these underweight children, suggesting that their diet would be rather limited.

If using coercion, such as offering rewards for eating vegetables, and pressure to eat are associated with lower weight children, it implies that the strategy is not successful in encouraging more healthy food intake. Several experimental studies do indeed suggest that such strategies are counterproductive and actually put children off the target foods , even if in the short-term more is eaten (129, 161, 169-171). Moreover, Birch and colleagues have expressed concern that this sort of pressure to eat leads children to ignore internal satiation signals and attend to external cues such as an empty plate: in the long run, the concern is that this could encourage overeating through low satiety responsiveness (129), in line with an earlier theory of overeating and obesity (172).

Nevertheless, there is evidence that use of non-food reward strategies can successfully improve children's diets, such as eating more fruits and vegetables, at least in the short term (173-175). These will be considered in Section 4.1.2.

In contrast to pressure to eat, use of food restriction by parents -- typically restriction of perceived unhealthy but often highly palatable foods – is associated with higher weight status and gain in longitudinal studies (176). Other studies show that parental restriction is associated with children's eating in the absence of hunger (177, 178), although this may depend on the child having an overweight mother (179). Restrictive eating may in part be a response to a child with an inherited strong appetite or 'enjoyment of food' disposition, who would be at risk of excess weight gain: even so, it is clear that the strategy is counterproductive. Experimental studies have shown that restricting access to food draws children's attention to it and enhances their desire for it, particularly if the food is palatable (180, 181) (see Section 4.1.2).

1.2.9 Conclusions

By the time children are weaned onto table foods, their eating behaviour, both in terms of appetite expression and food preferences, already shows predetermined tendencies, as a result of strong genetic influences interacting with their experience of the environment, including *in utero* flavour exposure and via preweaning feeding practices. These effects contribute to each child's risk of becoming obese. Key individual differences influencing children's eating behaviour and obesity risk include how easily a child feels full ('satiety responsiveness'), how much a child appears to enjoy food and eating, and their rate of eating. Other important aspects of a young child's temperament that help to explain variation between children in their eating behaviour include impulsivity and food neophobia. The former but not the latter has been linked to risk of obesity, whereas food neophobia may be associated with an unhealthily limited diet, especially in preschool children: highly neophobic children are very reluctant to eat fruit, vegetables and meats, but are usually happy to eat starchy staple foods, and palatable sweet foods. These children may need particular care, patience and effort to encourage healthier eating. Conversely, impulsive children may need some control over their access to highly palatable, but potentially fattening, foods. Another inherited variation is seen in sensitivity to particular tastes: although all children are born with a liking for sweet tastes and a dislike for bitter and sour tastes, some children are particularly sensitive to bitterness, and this could inhibit their intake of bitter-tasting vegetables: it may pay to avoid attempting to encourage children to eat particularly bitter vegetables. Successful interventions should train parents and carers in awareness of such inherited vulnerabilities and their environmental interactions.

Children's eating behaviour is fine-tuned and developed through their experience, overlaying genetic tendencies to select and interact uniquely with their particular environment. Much of this learning to eat, and to prefer certain foods, may occur subconsciously, or implicitly: examples include more readily accepting foods with increasing familiarity with the flavours, learning to prefer foods that deliver more energy, to like flavours that are paired with already liked flavours, or to eat more or less of a food through experience of its satiating qualities. Young children may be particularly sensitive to energy-related impact of foods - interventions should try to encourage this awareness of, or at least responsivity to, internal state.

A food's appeal will be influenced by association with positive or negative contexts, including social, emotional and physiological. Positive social modelling of healthy eating by respected others, especially parents and peers, is likely to be an effective strategy to encourage such eating in young children. However, approaches must be consistent, with an awareness that negative contexts and modelling can rapidly put children off foods: parenting practices to encourage healthy eating should avoid excessive coercion or pressure to eat.

Overall, there is consensus that interventions in preschool children may well be more effective than those in older children in a school setting, although evidence from such interventions is scarce. The younger the children, the less established and externalised are their eating habits, and there should be more opportunity for involvement, and training, of parents, as well as modification of the preschool environment.

1.3 Physical Activity

Habitual physical activity in humans is a complex trait that is determined by the interaction of biological and psychosocial factors and the physical environment. The definition of physical activity is now accepted as “any bodily movement produced by skeletal muscles that results in a substantial increase in energy expenditure above resting metabolic rate and includes leisure time physical activity, exercise, sport, occupational work, and household and other chores” (182). Several components of physical activity can be distinguished: spontaneous (i.e., activity associated with daily living), obligatory (i.e., inevitable, necessary activity to survive), and voluntary (i.e., exercise). In sum, these components represent the activity energy expenditure and when included with the energy cost of growth, thermic effect of food, and resting energy expenditure equal the total daily energy expenditure.

Habitual physical activity and total daily energy expenditure are of considerable interest given concerns for lack of adequate amounts of daily physical activity, energy imbalance, and the relationship between low levels of physical activity and energy expenditure with several chronic diseases, including obesity. In children and adolescents, physical activity plays an important role for normal growth, maturation, and development (183). Understanding why a child is active or inactive is, therefore, essential.

Physical activity (e.g. running, jumping, walking) seems to be a natural part of young children’s life, which – once learned – does not require intentional effort or planning to set in motion. At this young age, therefore, decisions to exercise are supposed to be made without the involvement of conscious cognitive control processes, i.e. in a rather automatic fashion, and can therefore best be described as habitual (184). When growing older, however, many children in industrialised countries gradually pursue and maintain an inactive lifestyle, probably partly due to concurrent daily sedentary activities (e.g. TV viewing, playing video games, using the Internet etc.). In a longitudinal study Kimm et al. (185), for example, found a significant decline in physical activity between the age at study entry (9-10 years) and 10 years later in a large cohort of black and white American girls. This decline in physical activity was inversely related to measures of adiposity (BMI, skinfold thickness), and occurred at all activity levels (active, moderately active, inactive). These results suggest that children’s daily activity habits are short lived and may therefore, not carry over to adulthood. Moreover, they suggest that lack of habitual activity plays an important role in weight gain, with no parallel evidence that energy intake has a similar role (185). Just like other health behaviours executed on a daily basis (e.g. dental care), it is important to promote and (re-) establish physical activity habits early in life so they may persist into adulthood. Consequently, educational strategies and other interventions have been designed aimed at children and adolescents to develop life-long patterns of physical activity, however with relatively little success (see section 4.1.2). It is important, therefore, to better understand the process of physical activity habit formation to guide further development of effective programmes.

1.3.1 Outcomes, operationalisations and other methodological considerations

Like eating behaviour, physical activity has been operationalised in a number of ways, ranging from self- or parent-report on exercise frequency and intensity, type and time spent with leisure time activities (e.g. activity diaries), to objective, direct measures such as number of steps taken per day (e.g. using pedometers or accelerometers) or indirect measures, i.e. physical fitness (e.g. 600 m field test) or skinfold-thickness. In addition, physical inactivity (e.g. TV viewing) can be construed as being directly opposed to physical activity and as such, has been used as an indicator of insufficient physical activity or sedentary behaviour, which competes with the time spent with physical activity. All of these variables have been used in studies with older children and adolescents. Nevertheless, preschool children's activity patterns differ from those of older children and adolescents in that young children's physical activity patterns do not usually occur as a planned, structured activity, but rather as short bursts of vigorous activity that are followed by less-intense recovery periods (186, 187). Evidently, this impacts the choice of valid outcomes in studies on preschool children's physical activity. While the results from studies with older children may provide insight into the types of variables that affect preschool children's physical activity, it is important, to assess the developmental appropriateness of outcomes used in studies investigating physical activity patterns in young children. The latter issue may also affect the degree to which outcomes of studies investigating physical activity in children of different ages can be directly compared.

Contemporary models identify biological (genetic) factors (188), deliberate health-related choices (behaviour) or psychosocial factors (189) and characteristics of the home and local environment (190) as important determinants of physical activity. It is important to note in this context, that the studies conducted in this field are almost exclusively correlational and mostly use cross-sectional designs. This has implications for the conclusions that can be drawn with respect to the assumed causal role of these factors, as implied by their status as determinants of physical activity in these models. Nevertheless, correlational studies have both theoretical and practical use: they generate hypotheses about possible causal relationships and about potential mediators that can be targeted in intervention studies (see section 4.1.2).

The literature describing correlates of physical activity in children has been reviewed several times with perhaps the longest standing tradition for research on psychosocial aspects. Sallis et al. (191), for example, have reviewed about 100 studies of child and adolescent physical activity correlates, summarising semi-quantitative results separately for children (ages 3-12) and adolescents (ages 13-18). Two more recent reviews concentrate on younger children: van der Horst et al. (192) review the evidence on 4-12 year olds and Hinkley et al. (193) on 2-5 year olds. As opposed to physical activity Hoyos Cillero and Jago (194) have recently reviewed studies investigating psychosocial correlates of screen viewing in young children. Other than psychosocial correlates of physical activity, recent work has focused on the associations between the physical environment, in particular the “built environment”, and physical activity in children (195). Compared to psychosocial aspects and features of the physical environment, relatively little attention has been devoted to understanding the biological basis of physical activity in children (196).

For the purpose of the present review we will summarise the results of these reviews by following the approach to categorise the factors affecting children’s physical (in-) activity into (1) biological (genetic) factors, (2) psychosocial factors and (3) the local environment.

1.3.2 Biological control of physical activity

The contribution of genetic influences to childhood obesity is discussed in section 1.2.2, so this will not be repeated here. As explicated in this section, there is considerable evidence for genetic influences on children’s eating behaviour. The same seems to be true for physical activity, so both behaviours could act as mediators of the previously reported genetic effects on BMI.

According to Bouchard and Rankinen (197) there are several lines of evidence supporting the notion of a biological basis of physical activity levels:

1) Current models that do not include biological factors account for only a moderate portion of the total variance in physical activity levels

2) Low adherence rates to physical activity programmes

3) Evidence from family studies and twin studies

4) Estimated heritability coefficients are significant and meaningful

5) Genome-wide scans have identified several chromosomal regions, which harbour genes and DNA sequence variation that contribute to physical activity

6) Association studies indicate differences in physical activity levels for a few candidate genes

7) Epigenetic mechanisms (e.g., maternal-foetal interactions) in animal models show altered physical activity during postnatal life

Reviewing the evidence for these seven lines of evidence is beyond the scope of this review. We will, therefore, highlight important findings and key relevant studies in the following paragraphs with an emphasis on the genetic and epigenetic aspects of the central question.

Genetic influences

Several studies have indicated that the physical activity phenotype can partly be explained by genetic factors (197). In general, the estimated heritability of physical activity varies considerably (range 18–69%) due to differences in measurement and expression of physical activity (e.g., retrospective questionnaire vs. accelerometer, sports participation vs. moderate-to-vigorous physical activity, etc.) and ethnicity (Whites, Blacks, Hispanics). After completion of the Human Genome Project (198), research is now in the early stages of identifying and testing candidate genes for physical activity. The only genome-wide linkage scan for physical activity traits available to date was carried out in the Québec Family Study cohort (199). The scan was based on 432 DNA markers across the human genome (except the sex chromosomes) that were genotyped in 767 individuals from 207 families. Physical activity measures were derived from 3-day activity diaries (total daily activity, inactivity, moderate to strenuous activity), and from a questionnaire used to assess weekly physical activity during the past year. The strongest evidence for the presence of a gene influencing physical inactivity scores was detected on chromosome 2. Suggestive linkages with physical inactivity were also reported with markers on chromosomes 7 and 20. Several regions of the genome were linked with indicators of physical activity, including regions on chromosomes 4, 9, 11,13 and 15.

There is also evidence suggesting that the dopamine D2 receptor gene (200) and melanocortin-4 receptor gene (201) are associated with physical activity in adults. In the only study involving children, Cai et al. (202) found that the percentage time in sedentary, light or moderate activity and total activity counts mapped to markers on chromosome 18, which harbours the melanocortin 4 receptor gene. To date, no studies have specifically examined the association between candidate genes and level of physical activity in children or adolescents.

In light of these findings, it is also conceivable that there are differential levels of environmental and biological control for the various components of physical activity, i.e. spontaneous, obligatory and voluntary physical activity. For example, Carlsson et al. (203) suggested that as participation in organised sport reflects an active choice, the genetic influence on physical activity might be more important today than in the past when participation in obligatory activity was higher. There are several twin studies of self-reported leisure time activity in adults, the largest of which used data from seven European twin registries (204). The authors found heritability estimates ranging from 48% to 71%, with little or no evidence of any shared environment effect.

Nevertheless, estimates of genetic and environmental effects on physical activity generated from adult studies cannot be assumed to generalise to children. There is evidence that the relative contributions of environment and genetics to voluntary physical activity are determined by developmental age, echoing similar findings on age-dependent percentages of heritability of BMI (see section 1.2.2). In a twin-study, Stubbe et al. (205), for example, found that the environment is the major determinant of voluntary physical activity in adolescence, and genetics are the most important determinant in adult life. More specifically, between the ages of 13 and 16 years, environmental factors shared by children from the same family largely account for individual differences in sports participation (78-84%), whereas genes are of no importance. At the age of 17-18 years, genetic influences start to appear (36%), and the role of common environment decreases (47%). After the age of 18 years, genes largely explain individual differences in sports participation (85%), and common environmental factors no longer contribute.

In line with these findings and more pertinent to this review because of the younger age of participants (9-12 years), Fisher et al. (206) assessed physical activity in 234 same-sex twin pairs on three dimensions: objectively-measured physical activity using accelerometry, 'fidgetiness' using a standard psychometric scale, and enjoyment of physical activity from both parent ratings and children's self-reports. Shared environment effects explained the majority (73%) of the variance in objectively measured total physical activity (95% confidence intervals (CI): 0.63-0.81) with a smaller unshared environmental effect (27%; CI: 0.19-0.37) and no significant genetic effect. In contrast, fidgetiness was primarily under genetic control, with additive genetic effects explaining 75% (CI: 62-84%) of the variance, as was parent's report of children's enjoyment of low 74% (CI: 61-82%), medium 80% (CI: 71-86%), and high impact activity (85%; CI: 78-90%), and children's expressed activity preferences (60%, CI: 42-72%). The authors conclude that children’s fidgetiness and enjoyment of activity are under predominantly genetic control, while objectively measured daily physical activity is influenced primarily by the shared environment.

These findings paint a much more differentiated picture, suggesting that the contributions of heritability and shared environment vary according to the type or dimension of physical activity, and developmental age. In general, it can be concluded that the genetic contribution to physical activity shows increasing expression with age, and that the influence of the shared environment is strongest at a young age. This is not only of theoretical interest, but strengthens the case for interventions designed to positively affect physical activity at a developmental stage, i.e. childhood, when the effects of the environment can be expected to be at their largest.

Prenatal environment, epigenetics, and physical activity

As is the case for maternal diet during pregnancy, and the child's birth weight, risk for cardiovascular disease and metabolic syndrome in later life (section 1.2.3) there is emerging evidence, mostly from animal models, that the intrauterine environment can also have an effect on physical activity. Using the model of maternal under-nutrition throughout pregnancy in the rat, Vickers et al. (207) investigated whether prenatal influences lead to alterations in postnatal locomotor behaviour. Rats were mated and randomly assigned to receive food either ad libitum (ad libitum group) or at 30% of ad libitum intake (undernourished group). At weaning, offspring were assigned to one of two diets (control or hypercaloric consisting of 30% fat). At 35 days, 145 days, and 420 days, voluntary locomotor activity in offspring from undernourished mothers was significantly less than offspring born of normal birth weight for all parameters measured, independent of postnatal nutrition. Furthermore, locomotor behaviour in programmed offspring was exacerbated by postnatal hypercaloric nutrition. This work is the first to clearly separate prenatal from postnatal effects and shows that locomotor behaviour may be affected by prenatal conditions. Moreover, the prenatal influence may be permanent as offspring of undernourished mothers were still significantly less active compared with normal offspring at an advanced adult age, even in the presence of a healthy diet throughout postnatal life. To our knowledge, no epidemiological studies have examined the association between in utero environment and physical activity during childhood.

The observed decline in physical activity of offspring born under poor in utero conditions can be explained by epigenetic mechanisms. This phenomena refers to the epigenetic processes involved in the unfolding developmental biology of the organism in which heritable changes in gene function occur without a change in the sequence of nuclear DNA, which includes how environmental factors affecting a parent can result in changes in the way genes are expressed in the offspring (208). In recent years, there has been rapid progress in understanding epigenetic mechanisms that include differences in DNA methylation and chromatin structure. Epigenetic mechanisms have been widely studied in cancer and more investigations are considering the role of epigenetics in complex diseases. Nevertheless, no study has directly related epigenetic models to the study of physical activity, as yet.

Summary

Current studies indicate that the inclination to be physically active or sedentary has a biological foundation. Twin and family studies confirm that physical activity-related traits are characterised by familial aggregation and influenced by genetic factors. Results from animal model studies indicate that single genes, and changes in gene function (e.g. by foetal programming) can markedly influence physical activity-related behaviour. Nevertheless, the genetic contribution to physical activity shows increasing expression with age. This strengthens the case for interventions in young children when the effects of the environment can be expected to be at their largest.

1.3.3 Psychosocial correlates of children's physical activity

The literature describing factors that are associated with physical activity in children, adolescents and adults is large and has been reviewed several times. Sallis, Prochaska and Taylor (191) reviewed about 100 studies of child and adolescent physical activity correlates and summarised semi-quantitative results separately for children (ages 3-12) and adolescents (ages 13-18). Variables that were consistently associated with children's physical activity were sex (male), parental overweight status, physical activity preferences, intention to be active, perceived barriers (inverse), previous physical activity, healthy diet, programme/facility access, and time spent outdoors. Variables that were consistently associated with adolescents' physical activity were sex (male), ethnicity (white), age (inverse), perceived activity competence, intentions, depression (inverse), previous physical activity, community sports, sensation seeking, sedentary after school and on weekends (inverse), parent support, support from others, sibling physical activity, direct help from parents, and opportunities to exercise.

Van der Horst, Paw, Twisk and van Mechelen (192) have provided an updated systematic review of 60 studies published between 1999 and 2005. The results for children aged 4 to 12 years show positive associations between physical activity and gender (boys), self-efficacy, parental physical activity (for boys) and parent support. For adolescents (age range 13-18 years) physical activity correlated positively with gender (boys), parental education, attitude to exercise, self-efficacy, goal orientation/motivation, physical education/school sports, family influences and peer support.

A recent review of studies in pre-school children (i.e. aged 2-5 years) (193) supports some of these findings for this younger age group: boys are more active than girls, children with active parents tend to be more active, and children who spend more time outdoors are more active than those who spend more time indoors.

While these results provide evidence for the importance of a range of social, psychological and biological factors for physical activity in children and adolescents, it is not clear whether they are moderators, mediators or confounders of the observed effects (209). Nevertheless, they can generate hypotheses for further study in longitudinal and intervention designs. The variables showing the most consistent associations with children's physical activity will be discussed in more detail in the following sections.

Parental influence

It is evident from these reviews that parental support plays an important role for physical activity behaviour in children and adolescents. There is strong evidence that children are more likely to be physically active if they have parents who are physically active themselves or if parents organise it for them (210-213). Children with physically active parents are nearly 6 times as likely to be active than children with inactive parents (214), and there is some evidence to suggest a dose-response relationship between number of active parents (0, 1, 2) and children's activity level (215). Timing of such influences is probably important, in that an association between parental and child behaviour can be expected to be much stronger at a younger (e.g. 0-10 years) than at an older age (10-18 years), echoing the increasing independence from parental eating practices in older children and adolescents.

The mechanisms involved in children adopting parents' behaviour are probably the same as outlined for eating behaviour (section 1.2.6), i.e. different forms of associative and observational learning, but also instrumental support. According to Kohl and Hobbs (216), mechanisms of parental influence on children's physical activity can be direct (by providing a supportive, nurturing environment), indirect (through modelling) or, more likely, an interaction of the two.

Using a prospective cohort design Mattocks et al. (217) recently investigated factors in early life (up to age 5 years) that are associated with objectively measured physical activity in 11-12 year olds. Parents' physical activity during pregnancy and early in the child's life showed a modest association with physical activity of the child at age 11-12 years, suggesting that active parents tend to raise active children. The authors conclude that helping parents to increase their physical activity may, therefore, promote children's activity. Ferreira et al. (218) found only associations in studies where father's and mother's physical activity levels were separated from each other: father's physical activity levels emerged as a probable positive correlate (in 52% of the cases), but not the mother's.

Loprinzi and Trost (219) recently evaluated a conceptual model linking parental physical activity orientations (parental physical activity, parental enjoyment of physical activity, perceived importance of child physical activity, parents' perception of their children's physical competence), parental support for their child's physical activity and child physical activity in two settings, at home and in a child care centre. The sample included 156 parent-child dyads; children's age ranged between 2 and 5 years. In partial support of this model, parental physical activity and parents' perception of their child's competence were positively associated with parental support for children's physical activity, which in turn was positively associated with the child's physical activity at home, but not in the child care centre. Regardless of the setting in which physical activity was assessed, parents' perception of their child's competence (to engage in physical activity) was directly positively associated with children's physical activity. This latter result emphasises the need for parents to provide sufficient instrumental and emotional support for physical activity. Because parents' perceptions of their child's competence were positively associated with parental support for physical activity, it may be useful to educate parents that, regardless of their perceptions of ability, all children can benefit from receiving adequate support for physical activity. In addition, the link between parental physical activity and parental support for physical activity suggests that one potentially effective strategy to increase physical activity in preschool children may be through promotion of physical activity in parents.

The most recent systematic review of studies examining parental influences on physical activity in children (220) identified 96 studies, the majority of which (n=55) investigated adolescents (12-18 years old), and 33 studies investigating children (6-11 years old). In children parents played an important role in moderate-to-vigorous physical activity, overall physical activity and leisure-time physical activity through direct involvement and being active role models. In organised physical activity a combination of parental activities were most successful, e.g. modelling, transport and encouragement. For adolescents, parental influence was clear. Nevertheless, parents' physical activity level, their attitudes towards physical activity, transport and encouragement were all significantly associated with adolescents' physical activity. Results from the longitudinal studies identified in this review (n=9) demonstrated that overall support predicted children's organised physical activity over time and father's physical activity predicted adolescents' overall physical activity. The latter result is in line with Ferreira et al.'s (218) finding of the greater influence of fathers' physical activity.

In summary, the findings reported here support the view that parents need to be involved in their child's physical activity in a variety of ways if their child is to lead an active lifestyle. The results from longitudinal studies, although limited in number as of today, demonstrate in agreement with cross-sectional studies that the overall physical activity support provided by parents predicts children's organised physical activity, and that fathers' physical activity predicts overall physical activity in adolescents. In conclusion, programmes designed to increase physical activity levels in children and adolescents should promote the importance of physical activity to parents, especially to fathers, and encourage them to increase their own physical activity level.

Peer influence

Despite the emerging picture on the importance of parental support for children's physical activity, a number of issues remain unresolved. For example, studies have mainly investigated positive role modelling of parents, while a small number of studies highlight the importance of peers, especially for older children or adolescents. Springer et al. (221) found friend physical activity participation and friend and family encouragement to be positively related to moderate-to-vigorous physical activity in 10-14 year old girls. Friend encouragement was the only variable positively related to vigorous physical activity. This is in line with results from our own studies (222, 223) in that we found perceived support for and participation in physical activity by peers to predict objectively measured physical activity (pedometer) in 9-11 year olds. Interestingly, peers did not affect dietary behaviour. Another interesting finding from these studies points to the importance of psychological factors: those youngsters who felt more accepted by their peers also took part in significantly more physical activity with friends.

Psychological factors

Psychological factors, in particular perceived self-efficacy, have been consistently shown to be associated with physical activity in children and adolescents. Perceived self-efficacy (derived from social-learning theory) (133) describes a personal belief that one can successfully perform certain required behaviours, in particular in demanding situations with unfamiliar and difficult characteristics (see section 1.2.7). In relation to physical activity, for example, such cognition could be “When I am asked to play football I can do it“. In addition to helping to develop and maintain healthy levels of physical activity, increasing young peoples' self-efficacy might help adolescents and – later on in life – adults to be more resilient to the potentially damaging effect of “bad” (i.e. discouraging from physical activity) behavioural models. An example of how reduced perceived self-efficacy impacts negatively on physical activity in children is provided by Faith et al. (224). They found that children who are the targets of weight criticism by family or peers have negative attitudes towards sport (e.g. self-efficacy) and report reduced physical activity levels. The authors conclude that it may be useful for interventions to identify such psychological barriers to physical activity, in particular obese children and adolescents. In a community sample of 376 fifth- and sixth-grade students (mean age 10.8 years) Jensen and Steele (225) investigated the associations between physical activity, weight criticism during physical activity, and body dissatisfaction. Girls who reported experiencing high levels of weight criticism and high body dissatisfaction engaged in significantly fewer vigorous activities than girls who experienced criticism in the absence of body dissatisfaction. These results were not evident among boys. These results are important as they suggest that low perceived self-efficacy and high body dissatisfaction could act as mediators between weight status and physical activity level. Moreover, this effect seems to be sex specific.

Nevertheless, it should be noted that these results pertain to an older age group than pre-schoolers, and as discussed in section 1.2.7, these psychological factors require a level of self-awareness and self-regulation at a cognitive level that is unlikely to be present in young children. Consistent with this hypothesis is the fact that perceived self-efficacy has been primarily shown to affect physical activity behaviour in older but not younger children (191-193). While these results are probably important for the design of more successful interventions for older children and adolescents, they are unlikely to be at the core of successful programmes for pre-school children.

1.3.4 Environment

In addition to the biological and psychological factors discussed in the previous sections, there is an emerging literature on the importance of the social, physical and policy-level environmental influences on children's physical activity (see 218, 226, 227 for reviews).

Children's motivation to be physically active, preferences in physical activity, and perceived barriers that prevent them from being physically active are likely to be reciprocally related to their perceived living environment (228). The perceived living environment may, therefore, directly affect their active or sedentary behaviour choices and opportunities. The living environment includes social influences (family and friends, school teachers, neighbours etc.), the built and natural environment (e.g. playgrounds and public open spaces, topography, streetscapes, physical activity and sports facilities) and also policies and rules that may promote or restrict physical activity. For example, schools may have rules about where children can or cannot play and run in the school grounds, or a local community may have a policy regarding the provision of bicycle paths.

The childcare centre or kindergarten and the playground within these environments constitute an important part of the living environment for young children. These environments have been the focus of correlational and interventions studies, and are, therefore, discussed in detail in the review on educational strategies (4.1.2). In the following we will give a brief overview of the literature on the effects of general aspects of the physical environment, road safety and neighbourhood on children's physical activity.

Influence of the physical environment

The changes that have occurred in urbanization over the past three decades can be characterised by a global rise in population living in urban areas (229): City sprawl and densification have led to an economical use of available space and the number of places dedicated to physical activity such as green areas has decreased. There are, however, important geographical differences between the percentages of each population that has access to green spaces within 15 minutes. For example, in Amsterdam, the percentage is 63%, in Bratislava 40% and in Warsaw it is 36% (230).

Krahnstoever Davison and Lawson (227) reviewed 33 quantitative studies that assessed associations between the physical environment (perceived or objectively measured) and physical activity in children (ages 3 to 18 years). They discussed their findings according to three dimensions of the physical environment: recreational infrastructure, transport infrastructure, and local conditions. The results showed that children's participation in physical activity is positively associated with publicly provided recreational infrastructure (access to recreational facilities and schools) and transport infrastructure (presence of sidewalks and controlled intersections, access to destinations and public transportation). At the same time, transport infrastructure (number of roads to cross and traffic density/speed) and local conditions (crime, area deprivation) are negatively associated with children's participation in physical activity.

Local transport infrastructure

Increasing manual locomotion is viewed as a promising intervention strategy to raise moderate physical activity levels of children and parents in their daily life. Research from the WHO showed that the average distance walked by English children aged 14 years and younger fell by 20% between 1985 and 1992 and that the average cycled distance reduced by 26%. At the same time, average distance travelled by car increased by 40% (229). According to the British Medical Association there has been a decrease in the percentage of primary school children walking to school from 63% in 1992/94 to 54% in 1999/2001. The fact that half of the trips made by car are shorter than five kilometres and could be done by foot or by bicycle highlights the possibility of intervention in this field (231). Nevertheless, active transport needs the presence of infrastructure for children: for instance, neighbourhoods with a greater proportion of park areas were associated with greater physical activity in children (232). In this study (232) 32 boys and 27 girls (age 4 to 7 years) wore accelerometers for 3 weekdays and 1 weekend day. A geographic information system was used to measure neighbourhood environment variables. The results of hierarchical regression analyses showed that neighbourhoods with increased proximity between homes and a greater proportion of park area are associated with greater physical activity in young children.

Safety concerns

Compared to previous generations, children now have greater restrictions placed on their ability to travel without an adult (233). Concerns for the safety of children have led to increased surveillance of children's activities, a shift from unstructured to structured play activities, and greater levels of "chauffeuring" to destinations. All of these factors have been associated with the currently observed decline in physical activity in children. These changes are assumed to be driven by fears for children's safety and the threat that they might be exposed to by strangers and traffic. Associated with this scenario is a change in parental attitudes where chauffeuring and close supervision of activities is considered good parenting practice (234).

The available evidence (as reviewed in 226) suggests that low levels of active transport and physical activity in children are associated with lack of perceived neighbourhood safety. As is the case for the majority of studies discussed in this review, studies demonstrating this association are mostly cross-sectional, and causality can, therefore, not be inferred. Many studies have investigated perception of safety rather than objective measures. In summary these studies show that perceived road safety and threat posed by strangers ("stranger danger") are major causes of parental anxiety in relation to their children's safety in the neighbourhood. The evidence available suggests that parent' views rather than children's are stronger influences on children's physical activity, including independent free play and active transport within the neighbourhood. It is unclear at this stage whether objectively measured road safety has more impact on children's physical activity than perceptions of road safety or "stranger danger".

In a recent study (235) Carver et al. examined parental restriction of children's active transport and physical activity outside school hours due to safety concerns, and how this restriction was associated with perceived risk and with youth physical activity levels. Walking/cycling to local destinations was survey-reported. Moderate-to-vigorous physical activity (MVPA) was recorded during non-school hours using accelerometers. Using surveys, parents reported perceived risk of their children being harmed in their neighbourhood, and restrictions they placed on their children's physical activity. Using linear regression analyses the results showed that perceived risk did not vary by age group and was positively associated with constrained behaviour among adolescents but not children. Children were subject to higher levels of constrained behaviour than adolescents. Constrained behaviour was negatively associated with active transport among younger boys and among girls in both age groups. Furthermore, it was negatively associated with younger boys' MVPA on weekends and with adolescent girls' MVPA during evenings. There were no associations between constrained behaviour and active transport or MVPA among adolescent boys. The findings demonstrate that constrained behaviour exhibited by parents may result in lower levels of active transport and of MVPA outside school hours. In particular, this was true for children and adolescent girls. The authors conclude that social interventions to improve perceived safety and physical interventions involving redesign of the built environment to improve actual safety may help to ease parental restriction of their children's active transport and physical activity in their neighbourhood.

As opposed to the restrictive effects of perceived safety issues, positive social interactions have been demonstrated to be conducive to children's physical activity. A range of aspects of social connectedness (e.g. child visits with peers, neighbourhood relationships, other children living in the neighbourhood) are associated with Italian's children independent mobility (236) and Australian youth walking and cycling in the neighbourhood (237). These results suggest that children living nearby, and trust and familiarity between neighbours can moderate parents' perceptions of safety issues.

1.3.5 Conclusions

Preschool children's activity patterns differ from those of older children and adolescents in that young children's physical activity patterns do not usually occur as a planned, structured activity, but rather as short bursts of vigorous activity that are followed by less-intense recovery periods. Nevertheless, such activity is essential for normal growth, maturation and development of motor skills and physical efficacy in young children.

There is a variety of evidence that variation in the inclination to be physically active or sedentary has a genetic basis, including interactions between genes and environment before birth. Nevertheless, the genetic contribution to physical activity shows increasing expression with age, perhaps in part due to convergence of environmental influences. This strengthens the case for interventions in young children when the effects of environmental modifications can be expected to be at their largest.

Predictors of activity in pre-school children include the findings that boys are more active than girls, children with active parents tend to be more active, and children who spend more time outdoors are more active than those who spend more time indoors.

Modelling by parents is likely to be very influential on children’s activity, as it is for eating. Overall physical activity support provided by parents predicts children’s organised physical activity, and fathers’ physical activity predicts overall physical activity in adolescents. Therefore, programmes designed to increase physical activity levels in children should promote the importance of physical activity to parents, especially to fathers, and encourage them to increase their own physical activity level.

Peers are also important, especially for slightly older children: Youngsters who feel more accepted by their peers also take part in more physical activity with friends, presumably by increasing their own self-efficacy. Conversely, overweight and obese children (especially girls) are unlikely to be physically active if they experience low perceived self-efficacy and high body dissatisfaction. This finding, however, pertains more to older children (> 8 years).

Perceived road safety and threat posed by strangers (“stranger danger”) are major causes of parental anxiety in relation to their children’s safety in the neighbourhood. Parent’ views rather than children’s are stronger influences on children’s physical activity, including independent free play and active transport within the neighbourhood. Social interventions to improve perceived safety and physical interventions involving redesign of the built environment to improve actual safety may help to ease parental restriction of their children's active transport and physical activity in their neighbourhood.

Table 1: Influences on development of young children's eating behaviour and their key stages

Developmental stage of influence				
Prenatal / *in utero*	Pre-weaning (0-6 months)	Post-weaning (6-9 months)	Post-weaning (9-18 months)	Early years
Genetic	Genetic	Genetic, innate likes/dislikes	Genetic, innate likes/dislikes	Genetic, Food Neophobia
Mother's diet[a]	Mother's diet[b]	Food texture exposure	Parental feeding practices	Parental feeding practices
	Extent of breast or formula feeding	Extent of breast or formula feeding	Parents' eating behaviour	Parents' eating behaviour
	Complementary feeding	Complementary feeding	Siblings' eating behaviour	Siblings' eating behaviour
			Parenting style	Parenting style
	Family food environment	Family food environment	Family food environment	Family food environment
			Carer/teacher modelling	Carer/teacher modelling

[a]Via both programming of foetal development and exposure to flavours and nutrients via amniotic fluid and placental blood.

[b]Via flavours transferring to breast milk from foods eaten

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4.1.2. Conduct a literature search of evidence for the effectiveness of educational strategies (e.g. number of exposures to food, methods of encouragement) practised by parents, teachers and health professionals in order to manage young children's energy balance related behaviours.

Executive summary and recommendations

Eating Behaviour

- Exposing children to brief tastes (not just sight and smell) of novel foods, in a positive social context, will encourage consumption of those foods. Success may depend on at least 5, perhaps 10 exposures, but the effect may be more rapid and more likely to generalise to other foods in very young children.
- Pairing bitter vegetable tastes with sweetness may encourage acceptance.
- Merely providing information to parents about encouraging healthy eating in children, or indeed telling children that a food is good for them, is unlikely to be productive.
- Using rewards to encourage eating of unfamiliar healthy foods can increase eating of such foods whilst the reward contingency is in place, but may impair liking of such foods once the reward is withdrawn. However, this negative effect is probably short-lived, and longer-term benefits of rewards on fruit or vegetable intake have been found, particularly where the reward is not another food and is promised but not given immediately after eating the target food.
- Restricting access to food, as a parental strategy, is likely to enhance children's desire for that food, provided the food is palatable (inherently desirable). However, for less desirable foods, such as fruit or vegetables, a restriction strategy is unlikely to have much impact on appetite for that food, and could confuse children with mixed messages. Parental strategies that use neither excessive restriction nor lack of restriction are likely to be of most benefit.
- Entertaining presentation techniques can encourage acceptance of otherwise relatively unattractive food such as some fruit or vegetables.
- Children should be allowed to learn to regulate their own meal sizes, by avoiding emphasis on external controls of eating, or distraction by external events. Portion sizes should be responsive to individual children's needs. However, serving larger portions of vegetables as a first course to hungry children may be an effective strategy to increase their intake of vegetables (or fruit).

- Positive social modelling of eating, by teachers, parents and especially peers, whether live or on video, can encourage healthy eating in young children. However, positive modelling may well be in competition with negative modelling by uninstructed peers, and any benefits of modelling may not generalise to foods of notably differing appearance, even if in the same food group.

Physical activity

- Structured opportunities for physical activity are the central part for interventions to promote physical activity.
- 60 minutes a day of structured physical activity are recommended for young children.
- Most reviewed structured interventions lasted 30 to 45 minutes, however, also 10-minutes-sessions several times a day may be enough to yield positive results, with the short time being nearer to children's natural activity pattern.
- Enough outdoor space and portable play equipment like balls stimulate more physical activity than fixed play equipment or playground markings.
- Environmental changes may be substantial only in multi-level interventions.
- Unstructured free play does not lead to more physical activity; however, it is vital to children's overalls development.
- Integrating opportunities for physical activity within existing preschool curricula may be a feasible approach to oblige to the many demands during a child care day.
- Thorough training and qualification of staff is a key element in promoting children's activity.
- An intervention should unfold an impact on all levels of the preschool: children, parents/family, environment, and teachers.

2. Scope of the review: Effectiveness of educational strategies to manage young children's energy balance related behaviours.

This part of the review will examine studies of eating behaviour and physical activity in children aged 4 to 6 years that provide evidence for the effectiveness of strategies used by parents/carers, teachers and health professionals to promote healthy energy-balance related behaviour.

2.1 Eating behaviour

2.1.1 Methods

This section is a critical narrative review of experimental evidence that included use of 4 to 6 year-old children as participants. Studies were located by searching English-language databases including Pubmed, Web of Knowledge, PsychINFO and Scopus. Citation paths within these databases were also used, as well as citations in reviews. In addition, leading groups in the field were contacted for information on relevant in-press material. Key terms included: child* with preschool, eat*, food, diet, food choice, preference, like, liking, acceptance, intake, satiety, appetite, exposure, reward, model*, parent*, feeding, strategy, fruit, vegetable, restrict*, portion, means-end.

Birch and Ventura recently reviewed the issue of what works in preventing childhood obesity (1). They listed both the risk factors identified by epidemiological research, and the strategies that have been evidenced to improve eating and weight risk. Extracting risk factors that are relevant to preschool children from their review, the following outcomes will be considered here: energy density of the diet (largely a fat/water trade-off), fruit and vegetable intake, unhealthy snacking, sugar-sweetened drink intake, portion size.

The list of preventative practices provided by Birch and Ventura is reproduced below (1, Table 2):

1. Promote breastfeeding to reduce obesity risk, provide 'flavour bridge' experience with flavours of maternal diet
2. Offer healthy foods and use repeated exposure to promote acceptance
3. Provide guidance on age appropriate portion sizes, energy density of foods
4. Discourage the use of restrictive feeding practices
5. Discourage the use of coercive feeding practices
6. Find ways to reduce energy density of foods
7. Provide guidance on responsive feeding, recognizing hunger and fullness,

setting limits, sharing feeding responsibilities with children

8. Promote 'do as I do' not 'do as I say': parents [or respected others] as positive models of eating

The evidence for strategies that may contribute to these approaches will be considered, where available for the target age group, with exception of point 1, as breastfeeding is not relevant to interventions in 4-6 year-old children.

2.1.2 Promoting acceptance of healthy foods by repeated exposure

Birch (2) studied the effect of 7 days of repeated tasting of a novel food (dates) on change in ranked preference for the group exposed to the food versus that for the unexposed group, in 37 3-4 year-old boys and girls (white). The preference for the novel food did not change significantly after exposure. For this early study, it was not clear what caused the lack of effect: it could be due to issues of amount of exposure, baseline preference, or visual appearance of the novel food for example.

Birch and Marlin (3) addressed the question of frequency of exposure, in a study of taste exposure in 14 2-3 year-olds (white boys and girls). The children were asked to taste new fruits or cheeses on 0, 2, 5, 10, 15 or 20 occasions: between 5 and 10 taste exposures were needed to see an increased preference for the new food (forced choice preference ranking).

Birch, McPhee et al. (4) studied whether such exposure to novel foods could increase preference if the food was merely seen and smelt but not tasted. Forty-three 2-6 year-old white boys were exposed to novel fruits (mainly canned or dried, so very sweet). Each child was exposed to 3 foods in each of the two sensory conditions (tasted or not), with one food exposed 5 times, one for 10 and the other for 15 times. Another food remained novel. When tasting, swallowing was not compulsory, but usually happened. On days after exposure, children had to choose between pairs of fruit (all combinations) on the basis of whether they (a) looked and (b) tasted best. From as little as 5 exposures, taste improved the preference for both the taste and the look of the fruit versus the unexposed fruit, whereas visual exposure only improved liking for the look of the fruit, not the taste. Moreover, by 15 exposures, tasting improved liking to a greater extent than looking, for within-modality responses.

Two more recent studies capitalised on the ability of taste exposures to increase acceptance, in designing interventions to improve liking and intake for novel, and somewhat disliked, vegetables. In the first study (5), on 49 5-7 year-olds, an exposure-only group tasted a sweet red pepper on 8 days over 2 weeks, at school, and was assessed for liking and intake before and after exposure, as well as at each session. A second group was offered a cartoon sticker as a reward for eating “at least one piece” of the pepper (except on test days), while a third group did not receive any exposure sessions, other than the first and last test sessions. Both exposure groups showed increased liking, although intake only rose significantly for the exposure-only group, compared to the unexposed group. In both exposure groups, increases in liking and intake reached a peak by 6 exposures. However, for intake, this peak was significantly lower for the reward group. The less effective change in intake in the reward group suggests the possibility that using a reward might partially devalue the rewarded food; another possibility is that it distracted attention from the tasting. This question is discussed in Section 2.1.3 on reward strategies below.

The second intervention from this group was designed to be carried out by parents at home (6): 156 parents of 2-6 year-old boys and girls were randomly assigned to Exposure, Information or Control groups after a pre-intervention taste test at which a 'target' vegetable was selected – 143 of their children completed the protocol. Intake, liking, and preference ranking was assessed before and after 14 days of intervention. For the Exposure group, the parent was asked to child offer their child a taste of the moderately disliked target vegetable once a day for 14 consecutive days. Advice was given about modelling and encouragement, engagement in preparation, etc., so that this was not a strictly ‘mere’ exposure condition. The Information group received leaflets with advice on how to increase fruit and vegetable consumption in children, but no tasting was required. The Control group were offered such advice only after completing the intervention. Only the Exposure group showed improvements in acceptance of the vegetable over all three measures. Interestingly, the worst effect was in the Information group: the authors speculated that providing just more information to already motivated parents may have been disappointing, and could also have intensified concern and parental pressure on their children, resulting in relatively adverse effects.

Havermans and Jansen (7) extended this sort of research by applying flavour-flavour learning to encourage a liking for vegetable flavours presented as purée drinks, in 13 4-5 year-old children. Target flavours were selected as those ranked 3 and 4 out of 6 flavours. During conditioning trials, one target flavour was sweetened with 20-g d-glucose, whereas the other was unsweetened. Children were asked to sip and swallow both flavours 3 times (separated by 5 mins) on each of 2 consecutive days. Before and after these conditioning trials, they ranked the unsweetened target flavours among a total of 6 flavours, to provide the preference measure. Ranked preference increased significantly for the sweetness-paired flavour, whereas the unsweetened flavour preference did not change. This lack of change suggests that the children did not taste the unsweetened flavour sufficiently frequently to produce any benefit from mere exposure. By comparison, it has been observed in young children with severe fussy eating problems that some novel foods may be accepted after far fewer than 10-15 exposures (8): possibly, once a child has learnt that novel foods can taste good and be safe, they become more ready to try others. However, compelling children to taste novel foods can be counterproductive (9).

Moderation by messages

One study revealed how sensitive attempts to encourage young children to eat novel foods can be to the information provided. Pelchat and Pliner (10) presented 40 3-8 year-old children with a novel cheese or a novel rice-like buckwheat side dish. They were asked either "Would you like to try it?" or "Would you like to try it? It tastes good!". Six to eight year-olds were much more likely to try either food than 3-5 year-olds, but taste information didn't affect this overall. However, the type of food made a difference: for the more popular novel cheese, emphasising that it tasted good actually reduced willingness to try it, whereas the reverse was true for the cereal. The authors suggest that the cheese looked like candy to the children, so was tempting to try, but stressing its good taste may have made children suspicious, so less willing to try.

However, positive messages can be effective: a study of the impact of positive messages about a novel vegetable, kohlrabi, contained in a children's story book, in 118 3-5 year-olds, showed a beneficial effect on willingness to try the vegetable, compared to a group receiving negative messages, after 2 reading sessions (11).

2.1.3 Rewarding eating: evidence for benefits and drawbacks

Results of the study by Wardle et al. (5) encouraging children to eat more sweet red pepper indicated that giving a sticker reward for trying the target food may weaken the benefit from repeated exposure. It has been argued previously that this could represent an 'overjustification' effect, whereby the value of the food, or the intrinsic motivation to consume it, is degraded by becoming the means to an end, i.e. the reward, which may be more immediately or inherently desirable (12, 13). Nevertheless, parents often claim success in using overt reward strategies of this sort (14). The evidence for positive, negative or neutral effects of differing reward strategies is now considered.

Birch, Zimmerman and Hind (15) compared the effects of treating a food as a reward versus receiving positive attention from an adult when eating the target food, in 64 3-5 year-old boys and girls. Preference for the target food increased in both conditions and was present at a

6-week follow-up. By contrast, Birch et al. (16) studied liking for fruit drinks in 12 3-4 year old boys and girls, when their consumption was instrumentally rewarded with a play activity of each child's choice on six occasions, in a laboratory setting. The children were asked to drink a flavour that was among their middle preferences when ranked. Liking for the rewarded drink was reduced.

Birch and colleagues were concerned that one reason for the above negative effect on liking was the requirement that the children should drink more than they did at baseline, during the rewarded phase. The sterile setting may also have been an issue. These points were addressed by Birch et al. (12) in a new design, set at preschool, for which 45 3-5 year-old boys and girls were recruited. The outcome of interest was liking for a target (neither liked nor disliked) flavour of milk drink. There were two reward conditions, verbal praise or a tangible reward (film ticket, followed by viewing a 10-min film). Within each of these, there were two drink intake conditions, either drinking *ad libitum* approximately the amount drunk at baseline, or being asked to drink a bit more (50 ml): thus there were 4 experimental conditions. There were also two control conditions in which the children drank their flavoured milk either before or after seeing the film, but without any suggestion of a reward contingency. After training, liking for the milk flavour decreased in all the experimental conditions, with no difference between them, whereas liking showed a slight increase for the control conditions. These findings are rather disturbing, as they show that even the social reward of verbal praise, whilst being able to increase consumption at the time, nevertheless results in reduced liking when the contingency was absent.

In a complex, and somewhat underpowered study, Stark et al. (17) reported using a combination of techniques to encourage healthier snacking in preschool children in a nursery setting, i.e. teaching healthy/unhealthy colour coding of snacks (red = bad, green = good), teaching children to 'cue' their choice with self-declarations as to whether the snack is good for them, and rewarding this cueing with stickers. The study also involved monitoring of snacking behaviour at home. In the first experiment, eight 3-4 year-olds were trained in the colour coding of biscuit and crisps (red) versus fruits and vegetables (green), and the nutritional benefit or otherwise of various snacks using pictures - praise was given for healthy choices. Subsequently, when selecting snacks to eat, appropriate 'cueing' by children was rewarded using the stickers. In total, this training continued for about 4 weeks, followed by a phase when this reward procedure was continued at home, and stickers were given for reported eating of 'green' snacks. Maintenance of healthy snack choice was then assessed over 9 days, after training had ended: all 7 children who completed the training consistently chose the healthy snacks over this brief period.

A second experiment was conducted by Stark et al. with nine 2-5 year-olds, to examine longer maintenance, and in the absence of verbal 'cueing': the procedure was similar except that the 'cueing' reinforcement was never used, just training on the nutritional value of different snacks, where correct choice and justification was rewarded with a sticker. Training was ended once children reliably chose the healthy snacks at the nursery (varying from 10 days to 6 weeks). During the maintenance phase, healthy snacks dominated the children's choices at nursery for 4-7 weeks, after which there was in general a return to preferring unhealthy snacks, even though some children received brief retraining. Home observations in 5 children showed a similar but somewhat less successful pattern. These findings suggest that reward was able to sustain but not maintain healthy snacking, although there was considerable variation across the children.

The concern that means-end, or 'if-then', contingencies could lead to devaluing of the 'means' behaviour (or intrinsic motivation) or food led to a series of three experiments using if-then contingencies to manipulate children's eating (13). In the first experiment (42 4-7 year-olds), six different moderately sweet and familiar foods were used (yoghurt, sweet crispy bread, carrot, apple, cheese, hazelnut). Children in the if-then conditions were told that, if they ate food X, they could have some of food Y, with foods counterbalanced for X and Y. Control children were merely offered X then Y, matching sequence with the other conditions. The foods were chosen for each child to be of middle preference. Three such sessions were given, on separate days. Liking for all foods was assessed a few days later and after 6 weeks, when a final choice test was also given. Both liking and choice increased for the 'then' (2^{nd}) food, whereas liking for the 'if' food decreased immediately, but returned to baseline at 6 weeks. These results support Birch's earlier findings that 'reward' foods become more liked (2), but were not unequivocal support for devaluing of foods seen as means to an end, given that the value was at baseline by 6 weeks.

A second experiment (44 3-6 year-olds) increased the training sessions from 3 to 6, and used somewhat disliked foods as the 'then'/end 'reward' foods, and middle preference foods as the 'if' foods. One control group received this sequence but without an explicit if-then explanation; the other received both foods simultaneously ("You can have both snacks"). Although there was a relative improvement in liking for the second, initially disliked foods, there was not a significant difference between if-then conditions and the control groups, so simple familiarity could be the cause. Liking of foods in the 'if' or 'means' position remained stable.

A third experiment tested whether using novel foods versus familiar foods altered any if-then contingency effect on liking (56 girls and boys aged 3-6 years). Papaya was the novel food and apple the familiar one, as both were rated with middle preference out of 6 fruits. The novel papaya was the ‘if’ food for one group and the ‘then’ food for another. Control groups followed the sequence without any contingency explanation. Only one training session was used. Although papaya was less liked compared to apple, there was evidence for an if-then effect independently of the novelty or familiarity of the fruit. This suggests that attempts to encourage eating of new foods should avoid using the food as a means to an end by rewarding with a familiar food, and instead consider using the reverse contingency. Mikula (13) argued that overall the findings suggest that repeated ‘if –then’ experiences with the same foods will lose their impact, as expectations are modified. That is, children learn that ‘if-then’ contingencies mean that the ‘if’ event will be less pleasant than the ‘then’ event, and they bring these expectations to any subsequent such contingencies (13, 18, 19). But, with familiarity, the expectations can change.

A similar study was carried out by Newman and Taylor, on 86 4-7 year-old children, using snack foods of moderate appeal. There were 3 conditions: means-end (if-then) contingency where one snack rewarded eating another; temporal sequence control, in which both snacks were eaten sequentially to match the sequence used in the means-end condition, but with no mention of any means-end requirement; a mere exposure condition, similar to the temporal control, except that the order was chosen by the child. There was only one trial for each condition. The results showed that liking (preference ranking) was reduced for the first snack eaten in the means-end condition, but not in the other conditions. There was little evidence for an increase in liking for the snack that acted as a reward. These findings support those of Birch and colleagues, but are somewhat different from those of Mikula (13). It is notable that this latter study was not cited by these authors.

Hendy (20) applied these principles, as well as a modelling strategy, via teachers in a nursery setting, in 64 3-5 year-olds. Four new fruits and vegetables were placed on children’s group tables at lunchtime on 3 days, with the following five contexts: (a) mere exposure – apart from briefly answering children’s questions, no further action was taken by the teacher after placing the fruit and vegetables (b) modelling – teachers ate each of the new foods and said “I like to try new fruit” (c) reward - teachers said twice, "If you try two of these new foods with at least one bite, you can have a special dessert. If you try all of these new foods, you can also have candy to take home for later." The desserts were a frozen fruit-juice bar or chocolate-covered ice cream; the candies were fruit-flavour gums or a chocolate bar (d) insist/try one bite – each child was given a piece of each new food and told “Please try one bite of each new food?”, but was not forced to eat it (e) choice-offering – teachers said twice during the meal to each child, for each food, “Do you want any of this?”;

a small amount was offered if they said yes. Observers recorded the number of bites made for each food, from which the dependent variables were formed.

For both the number of new foods sampled and the number of meals during which at least one new food was sampled, reward, insist and choice strategies all had higher scores than the exposure control, but modelling was not significantly greater. This was also true for total number of bites across all meals, but choice was most effective, followed by reward then insist. Modelling (albeit rather neutral) did not perform better than exposure: this seems quite surprising, and is discussed further below when other modelling strategies are examined. It may be encouraging that the means-end reward strategy increased acceptance of the new foods, but it should be remembered that is was while the contingency was operating – there was no assessment of liking at a later stage. In fact, there was evidence that sampling was highest for the first lunch, which might suggest deterioration in acceptance over trials.

Despite the concerns about using rewards to encourage healthy eating, Hendy, Williams and Camise (21) reported a successful intervention using reward to increase fruit and vegetable acceptance, in 188 6-9 year-old children ("Kids Choice Program"). The authors were sensitive to the possibility of the 'overjustification' effects of using reward, but argued that this risk could be reduced by using small and delayed reinforcement, avoidance of (sensory-specific) satiation effects by offering food choice and requiring that only a small amount of food be eaten to receive reinforcement, and including conditions that encourage peer participation and modelling. At baseline and during the intervention lunches, fruit and vegetable intakes were monitored; also at baseline and afterwards at 2 weeks and 7 months later, fruit and vegetable preferences were assessed by interviewing the children; parents also answered a questionnaire on their children's fruit and vegetable preferences.

Children were rewarded for either fruit or vegetable intake over 18 meals. Admired peers were trained to introduce the process of reward to the children. Children were told that each day they ate fruit (or vegetables) during school lunch the research team would punch one hole in their plastic nametag necklace. They were also told that once a week they would have a Reward Day when they could trade in three holes in their nametags for a small prize of their choice (a 'cancel' hole indicated that the trade had been made). To gain a hole, they had to eat at least 1/8 cup of the target food. The intervention was successful in increasing trying of fruit when fruit was reinforced, but not vegetables, and vice-versa when vegetables were rewarded. Reported preferences 2 weeks later also increased for the rewarded food, with somewhat stronger results for fruit than vegetables. However, at 7 months, these preferences did not differ from baseline. This loss of effect might be due to an insufficient number of reinforced exposures to the target foods, and/or continued competition with more intrinsically rewarding foods experienced over that time, but probably not due to a negative effect of reward, given the positive results at 2 weeks.

Secondary analyses of the Kids Choice Program data have also shown that both normal-weight and overweight children benefit equally from the programme (22), and that fussy-eating children can show improved acceptance of fruit and vegetables (23).

Another programme that combines both peer modelling and reward is the "Food Dudes" intervention. This involves primary school children (age 4-11 years) watching bespoke video films of heroic peers who gain power over their enemies by eating (and enjoying) fruits and vegetables. The children also gain small rewards for eating fruits and vegetables themselves that were provided for free during the intervention. Video exposure lasted for 16 days, after which rewards were tailed off. In one setting (24), fruit and vegetable intake increased on weekdays in school and at home during the intervention, and liking was increased after the intervention. In another setting (25), compared to a control school, parents of children at the intervention school were including more fruit and vegetables in the children's lunchboxes that pre-intervention, even 1 year post-intervention. Although it is not clear what aspects of the intervention may be critical, the results are encouraging.

There remains also the problem that Birch et al. (12) found a negative impact of verbal praise. This issue has recently been addressed in a large study ("Eat Your Greens") of 450 4-6 year-old children in South London, examining the impact of rewards on their vegetable liking and intake (26). There were four conditions: no treatment control; exposure plus tangible reward (stickers for tasting), exposure plus verbal praise for tasting, and mere exposure, i.e. repeated tasting without reward. A moderately disliked vegetable was chosen for each child, who was then given 12 days' exposure to one of the conditions (or nothing for control). Liking and intake were measured at baseline and at 1, 30 and 90 days after the intervention. At 1 and 30 days post-intervention, the sticker reward group showed the biggest improvement in intake, followed by the praise reward group, and both were superior to exposure only or control. These two reward groups produced equal improvements in liking, although the exposure only group also successfully increased liking. Ninety days later, ranked preferences remained higher for these treatment groups compared to control, and increased intake was maintained best for the sticker reward group. These results are encouraging, and refute previous findings showing negative effects of reward, both tangible and verbal, usually on liking.

2.1.4 Use of restriction and control: is it all negative?

As discussed in Section 4.1.1., restrictive and controlling parental feeding practices are associated with increased risk of weight gain, and eating in the absence of hunger, in young children (27-29). Direct experimental evidence relating to these concerns is now considered.

In the first investigation as to whether restriction of palatable foods to children might enhance their desire for them, two experiments were run (30). In the first, 31 3–5-year-old children participated in twice weekly sessions for 5 weeks. At each 20-min session, children had free access to a bland control food (wheat crackers), but had to wait 10 mins for a bell to signal access to the palatable food (fish-shaped crackers) for 2 mins, after which it was removed. In the second experiment, 37 3-6 year-old children took part on 4 days per week over two weeks. This time children experienced both 4 unrestricted snack sessions, where both foods were present, and 4 restricted sessions where the restricted palatable food was only available for the middle 5 mins of a 15 min session, again signalled by a bell.

Results of the first experiment revealed a substantial increase in desire for the restricted food as observed during the procedure. However, 3 weeks later, there was no indication of a difference between the foods (appetite for both had declined). Results were similar for the second experiment, and extended to actual intake (but delayed measures were not reported). These effects were also positively related to the mothers' restriction of the palatable foods at home.

Jansen et al. (31) designed a study to answer the question whether restriction could bias desire for a food if it was no more palatable than the unrestricted food, in 74 5-6 year-old children. To achieve this, they used M&M chocolates (sweet) and crisps (salty), each in two colours, red or yellow. In phase one, there was a control group who could eat ad libitum from either colour food, and a prohibition group who was told not to eat the red food. This resulted in a greater desire for the red restricted food in that group. In the second phase, all children were allowed to eat either colour of food. Previously prohibited children ate more of the red 'forbidden' food. The study also found that the children least affected by restriction were those whose parents normally apply moderate restriction at home, whereas children experiencing either high or low restriction at home both ate more energy overall. This benefit of moderate restriction echoes findings in older children that parental control can benefit fruit and vegetable consumption in their children (32). The design used by Jansen et al. (31), where the restricted food only differed from the unrestricted in terms of colour, eliminated the possibility that restriction enhances desire through sensory dishabituation or removal of sensory specific satiety.

Interestingly, a recent experimental study from the same group, in 70 5-7 year-old children, suggests that careful use of restriction of a healthy (but less palatable) food such as fruit might help to encourage its consumption (33). Two groups of children were forbidden to eat fruits and sweets, respectively, whereas a control group was allowed to eat everything. As with other restriction studies, desire for sweets remained high in the sweets-prohibited condition, whereas it decreased in the fruit-prohibited and no-prohibition conditions. However, this effect of prohibition on desire for the prohibited food was not seen for fruit. For intake, children in both the fruit- and the sweets-prohibition conditions consumed more of the formerly forbidden food during a taste session as compared to the no-prohibition condition. In addition, total food intake was higher in the two prohibition conditions than in the no-prohibition condition. This is an interesting result, although it is not easy to see how parents might reliably put it into practice, and there must be a concern about creating mixed messages about eating healthy foods.

Perhaps a more positive message can be taken from another recent attempt to examine the impact of restriction on fruit intake in 4-7 year-old children (34). Here there were two fruit conditions: a normal presentation condition and a visually appealing (or at least entertaining) condition, were the fruit appeared in a boat-like sculpture. Children could initially either eat from both versions or from only one or the other presentation versions. In a second ad libitum phase, there was no effect of restriction on fruit intake, but children ate much more of the entertaining fruit presentation. The message is ‘make food fun to eat’.

2.1.5 Balancing internal and external influences – satiety responsiveness and portion size

As discussed in section 4.1.1, healthy regulation of eating requires a learned integration of internal and external cues, so that amount eaten matches need. There has long been concern that overemphasis on, susceptibility for, or attention to external influences can promote overeating and obesity (35), and this idea has been revisited recently (36). A key study of meal size conditioning in contexts that emphasised either internal or external control supports the importance of this issue: Birch et al. (37) gave 22 3-4 year-old children experience of eating high- and low-energy yoghurt preloads (60 vs. 145 kcal), with distinctive fruit flavours, followed 15 min later by ad libitum eating of liked snacks. The idea was to test whether 3 pairs of trials in which low- and high-energy yoghurts were eaten prior to the snacks would lead to more or less of the snacks being eaten, when tested after equicaloric yoghurts that had the flavours associated with the different energy levels during training.

Eating less after the high-energy yoghurt flavour than the low-energy yoghurt flavour would show good regulation by attention to internal cues. The important manipulation was that half the children ate the food in a context emphasising internal control, whereas the other half ate in a context stressing external control. The internal context involved two adults discussing with the children, during the yoghurt eating sessions, gastric feelings of hunger and satiety, using a doll model, as well as how we know if we have eaten enough. In the external context, a bell signalled the start of the eating session, and the adults discussed issues such as regular eating time, and amount of food on the plate, with the children. Children in this condition were also rewarded with toys or stickers for eating all of the yoghurt. This was followed by 2 pairs of extinction testing, with equicaloric but differently flavoured yoghurts followed by ad libitum snacking, and neutral context. Those children trained in the internal context ate more after the low-energy paired flavour than after the high-energy paired flavour, whereas for the externally trained children there was no difference in snack intake after the different yoghurt flavours. Thus, emphasising external control of eating removed the children's ability to learn to regulate intake based on association of energy-related internal cues with the sensory cues from food.

This sort of finding inspired a strategy to try to reduce children's energy intake at lunch (38): 77 2 to 5 year-old children ate either a high energy-dense macaroni cheese entree or a 30% less energy-dense version before lunch. Eating the less energy-dense version reduced energy intake from both the macaroni cheese entree and from lunch, despite children eating more weight of the less energy-dense entree.

An important external influence on amount eaten is portion size (39). Moreover, one study found that increasing main course portion size proportionately increased lunch intake in 4-6 year old children, but not in 2-3 year-olds, suggesting that this external influence may increase quickly with age (40). Perhaps also in line with a susceptibility to such external control, a subsequent study found not only that doubling main course portion size increased overall lunch intake in 3-5 year olds, but that those children who were more responsive to portion size also ate more in a test of eating without hunger (41). However, there was no clear relationship with this overeating risk and age-adjusted BMI for this age group.

Recently, young children's responsiveness to portion size has been used to advantage to promote greater vegetable consumption. Spill et al. (42) served a first course of raw carrots to 3-5 year-old children at lunch. Doubling the portion size of the carrots led to a 47% increase in carrot intake, without significantly altering lunch energy intake overall. Another study doubled the portion size of side dishes, rather than first courses, of carrots, broccoli or apple sauce, eaten with a pasta meal, in 43 5 to 6 year-old children (43). This resulted in

43% more of the apple sauce being eaten, but no increase in the amount eaten of the vegetables. These findings suggest that it is more effective to serve large portions of vegetables as a first course.

2.1.6 Effects of modelling and observational learning

The probable theoretical and practical importance of observational learning and modelling has been discussed in section 4.1.1. It is clearly a strategy that both parents and teachers believe to be effective (44, 45). However. surveys of effects of the family food environment necessarily confound modelling with availability and exposure (46). Here, experimental evidence of its effectiveness in promoting healthy eating in young children is reviewed.

A simple way in which a model (peer, parent or teacher) might influence children's acceptance of new foods would be to demonstrate eating the food whist at the same time showing a positive emotional response – perhaps the lack of benefit from Hendy's teacher models, discussed earlier, was due to a lack of positive emotion whilst modelling the trying of new foods (20).

Certainly, there is evidence that negative emotional responses by peer models will put (8-12 year-old) children off the flavour, but not the paired colour, of drinks, if drunk at the same time as watching a video of a peer drinking the same colour drink whilst making an expression of dislike (47). Unfortunately, there was no positive model in that study that might have demonstrated an increased liking for the drink. Nevertheless, the use of video film of peers modelling healthy eating – specifically enthusiastic consumption of fruit and vegetables - has been shown to be effective in improving fruit and vegetable consumption in primary school children ("Food Dudes" intervention), as discussed above in Section 2.1.3 (24). However, it is not clear from those studies to what extent the use of rewards was also critical in this effect.

Hendy and Raudenbush (45) subsequently confirmed, in a series of studies with 3-5 year-old children, that teachers' modelling of eating new or familiar foods was only successful in improving acceptance in the children if the teacher expressed obvious and audible delight at trying the food – silent modelling was ineffective. Curiously, when the enthusiastic teacher model competed with a similar peer model, girls were much more likely to try the new food following the peer model than the teacher model, whereas boys in this study were resistant to either model.

This inspired a subsequent study of effectiveness of peer modelling for increasing acceptance of novel foods in children (48). Peer models were trained to demonstrate eating of the new foods by rewarding such modelling with small toys. Girls proved to be more effective models than boys, but the benefit of modelling was no longer present one month later. The trained models preferred (on ratings) the food they had been rewarded for eating, but ate as much of the other untrained foods, suggesting at least no detrimental effect of the rewards.

A potentially less positive aspect of peer modelling (or peer pressure as in social conformity) was revealed in an earlier study, where a ‘target’ child’s preferred food was usually reversed to align with the opposite preference expressed by 3 or 4 peers, after four shared eating occasions (49) – good only if the other children were choosing more healthy foods.

There is evidence that the benefit of modelling eating a food may be quite specific to aspects of the food being modelled. Addessi et al. (50) created semolina-based novel foods, using novel flavourings and added colours (red, yellow, green), designed to be novel and somewhat disliked initially by 27 2-5 year-old children. Adults either modelled eating uncoloured semolina (Different condition) or the same colours as the children were asked to eat (Same condition), or did not eat any (Presence condition). Each child was exposed to every condition, with a different colour-flavour combination each time, and these combinations were counterbalanced across the group. The results were quite clear: only the Same condition, where adults modelled eating the same colour of food as the child, reliably enhanced intake and acceptance of the novel food. Of course, the children were aware that different colours cued different flavours, even if the texture was the same.

A recent study examined whether both positive and negative modelling could increase or decrease consumption of a novel ‘blue’ food (coloured potato bread or quorn given novel names), relative to a mere exposure control (51). In addition, the design tested whether positive modelling would counteract any adverse effect from negative modelling. A novel blue food was also presented together with the target food, to assess any generalisation. Older children (6-11 years) from a separate school acted as models to 3-7 year-old participants. A first experiment in slightly older children (5-7 years) showed a benefit on intake from positive modelling and a suppression of intake from negative modelling. Furthermore, this negative effect was diminished following a positive modelling session. A second experiment in younger children (3-4 years) gave broadly similar results, except that there was no reversal of the negative modelling when followed by positive modelling. A further encouraging aspect of this study was that the beneficial effects of modelling seemed to generalise quite well to a novel (but also blue) food, suggesting again that colour may be a key facet to permit generalisation.

One study investigated the possible synergistic reinforcing effects of either energy in a yoghurt drink or teacher modelling or both, on yoghurt flavour preferences in 4-7 year-old children (52). The energy condition involved either a low-energy aspartame-sweetened yoghurt drink, or an energy-rich yoghurt drink. Modelling involved teachers enthusiastically eating the yoghurt both before, and mothers doing so during, the time the child ate the yoghurt, as well as relating a story about a cartoon hero branded with the yoghurt's name. Each child took part in 9 such conditioning trials, on a flavour of yoghurt that they had initially ranked as mid-preference. Children were allocated to one of four groups: low-energy without modelling; low-energy with modelling; high energy without modelling; high energy with modelling. Only the high-energy with modelling group showed a reliable increase in preference after training, suggesting that modelling works better with energy-rich palatable foods. However, it is also worth noting that the children were asked to consume all 200 ml of the yoghurt on every occasion, and the high-energy yoghurt was likely to be more sensorily appealing than the low-energy version. So although there was an interaction of both reinforcers, it is not clear to what extent caloric or sensory reinforcement was involved. Modelling may draw attention to the sensory experience, and any contrast with expectations could have a detrimental effect, particularly where finishing of the yoghurt was demanded.

In summary, these experiments by and large show that positive social modelling of eating, by teachers, parents and peers, whether live or on video, can encourage healthy eating in young children. Older peers are particularly effective models, and younger children may be especially susceptible. However, it should be remembered that negative reactions can be very influential also. Large-scale interventions are very likely to include an aspect of social modelling of eating: one such example is the "Tigerkids" programme developed for kindergartens in Germany (53). This is a multifaceted programme, with considerable effort aimed at training nursery staff in nutritional education knowledge and techniques. Modelling is a key component, together with aspects like engaging children in food preparation, and incorporating learning about food groups into play. The evidence so far is that this intervention led to greater numbers of children eating high amounts of fruits and vegetables.

2.1.7 Conclusions

Children can be encouraged to eat moderately disliked and/or unfamiliar foods, including vegetables, by repeated brief tasting of the target food, in a positive social context. At least 5, and perhaps 10 such taste exposures may be necessary for a reliable improvement in liking or intake.

Using rewards may be an effective strategy to encourage healthier food choice, provided the reward is not a more highly liked food - otherwise, a reduction in liking for the rewarded food may occur, at least in the short term. Using tokens or other representations of reward, for later exchange, may be a safer approach to rewarding eating. However, verbal praise has obvious intrinsic appeal, as well as convenience, and has recently been shown to produce a quite long-lasting increase in liking for vegetables.

Efforts should be made to ensure foods such as fruits and vegetables are made as intrinsically appealing as possible, including enhancing the visual appearance, to entertain the child, and perhaps sweetening the taste.

Parents (and other carers) should avoid strategies that include excessive coercion or pressure to eat, that could distract a child from learning to regulate their eating based on postingestive and other physiological cues that can be associated with the food eaten. Such approaches are also likely to engender a negative social and emotional experience that could impede acceptance of the food.

Excessive restriction of foods that the child knows are available is likely to be counterproductive: instead, parents or carers can exert positive control by avoiding availability of, or exposure to, unhealthy foods, and by manipulating portions sizes in favour of healthy foods, especially early in the meal.

Finally, young children can be encouraged to eat healthily by positive and active social modelling, especially by parents and peers. This could also be achieved via several media, including films and books, and should include as wide a variety of healthy foods as practicable.

2.2. Physical activity

Physical activity does not only help to achieve a good energy balance – it is also known to contribute to a variety of psychosocial milestones (54). Many experts recommend at least one hour of structured physical activity (55, 56). However, although teacher and parents often assume that preschoolers are very active, several studies show that their PA levels are relatively low (57, 58). Since the majority of children at the age of 4 to 6 years is in childcare during a considerable amount of daytime, this setting has great potential – and also responsibility – for intervention. There are three main approaches known to promote physical activity in kindergarten (59). These are not exclusive categories, but smooth transitions exist.

- The traditional approach is to train motor skills that are adequate for the child's developmental status. The training is expected to have a positive influence on the child's coordination, strength, agility and endurance.
- Movement education intends to convey educational goals like pro-social behavior, sticking to rules and mutual respect by a multitude of fundamental movement experiences that children can invent on their own. Based on this approach, especially in Germany and Denmark the so called "Bewegungskindergarten" ("movement kindergarten") or "sports kindergarten" have emerged. The principle of a Bewegungskindergarten is to conveymuch of the curriculum through movement experiences by integrating PA in daily activities and letting room for children's natural need to move. They provide more time and adequate space to move, a richer portable play environment as well as better PE-trained teachers.
- Psychomotor education regards the sensorimotor development as a basis and prerequisite for cognitive achievement which can thus be influenced by an adequate and goal-oriented encouragement.

This section will examine studies on physical activity in children aged 4 to 6 years that provide evidence for the effectiveness of strategies used by teachers and health professionals as well as strategies to alter the environment to promote higher levels of physical activity. Studies presented were conducted mainly in child care settings: in kindergarten, preschool, child care etc.; a few studies in elementary school with children aged 5-7 were added.

2.2.1 Methods

Since the majority of the literature focuses on older children and adolescents, whereas studies on pre-schoolers are scarce and only slowly beginning to emerge, this is not a systematic review. We were searching English and German databases (Pubmed, PsychINFO, PSYNDEX, ERIC, FIS Bildung) for reviews and studies since 1995 using the following keywords: physical activity, preschool, children, intervention.

2.2.2 Children: Curricular opportunities for physical activity

In this part of the review the focus is on findings from studies that implemented and evaluated the effect of increasing physical activity on various outcomes.

Outcomes considered are:

- Time spent in PA (e.g. measured by accelerometers or observers)
- Physical skills (measured by motor tests)
- Measures of body composition (e.g. BMI, skinfold thickness)

Studies focusing solely on physical activity

In a cluster-RCT, Mo-suwan et al. (60) added a 15-min walk before morning class and a 20-min aerobic dance session (led by trained personnel) following the afternoon nap 3 times/week, i.e. a total amount of extra physical activity for 105 minutes per week. The intervention lasted ca. 30 weeks and was conducted in 2 kindergartens in the south of Thailand. The intervention group consisted of 82 boys and 65 girls with a mean age of 4.5 years, 88 boys and 57 girls (same mean age) served as a control group. In the intervention group, triceps skinfold thickness decreased more than in the control group. Although no difference was found between groups regarding BMI, the likelihood of having an increased BMI slope was lower in intervention girls than control group girls, but not for boys. The authors assumed that girls might have followed the exercise programme more strictly than boys. Additionally, since it is known that girls are basically less physically active (see section “Psychosocial correlates of children’s physical activity” in the first part of the review), the exercise programme might have had a substantial effect on the girls’ energy expenditure.

Basing their intervention on dance lessons, Venitsanou and Kambas (61) studied 36 boys and 30 girls in Greece (no control group). The intervention lasted 20 weeks with two 45-minute dance lessons per week, i.e. a total amount of extra physical activity for 90 minutes per week. Children were measured with a motor proficiency test (MOT 4-6) before and after the intervention. While there was no difference in the pre-test scores, the children showed a significant 22% higher post-test score.

Binkley and Specker tested the effect of calcium supplementation on bone mineral content and followed-up the children for 2 years (62, 63). During the one-year intervention, preschool children in 11 day care centres (239 children aged 3-5 years) were randomised to either a gross motor activity group (GMA) or a fine motor activity group (FMA). The groups were held for 30 minutes/day on weekdays for 12 months, i.e. a total amount of extra physical activity for 150 minutes per week. Children in the GMA group had 5 minutes of warm-up, 20 minutes of jumping, hopping and skipping, whereas children in the FMA group were sitting quietly doing arts and crafts projects. 6 months after the intervention ceased, children in the GMA group still spent more time in vigorous activity as assessed with accelerometry.

In a cluster-RCT by Reilly et al. (64), the 24-week long intervention was an enhanced physical activity programme consisting of 30-minutes sessions for 3 days/week, i.e. a total amount of extra physical activity for 90 minutes per week. The intervention group consisted of 128 boys and 140 girls with a mean age of 4.2 years, 145 boys and 132 girls (mean age 4.1 years) served as a control group. Additionally, intervention group families were given a resource pack of materials with guidance on linking physical play at nursery and at home and two leaflets. During the intervention, nurseries displayed posters focusing on PA for 6 weeks. Neither after 6 nor after 12 months was an effect found on measures of PA (accelerometry). However, children in the intervention group showed significant improvement in fundamental movement skills at 6 months (was not assessed at 12 month). The results stand in contrast to the findings of their pilot study. Here, the same intervention was conducted over 12 weeks and they observed significant improvements in physical activity (65). The authors attributed the failure to replicate the findings in the main study to the different competencies of the intervention personnel: in the pilot study the programme was delivered by nursery headteachers, in the main study by nursery staff. This gives evidence of the importance of qualification and training of staff which will be covered later in this review.

That an improvement of PA and a better qualification of educators in PA can have significant impacts on children’s physical skills is also shown by Krombholz (66). Using a longitudinal design over two years, he investigated the effect of improved physical activities in German kindergartens. 11 kindergartens (228 children) served as the experimental group, 11 kindergartens (216 children) as controls. Children in the intervention group had more opportunities for unstructured and structured physical activities; the indoor and outdoor environment was rearranged to be more activity-friendly. A central part of the intervention was to train staff and to raise their awareness and their competencies for the physical activity needs of children, for motor development and for structured and unstructured PA-programs and activities. Children in the intervention group showed significant greater improvement regarding gross motor skills (body coordination and fitness, 8 items) and fine motor skills (2 items). No differences could be found in tests of concentration and vocabulary and in indices of overweight (BMI and skinfold thickness).

Trost et al. (67) studied the effect of a so called “move and learn”-curriculum in a cluster-RCT in a preschool. 22 children served as intervention group, 20 as control group, their mean age was 4 years. In the two weeks before the intervention started, baseline measurements of the children were assessed. Teachers were trained 3 hours in the contents of the curriculum: physical activity was integrated into all aspects of the pre-school curriculum, including maths, social science, language arts and nutrition education. During the eight-week-intervention, teachers were required to provide two 10-min lessons per preschool-session, 2 sessions a day, 4 days/week, i.e. a total amount of extra physical activity for 160 minutes per week. Physical activity was measured with accelerometry twice a week during the intervention. Additionally, PA levels during specific learning contexts were determined with a direct-observation system (OSRAP). Children in the intervention group were significantly more likely than children in the control group to exhibit MVPA during some specific contexts, namely circle time, free-choice time outdoors and free-choice time indoors. No differences were found in the contexts of transitions and snack time. The study shows that integrating movement experiences into an existing early childhood curriculum can be an effective strategy to promote physical activity.

In the context of expanded early childhood curricula this is an important finding. It is supported by a study from Connor-Kuntz & Drummer (68), showing that accompanying physical activity with language is not more time-consuming while having the same effect. With more and more educational goals, preschool teachers feel (time) pressure to fulfil them, often at the expense of free play and being active. Therefore, physical activity has to be implemented in childcare in a way that it can be integrated into the daily routine and into the other goals of the curriculum. The following two studies have taken a look at the so called “Bewegungskindergarten” where this approach is already realised, or rather, where it is realised vice versa (the curriculum is more or less integrated into physical activity):

In a small correlative study in Germany, Rethorst (69) compared two Bewegungskindergartens with one kindergarten that works with a traditional concept. Children’s motor development was assessed with a motor proficiency test (MOT 4-6) three times during the 2-year longitudinal study. At baseline, children showed no difference; from the second time of measurement on (ca. 1 year later), children from the Bewegungskindergartens scored significantly better. Moreover, children in Bewegungskindergartens scored higher on optimism and self-confidence. A similar German study – however with a different result – was conducted by Jasmund (70), who compared seven Bewegungskindergartens with four conventional ones. She looked for the relation between childcare policy and children's development, including motor development. Children were assessed three times within one year; however, the motor proficiency test showed no significant difference between children of the two types of kindergartens. The author then assumed that the conventional kindergartens may have implemented the physical activity guidelines from the early childhood curriculum so well that no difference could be found anymore. This finding is rather encouraging in that it shows that a typical kindergarten can also serve the needs for physical activity in children.

Studies with a focus on nutrition and physical activity

Eliakim et al. (71) studied a 12 week-long intervention in 101 preschool children in Israel in a cluster-RCT with the focus on obesity. Children in the 2 intervention groups received nutritional education as well as a physical activity programme that consisted of a 45-min exercise training six days per week based on circuit training, i.e. a total amount of extra physical activity for 270 minutes (or 4,5 hours) per week. Additionally, children were encouraged to reduce sedentary behaviour and to increase PA in their spare time. Physical activity was measured with a pedometer, fitness with a 600-m field-run-test. Intervention groups showed significantly greater amounts of physical activity compared on a daily basis as well as during and after-school. They were also significantly faster on the field-run. Moreover favourable changes were observed in indices of adiposity.

In a RCT, Warren et al. (72) found no effect on physical activity after a 20 week-long intervention during lunchtime in 213 children aged 5-7 years old. Children were randomly allocated to three intervention groups (nutrition only, PA only, nutrition and PA combined) and one control group. Based on Social Learning Theory, in the two groups with PA component, children were taught the concepts of energy and activity; playground activity and reduction of television were promoted and an activity pyramid was introduced, i.e. no real extra amount of physical activity was added. Physical activity was assessed by questionnaire. However, there was no effect found on the playground activities before and after the intervention. This finding shows that a purely cognitive approach is not effective in children of that age – at least regarding the physical activity component.

In a cluster-RCT by Fitzgibbon et al. (73, 74), the intervention was implemented in two different minority samples in the United States: first in an African-American cohort, then in a Latino cohort. The physical activity element consisted of a 40-min intervention by trained early childhood educators 3 days/week: 20 min nutrition education and 20 min for activity session (including games, imaginary aerobic role plays, 5-min warm-up, 10-min Aerobic, 5-min cool-down), i.e. a total amount of extra physical activity for 60 minutes per week. Parents received weekly homework and newsletters containing information on nutrition and physical activity, they were also offered twice weekly aerobic classes. Although in the first cohort lower BMI increases were reported in the intervention group at both 1 year and 2 year follow-up, no difference was found in the Latino cohort. Moreover, there was no effect found on physical activity in either cohort.

KOPS is a cluster quasi-RCT, primary school based intervention in Germany with almost 5000 children taking part in their first year at school (75). Teachers were trained within a half day structured nutrition programme. Intervention in class consisted of a 6-h course of nutrition education (done in 8 sessions within 2 to 3 weeks, one of the simple key messages was “keep active for at least 1 h per day”). Each session was followed by 20 min of “active breaks“, so a total amount of extra physical activity for 80 minutes per week was given. The effect of this intervention was assessed about 4 years later with 1764 children. There were no effects on mean BMI and obesity.

Manios et al. (76) implemented a six-year long study on the island of Crete focusing on children’s diet and physical activity. The practical part of PE classes (2 hours per week) was fitness-oriented rather than motor-development-oriented, focusing primarily on non-competitive and recreational forms of exercise of moderate intensity; the main aim was the increase of total class participation. A subsample of 238 (intervention) and 187 (control) children drawn randomly out of baseline group was followed-up 4 years after the end of the intervention (i.e. for 10 years). At the end of the intervention and 4 years after the intervention, boys but not girls in the intervention group devoted more time to moderate to vigorous physical activity – assessed by a standardised activity questionnaire compared to controls. This result stands in line with findings that boys are more physically active than girls.

Bayer et al. (53) studied the effect of a cluster-randomised kindergarten intervention in Bavaria, Germany. The intervention kindergartens (1318 children) took part in the “TigerKids” behavioural intervention programme developed to enhance physical activity and to modify habits of food and drink consumption of children attending kindergartens. The key targets were: at least 30 minutes/day of vigorous PA games (total amount of extra physical activity for 150 minutes per week), regular consumption of fresh food and vegetables and non-sugared drinks. Additionally, parents received “TippCards” with examples to integrate PA in the daily routine and encouragement of physical active leisure activities for families.

The control kindergartens (1340 children) ran the normal curriculum. Effects of interventions were controlled after 3-9 months (sample 1) and 12-20 months (sample 2) compared to controls. Main outcomes were consumption of food and drinks (questionnaire), motor skills (1 item: side to side jump) and overweight / obesity (BMI). Intervention children consumed more fruits and vegetables and less high caloric drinks (assessed in parental questionnaires). However, no effects of intervention were found in prevalence of overweight and obesity and motor skills.

Multi-level studies

Niederer et al. (77) designed the Swiss Ballabeina study, a cluster-RCT that takes place in 40 preschools for one year and is characterised as a “multi-disciplinary multilevel lifestyle intervention”. It focuses on physical activity, nutrition, media use and sleep duration and aims at children, teachers and parents. Teachers were coached by PE teachers (so called Health Promoters) who were further trained by a dietician and a physician. These HPs intervened on the level of the teachers, the children, the parents and the local community. Teachers visited two afternoon workshops on PA, nutrition, media use and sleep prior to the start of the intervention; families received tips for PA and nutrition home activities plus information material. Children had 45-min PA lessons 4 times per week plus one 45-min nutrition lesson per week, i.e. a total amount of extra physical activity for 180 minutes (3 hours) per week. PE lessons focused on the training of coordination and endurance, additionally sports equipment such as balls and skipping ropes was offered and organised. Nutrition lessons were based on five messages: “drink water”, “eat fruit and vegetables”, “eat regularly”, “make clever choices”, “turn your screen off when you eat”. Two additional lessons covered information on sleep. Measurements were taken at baseline and at the end of the intervention. So far, findings were shown on conferences only. Compared with controls, children in the intervention group had no difference in BMI, but a more favorable improved performance in aerobic and overall fitness and significant relative decreases in body fat % body fat and waist circumference. There were significant differences in reported, but not in measured PA, in media use and in some aspects of nutritional behavior, but not in sleep duration (presented at ENDO 2010).An almost identical study is being conducted in Germany (78). PAKT (“prevention through activity in kindergarten”) takes place in 41 kindergartens. The cluster-RCT lasts one kindergarten year. Children receive 30-min sessions of physical education daily (theoretical base: psychomotor education), instructed by kindergarten teachers under supervision of the research team, i.e. a total amount of extra physical activity for 150 minutes (2.5 hours) per week. Teachers were trained in workshops and during intervention and received written instructions. 52 PA homework cards were developed for parents, additional to written information and information evenings. Up to now, preliminary findings were presented at conferences. Significant effects were reported in LPA, MPA and MVPA as well as in selected aspects of motor skills (balancing, standing long jump, jump coordination) and statistically significant improvements in body fat (skinfolds). No effects were found for BMI and other selected aspects of motor skills (flexibility, complex motor performance).

2.2.3 Towards a PA-friendly environment

In the scarce field of studies covering educational strategies to influence children's healthy energy balance related behaviour and to prevent obesity in children at kindergarten age, studies with the focus on environment and policy have their own standing. Recently Trost, Ward and Senso made the effects of child care policy and environment on this kind of activity of children to the main issue of an own review (79).

There is empirical evidence that shaping the child care environment has an influence on physical activity of children in these institutions. Studies measuring physical activity of kindergarten children have consistently shown considerable between-center variability in physical activity behaviour (80, 81, 82). These studies focus on determinants of physical activity, the study design is correlative. Although the focus in this part of the report is on intervention studies, in this section correlative studies on environment are important to identify effective educational strategies. However, in cross-sectional studies causality cannot be determined for certain, a point that has to be kept in mind when findings of these studies are discussed in the following.

Play environment can be either fixed or portable. Fixed play environment refers to the indoor and outdoor play space of a child care setting. It comprehends also fixed play equipment like climbing towers, swinging equipment, slides and balancing surfaces (83). Portable play environment means types of play equipment that can be transported and used in various locations. Important here is the availability in form of existence in the kindergarten, but also whether it is freely available for the children to use (83). The last point makes clear that environment in a broad sense is closely connected to staff behaviour that can be seen individually or as the policy of the house.

Fixed Play Environment

Alhassan et al. (84) studied the effect of more unstructured outdoor time on the physical activity of children. In this small interventional study in one preschool, 30 min of more outdoor time each in the morning and afternoon for 2 consecutive days had no significant effect on the physical activity (measured by accelerometer) in the intervention compared to the control group. The small sample and the short duration of the study make it difficult to dismiss the possibility that simply more recess outdoor time may have an influence on physical activity.

The connection of quality of preschool and motor behaviour of children was analysed by Dowda et al. (85, 86). In 9 preschools Dowda et al. (85) found that 3-5 year old children who attended preschools with lower quality spent more time in sedentary activity; however, when preschools offered more field trips and had more college educated teachers, the children participated in more MVPA. Similar results were found by Dowda et al. (86), who examined policies and characteristics of 20 preschools and the extent to which they influence the physical activity (measured by accelerometry) of the 299 enrolled preschool children. In preschools that had higher quality scores, less fixed playground equipment , more portable playground equipment, lower use of electronic media, and larger playgrounds, children spent less time in sedentary activities and more time in MVPA. These studies respective findings (84, 85, 86) didn’t account for how the outdoor environment is designed. The question what characteristics of fixed play environments have an influence on physical activity, is addressed predominantly by cross-sectional studies. Dowda et al. (86) found in the already cited study that the outdoor playground size is significantly connected with the measured MVPA and sedentary behaviour in children. Playground sizes 4175 ft^2 or bigger were connected with significantly more MVPA than smaller playground sizes. They also found that the quantity of fixed playground equipments, like slides, is not associated with promoting physical activity. Instead, more fixed playground equipments are significantly connected with higher sedentary Activity and lower MVPA and less equipment with lower sedentary activity and higher MVPA. The cause for this may be that children tend to gather on and under this anchored equipment. Brown et al. (87) found that children, when observed on fixed playground equipment, spent only 14% of the observed time in MVPA. In contrast, when the children were acting with balls and objects they spent 27% of the intervals in MVPA. This was a cross-sectional study directly observing PA of 371 children outside in preschools and the contextual conditions of their play. Looking at the other coded outdoor contexts, children spent with open space 23% of the observed intervals in MVPA, with wheel toys 13.5%, and with sociodramatic props 11%.

Bower et al. (88) examined associations between physical activity behaviour and the physical activity environment in childcare centres. In a cross-sectional design, they used direct observation of children’s physical activity in 20 child care centres and collapsed individual data to center-level data. They found that the active opportunities subscale, consisting of the quantity of occasions of structured physical activity and the occasions of outdoor play, as well as the minutes of active opportunities, was related most strongly to mean activity levels, to MVPA and, inversely, to sedentary activity. Minutes of active opportunities were important, but the findings do not reveal if this time is spent in free play or in structured activities; and if other environmental factors also affected physical activity. The Portable and Fixed Environmental subscales were significantly related to the proportion of time in MVPA. The findings also suggest that the features of the equipment in the fixed environmental subscales, like climbing structures and balancing surfaces, are associated with lower intensity physical activity.

Cardon et al. (89) investigated how physical activity levels are influenced by environmental factors during recess in preschools. They used preschool playground observations and pedometry in a cross-sectional study design to examine the contribution of playground variables to physical activity levels of 783 children in 39 randomly selected preschools. Mainly field markings and fixed play equipment as swings or slides were present in the observed preschools. Less children per square meter of play space and shorter recess periods were significantly associated with higher step counts and higher PA. These findings about the availability of enough space to move are supported by the findings of Dowda et al. (85) and Boldemann et al. (90). However, playground markings, access to toys and the number of playing or aiming equipment pieces were no significant physical activity predictors. These open questions were focused in a later study of Cardon et al. (91). They conducted an interventional study (cluster RCT) and provided in one part of the sample playground markings, in another part play equipment and in a third part play equipment and playground markings, supplemented with a control group. The physical activity of 636 children in 40 preschools were measured with accelerometer, but after 4 to 6 weeks of intervention, no significant effect of either of the interventions was found compared to the control group. It can be concluded that creating an activity friendly environment by providing playground markings alone, may not be sufficient to increase physical activity in preschool children.

Portable play environment

In the same study by Cardon et al. (91) they also used the provision of portable play equipment like different balls, throwing discs and rings, hoops and others as an intervention. As already mentioned they found no significant effect of providing this play equipment as exclusive intervention or combined together with providing play markings.

These findings are in contrast to the results of the interventional study of Hannon and Brown (92). They added additional equipment – consisting of different material to support multiple locomotor activities like tunnels and hurdles, and manipulative activities like balls and bean bags, to the outdoor playground of one preschool with 64 children in the final sample.

Measuring with accelerometer at baseline and on the 5 post-intervention days they found significant positive effects on MPA and VPA, and also on decreasing sedentary time. Comparing this to the findings of Cardon et al. (91), it can be concluded that the effect found by Hannon/Brown probably was caused through the novelty of the play equipment – a valuable, but not sustainable effect.

In the cross-sectional study of Dowda et al. (85) already presented before (section fixed play environment) the presence of portable playground equipment was identified as one environmental condition that is significantly associated with more MVPA and less sedentary behaviour observed in children as a result of mixed-model analyses of variance. The two groups of preschools, either promoting or not promoting physical activities, were differentiated by the criterion if they had none or at least one portable playground equipment. Compared to reality in most European preschools this does not seem to be a strong criterion to differentiate. But also Brown et al. (87, presented above) found that children playing with balls and objects are more likely to have a higher MVPA than in other outdoor contexts and Bower et al. (88, presented above) found strong correlations (r=.358) of the subscale portable play environment of the EPAO-instrument to the observed MVPA.

These findings give hints that:

1. the provision of more free play outdoor time as a single intervention does not have an effect on physical activity when the levels of activity are rather low in those situations.
2. the provision of fixed or portable playground equipment for itself as a single intervention may not have long-term effects besides its novelty character, but
3. fixed and portable playground equipment are essential for structured and unstructured PA in kindergartens, schools and at home, but may have a differential effect on children's physical activity; it seems that outdoor space and opportunities for the children to move, portable play equipment like balls and other objects are likely to stimulate more PA than fixed play equipment and playground markings do.

2.2.4 The overall quality of the organization

The cross-sectional studies of Dowda et al. (85, 86) have already shown that the quality of preschools has an effect on the physical activity of the enrolled children. In both studies the quality measured with the "Early Childhood Environment Rating Scale Revised" (ECERS-R) was a predictor for healthy energy balanced related behaviour. In the 2009 study (85) it was significantly correlated with more MVPA and less sedentary behaviour. In the 2004 study (86), children attending preschools with overall higher quality in terms of the ECERS-R spent significantly less time in sedentary activity than children attending lower quality preschools did. The ECERS-R (93) is based on current understanding of recommended practices in early childhood education and an internationally renowned instrument in science and practice. It contains 43 items organised in seven subscales which evaluate space and furnishings, personal care routines, language-reasoning, activities, interaction, programme structure and parents and staff.

A similar approach is taken on by an environmental intervention called “The Nutrition and Physical Activity Self-Assessment for Child Care (NAP SACC)” (94). The NAP SACC guidelines and instruments serve as best-practice guidelines for healthy weight development and consider the components of active opportunities, fixed play environment, portable play environment, sedentary opportunities, sedentary environment, staff behaviour, staff training/education and physical activity policies.

Two studies have been conducted to determine the feasibility and the impact of the NAP SACC intervention. Benjamin et al. (95) provided the NAP SACC programme, consisting of self-assessment, action planning to tackle selected areas, education workshops and a concluding self-assessment, in a pilot study to 19 child care centres. The physical activity score of the preschool improved from baseline 34.23 to 41.00 after intervention as did the overall score on the basis of centre director’s self-assessment with the assessment-instrument provided by the research team. Because of the fact that the outcomes were based on self-report, the results should be interpreted with caution.

Following this study, Ward et al. (96) implemented NAP SACC in a similar intervention programme, but in a bigger sample of 84 child care centres and measuring the outcome with a newly developed observational instrument, this time completed by the research staff. Here, no overall difference was found using an intention-to-treat analysis. However, exploratory analyses suggest significant positive findings among the centres that actually implemented the programme in all or most components. According to the authors, it is unclear whether the overall lack of significant results in the ITT analysis occurred because of inadequate strength of the intervention, a lack of implementation fidelity, an inadequate assessment tool, or a combination of these factors in this intervention with a minimum of extra resources.

2.2.5 Social Environment: Staff behaviour and perspectives, parents’ perspectives

Staff qualification and behaviour are important moderators of children’s physical activity behaviour. This conclusion can be drawn from curriculum-oriented studies, where substantial resources were invested and differentiated programmes developed for the training of staff (e.g. 66, 67, 77, 78) or external experts were used (60, 71, 72, 75,). This is also the assumed result of studies with no effect in the main studies that used intervention staff with lower qualification than in the pilot studies (64, 65).

Correlative studies that examined predictors of the environment for physical activity also found results for the so-called social environment. Brown et al. (87, presented already above) reported that during outdoor play, child-initiated activities were more frequent and connected with more intervals in MVPA (19.5%) than adult-initiated ones (15%). The different social groupings in which children played were associated with different amounts of MVPA: in solitary play 28.5% was in MVPA, in one-to-one-play with a peer it was coded in 21.1% of the intervals, in groups without adult in 19.4% and with adults in 11.2% of the intervals in MVPA.

One might ask, then, if the presence of an adult is beneficial for the aim to foster physical activity. Brown et al. comment on this question, that when teachers were present, they hardly ever implemented teacher-arranged activities to enhance children's physical activity or encouraged it. Their observations showed that in those rare situations where teacher-arranged physical activities and outdoor games occurred simultaneously, they resulted in relatively high proportions of children's MVPA. Brown et al. concluded from their results: "what we are advocating for is not interference with children who are already very physically active. Rather, given the extant information on pre-schoolers' limited physical activity, we believe that strategic adult involvement by organising, modelling, encouraging, and acknowledging children's physical activity (…) may be warranted for many children" (p. 54). These conclusions are based upon staff behaviour in outdoor play that is obviously more or less recess time, not structured physical activity. Given this, it is clear that adult involvement is multifaceted and that there is no unique way, what works best in every situation to foster physical activity. Staff has to learn the pros and cons of different behaviour and how to work context-sensitive.

Bower et al. (88, presented above) found a substantial association between the subscale Physical Activity Training and Education of the EPAO-instrument with the proportion of sedentary time (r=-0.351) and mean activity intensity (r=0.404). One result of the study by Cardon et al. (89) was that there is an influence of teachers' presence on physical activity, but just for girls: The step counts (pedometer) were significantly higher with a smaller number of teachers present. Cardon et al. see here the same causes as Brown et al. (87): many teachers supervise by sitting down or standing still and not actively promoting PA.

The advantage of a small-scale (5 children) formative single-case study design by Brown et al. (97) is to give more in-depth descriptions based on empirical findings, how staff behaviour has to be shaped to enhance preschool children's physical activity. They developed and evaluated two teacher-implemented PA activities that consisted of the components teacher-guided discussion of PA, “Plan, Do and Review“-Process with children, teacher pep-talk, teacher participation in PA, teacher encouragement and acknowledgement of physical activity. Observations during teacher-implemented activities indicated increased MVPA on intervention days compared to non-intervention days. One important experience was that teacher enthusiasm and their encouraging and acknowledging strategies were the critical issues to achieve effects. This leads to the point that teachers’ view of physical activities and related interventions, for example that they are acceptable and feasible, is probably a crucial point for being enthusiastic and thus reaching an effect (97, 98). Another central finding was that longer bouts of intense physical activity beyond 5 minutes seemed to be less appropriate for pre-schoolers. “Shorter albeit relatively intense and sustained physical activity periods embedded strategically throughout the morning and afternoon recess may be better suited to the emerging fitness levels of many young children” (97, p. 141-2). These physical activity periods seem to be also “excellent” opportunities for children to learn pro-social behaviour and self-regulation especially if teachers encourage this.

As a conclusion, it can be stated that the social contextual factors seem to be influential predictors of PA; in the examined preschools in the United States children showed more MVPA in solitary play or play with peers than when adults are present: teachers are probably not enough enhancing children’s PA and encouraging them, but more passively supervising, causing this negative effects. Staff training seems to be necessary on these issues.

Teachers and parents perspectives about children’s physical activity were focused by several studies including formative research to develop physical activity intervention components in complex studies like the IDEFICS study (99). They conducted 36 focus groups with 189 parents and 20 focus groups with 155 6-8 year old children. They aimed at detecting environmental and personal influencing factors of physical activity behaviour from the view of their target population. Parents and children laid the greatest emphasis on environmental physical, like the safety and perceived safety of facilities, institutional and social factors, like the role modelling of parents and the social norms. Interesting here were also the personal factors like the importance of parental beliefs, e.g. “young children should not participate in organised activities” or “my children don’t like to walk or cycle”, but also supporting beliefs like “participating in organised sports keeps my children out of trouble”. These findings are supported by other studies like the focus group study of Dwyer et al. (100) with parents and preschool staff about facilitating factors and barriers. Here staff expressed concern that free, creative active play was being lost and that alternate activities were increasingly sedentary. These perspectives have to be considered and tackled in forthcoming interventions to facilitate that good concepts are also implemented in the daily routines in the families at home and in childhood care.

2.2.6 Conclusions

Interventions for the prevention of overweight and obesity – and generally for enhancing the health status – follow two strategies:

- healthy eating behaviour and
- increasing energy related behaviour: reducing sedentary time, increasing physical activity time

Reaching this is no easy aim or as McCrory (101) concluded: there will be no “cheap solutions for big problems”. This becomes apparent throughout this review.

We included 26 studies in the review. Because of the “nascent stage of development” (102, p. 532) of research in this area, we included studies with different designs, interventions outcomes and measurements.

One part of the review deals with studies giving children curricular opportunities to increase physical activity and motor-related competencies. Many of these interventions used a formal curriculum with structured physical activity. To guide forthcoming interventions following questions should find an answer:

- How much extra physical activity is necessary?
- Is enhancement of play environment helpful for more physical activity?
- What is the appropriate balance between structured activity and free play?
- Is physical activity another goal in the curriculum or should it be integrated with other curricular aims?
- Is teacher training needed and what should they learn?

How much extra physical activity is necessary?

The reviewed studies provided additional time for physical activity between 60 and 270 minutes per week. None of the sessions lasted longer than 45 minutes with a range from 20 minutes to 45 minutes per day. The sessions were implemented between 2 and 6 times per week. Studies reporting a success in physical activity outcomes had sessions that lasted at least 30 min per day.

Looking at the length of the individual unit, it is noticeable that one successful programme had very short sessions with a length of only 10 minutes each (Trost et al., 67). This supports the findings that young children’s physical activity patterns occur rather as short bursts of vigorous activity followed by less intense recovery periods (see part 1.3.1 in section 4.1.1), which is also shown by the single case study in this review (97) and in the study by Cardon et al. (89). It was observed that children were most active in the first 10 to 15 minutes of the time spent outdoors.

However, these conclusions are based on rather few, very different studies. Long term studies about the effects of physical activity in childhood on health outcomes in adolescence or adulthood do not exist, so cautious interpretation is necessary.

Is enhancement of play environment helpful for more physical activity?

In this review two studies modified the play environment (91, 92) by providing additional portable play equipment and playground markings. There was no effect detectable besides a novelty one (92). According to cross-sectional studies (85, 87, 88), outdoor space and opportunities for the children to move (see also 89), portable play equipment like balls and other objects seem to be likely to stimulate more physical activity than fixed play equipment and playground markings. The interpretation here is that enhancing the environment has no sustainable effect in an intervention that modifies only this. But it is an inevitable part of the complex system of staff behaviour, structured and unstructured PA-related activities, play environment and parent factors in a preschool. Interventions have to focus also on the environment as can be seen in the complex, multi-level studies reviewed (66, 77, 78).

What is the appropriate balance between structured activity and free play?

Although the only study that provided more free play time did not find positive results (84), it would be wrong to assume that free play time is not necessary. In children aged 4-6 years, play and physical activity are closely connected. Play has the relevance of being a “fundamental life system” and is the central mode of how children are developing and learning (103), serving multiple important functions in the child’s development. By playing, children move on in their emotional (e.g. becoming aware of, experience and regulation of emotions), social (e.g. cooperation, contracting friendships, role taking), motor (e.g. gross locomotor movement, eye-hand coordination, reactivity, endurance) and cognitive (e.g. logical thinking, rules, form perception) development. Play is therefore deeply connected with intrinsic motivation of children, because it is active, autonomous/self-determined, spontaneous and competence-oriented (ibid.). One important characteristic of play is that it is voluntary and for its own sake, characterised by freedom. Experts advise that preschool children should have generous amounts of free play time (104, 105, 106). Therefore, programs of structured physical activity should not to be implemented at the expense of children's free play.

Is physical activity another goal in the curriculum or can it be integrated with other curricular aims?

Having more time for physical activity is even more important in the light of the pressure of expanding preschool curricula that have emerged in the aftermath of the PISA studies (Programme for International Student Assessment): more and more, the preschool serves as a place for academic preparation threatening self-determined activity and free play time (107,108). It is important, then, that physical activity/physical education can be easily integrated into the daily routines and the existing curriculum of a wide range of kindergartens and must not be seen as something that is competing with other educational goals. Some studies in this review have taken this integrative way and were successful (66, 67, 68, 69, 70). Children's learning in this age is holistic, integral: they learn in direct experience with the material and social environment, and not in separated aspects like motor development, language, social learning, etc. (109). This supports the conclusion that the promotion of physical activity should be and can be integrated in other aspects of the curriculum.

Is teacher training needed and what should they learn?

To promote more physical activity of children in preschool settings, teacher training is important. This conclusion can be drawn on the one hand from curriculum-oriented studies, where substantial resources were invested and differentiated programmes developed for the training of staff (e.g. 66, 67, 77, 78) or external experts used (60, 71, 72, 75). On the other hand the importance of sufficient training gets obvious in studies that used preschool staff (64, 67) and faced problems with inadequately trained teachers. The findings support the importance of teacher's knowledge about physical activity and motor development and their ability to support children's learning and their development of skills. But teachers need also enthusiasm to encourage and acknowledge PA of the children (97) and awareness for the needs of children and the learning potential of educational situations (66).

Developments in early childhood education in the last years are characterised by the main trend to individualise pedagogies. This is caused by the effectiveness of education that takes up individual needs and focus points of learning and development. This is in accordance to the predominant, "postmodern", picture of the child as an active, competent learner that has knowledge and skills and that chooses his or her own learning focus. Therefore learning should be co-constructive (110,111). To observe and understand the individual child is the basis for a teacher's decision what educational strategy may be best to support the individual child. Therefore designing an intervention should not use a fixed physical activity curriculum that is implemented on groups of children, but it must include the flexibility to take up the needs of the individual child. To achieve this, special teacher training is inevitable.

Answering the question, what educational strategies serve best for supporting children in increasing physical activity, is limited by the small array of relevant studies and the incorporated differences. Nevertheless, it can be concluded that an intervention should unfold an impact on all levels of the preschool: children, parents/family, environment, and teachers.

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Table 2: Studies included in the physical activity section

Study and Location	Sample and Design	Intervention Focus and Description	Outcome and Measure	Summary of Results
Children				
Mo-suwan et al. (1998); Thailand;	310 Children at baseline (I: 158, C: 152); 292 children at end of intervention (I: 147, C: 145), mean age 4.5 yrs; 10 classes of 2 kindergartens Cluster RCT	Obesity: kindergarten-based exercise program by specifically trained personnel 3 times/wk: 15 min-walk in the morning, 20 min aerobic dance, 1 h PE/wk Duration of Intervention: ~30 weeks Follow-up at end of intervention	Triceps skinfold; Anthropometric measures	Triceps skinfold for intervention children decreased from 12.2% to 8.8%, in control group decrease from 11.7% to 9.7%; Reduction in prevalence of obesity greater than control group, but not significant (p=.057); gender difference: just girls lower likelihood of having an increased BMI-slope I vs. C, boys equal likelihood
Warren et al. (2003); UK; „Be Smart“	218 children (3 I-groups: 164, C: 54) at baseline, Age 5-7 yrs, mean 6.1, 181 children at follow-up 3 primary schools RCT	Obesity: School- and family-based interventions, with three different intervention groups: nutrition group, PA-group, Combined PA and nutrition group. Each 25 min-lessons delivered by project team with elements raising the value of the targeted behaviour, being active (PA or taste healthy food), providing incentives, developing practical skills for self-confidence, working with parents Duration of Intervention: 20 weeks over ~14 months Follow-up: 14 months	PA (children and parent report), BMI, Skinfold	No significant changes in rates of overweight and obesity. Reported increase of PA in school, from the parental questionnaire no intervention effect out of school; but significant improvements in nutrition knowledge in all groups (p<.01), highly significant in nutrition and combined group (p<.001), increase in fruit and vegetable intake significantly (p<.01 and <.05, respectively)
Binkley, Specker (2004); United States	161 children after follow-up, 3-5 yr; in 11 child care centers; RCT, partially blinded;	Bone health: Assignment to fine or gross-motor-group (GM); GM 30 min/d, 5d/wk for 12 months PA-activity intervention and calcium intake	PA (accelerometer)	GM-group at 18 months greater accelerometer counts/day (p = .04) and more time in VPA (p =.05), not at 24 months
Rethorst (2004); Germany; „Kinder in Bewegung“ [children in movement]	160 children (E: 107, C: 53) at baseline, at follow-up 57 children (I=31, C: 26), age 3.5-7 3 kindergarten (E: 2, C: 1) Longitudinal „controlled“ study	Motor Development: Not Intervention but comparison of kindergartens with different approaches in physical education; experimental kindergartens („Bewegungskindergärten“) were characterised through a complex set of conditions like more time for PA, more and adequate space to move, a richer portable play environment; plus better in PE trained	Motor development (Test battery MOT 4-6) with a focus on coordinative proficiencies Socio-emotional development (diverse rating questionnaires)	Children in experimental kindergartens had a significant greater improvement in motor proficiencies compared to children from control group (p<0.05), no significant differences at begin of longitudinal study

		teachers, plus PA-related information for parents and collective activities with them to activate PA; central is that children's PA should be integrated in center's daily activities, to let room for natural need to move		
Venetsanou, Kambas (2004); Greece	66 children (I: 28, C: 38) at baseline, age 4-6yrs, 1 kindergarten Controlled Pre-Posttest-Design	Motor Skill: 45 min/d, 2 d/wk, for 20 wk; intervention programme: 5 min warm-up, Greek dance program as a combination of Music/movement elements, singing games and dances, focusing on activities that contribute to development of coordination, closing with a traditional Greek game to recapitulate the main concepts; Principles: psychomotor education, rhythmic education (Orff), age(development stage appropriateness	Motor proficiencies (MOT 4-6); measured pre and post intervention	Intervention group showed a 22% higher post-test score than control (p<.001). No difference in pre-test motor proficiency scores
Krombholz (2005); Germany	Baseline 769 Children (I: 339, C: 430) age 4-6, follow-up after ca. 2 yrs 444 children (I: 228, I: 110), drop-out because of transition into school 22 Kindergarten (E: 11, C: 11) Longitudinal controlled trial with three times of measuring	Motor Development: complex quantitative and qualitative Improvement of physical activity setting: activity-friendly rearrangement of indoor and outdoor play environment; raised awareness and qualification of teachers for physical activity needs of children, for motor development and structured and unstructured PA-programs and activities Duration of Intervention: two years Follow-up at end of intervention	Motor Development: Goss-Motor: Fitness and Gross Body Coordination (tests); Fine Motor Skills (tests) Anthropometric measures; aspects of cognitive proficiencies	Statistically significant improvements in gross and fine-motor-development greater in Intervention vs. control-group after 2 yrs, MANOVA motor development significant (p=.037) ANOVA in selected gross motor aspects: Seitliches Hin- und Herspringen (p=.01), Balancieren rückwärts (p=.04), Pendellauf (p=.02) und Halten an der Reckstange (p=.03)
Fitzgibbon et al. (2005); United States; „Hip-Hop to Health Jr.“	Baseline 409 Afro-American children (I:197, C. 212) age 2-5 yrs, 300 at 2-yr follow-up (I: 146, C: 154) 12 Head Start centers; Group RCT	Obesity: 40-min interventions by trained early childhood educators, 3 d/wk, 20 min for healthy eating or exercise concept with an activity (often with handheld puppets) and 20 min for on-going PA (including games, imaginary aerobic role plays, 5-min warm-up, 10-min Aerobic, 5-min cool-down); weekly parent newsletters with homework Intervention for 14 wk	BMI; exercise frequency and intensity, television viewing (Parent report); measured pre, post, and 1- and 2-yr follow-up	No significant differences between intervention and control group for exercise frequency; mean BMI-increases in intervention group significally lower in 1-yr and 2-yr-follow-up

Fitzgibbon et al. (2006); United States; „Hip-Hop to Health Jr.“	Baseline 401 Latino children (I: 202, C: 199), age 3-5yrs, 331 at 2-yr-follow-up (I: 171, C. 160) 12 Head Start centers; Group RCT	40-min interventions by trained early childhood educators, 3 d/wk; 20 min for healthy eating or exercise concept with an activity (often with handheld puppets) and 20 min for on-going PA (including games, imaginary aerobic role plays, 5-min warm-up, 10-min Aerobic, 5-min cool-down); weekly parent newsletters with homework Intervention for 14 wk	BMI; exercise frequency and intensity, television viewing (Parent report); measured pre, post, and 1- and 2-yr follow-up	No significant differences between intervention and control group for any measurement period, no difference in BMI in follow-up
Reilly et al. (2006); Scotland; „Movement and Activity Glasgow Intervention in Children (MAGIC)“	545 children (I: 268, C: 277) at baseline, mean age 4.2 yrs., 504 (I: 245, C: 259) at 12-month follow-up Stratified by type, size and SES of area 36 nurseries (I: 18. C:18) Cluster RCT, single blinded	Obesity Enhanced PA-programme in nurseries by nursery staff: 30 min, 3d/wk for 24 weeks, display of posters; plus home based health education aimed at increasing PA through play and reducing sedentary behaviour (parent resource pack of materials) Intervention for 24 weeks Follow-up at 6th and 12th month after start of intervention	BMI, PA and sedentary behaviour (accelerometer), fundamental movement skills (Test Battery)	The intervention had no significant effect on PA, sedentary behaviour or BMI at six and 12 months-follow-up. Significant improvements in movement skills for children in intervention group vs. control children at 6month-follow-up (p=.0027), greater improvements in girls than in boys. Pilot study successful: mentioned possible cause for difference in effect: PA-programme in pilot was delivered by nursery headteachers
Manios et al. (2006); Greece; „Cretan Health and Nutrition Education Programme“	579 children drawn after 3 years of intervention randomly out of Baseline group, baseline mean age 6.3 (grade 1), 425 children (I: 238, C: 187) at 4yr-follow-up, then mean age 15.3 yrs Subsample 21 elementary schools (I: 12, C: 9) RCT	PA: School-based intervention: school teachers taught health promotion programme incorporated in PE-classes with a theoretical part (4-6 h per year) and a practical part (2 h/wk PE classes). The practical part was fitness-oriented rather than motor-development-oriented, focusing primarily on non-competitive and recreational forms of exercise of moderate intensity, main aim was the increase of total class participation. Duration of Intervention: 6 school year Follow-up at end of intervention and 4 years after	PA (standardised questionnaire by parents / children) at baseline, post-intervention and follow-up; Anthropometrical measures; Fitness (EUROFIT Test battery), Health knowledge (questionnaire), biochemical measures	Favorable effect of the intervention on boys` physical activity levels maintained 4 yrs after the end of the programme: MVPA levels significant higher (p=.029) in intervention vs. control boys, not in girls (p=.488)
Plachta-Danielzik et al. (2007); Germany; „KOPS“	4997 Children (I:780, C: 4217) at baseline, age 5-7 yrs, 1764 children (I: 345, C: 1419) at 4yr-follow-up 46 elementary schools Cluster quasi-randomised CT	Obesity: School based intervention given by a skilled nutritionist and a trained teacher: 6h course of nutrition education: six units performed during 2-3 wks. Part of the education programme were pointed messages like “keep	BMI, Skinfold Thickness, % fat mass, daily physical activities (parents questionnaire), nutrition outcomes (knowledge, consumption) (parents questionnaire)	In the four year follow-up no effect of the intervention on mean BMI was found. The effect on prevalence was significant in children from families with high SES and marginal significant in children of normal-weight mothers. The effect was most

		active at least 1 hour a day'" conveyed as fairy tales, interactive games, and by preparing a healthy breakfast. After each unit running games were offered for 20 min. Teachers trained within a half-a-day nutrition education programme. In addition a family based intervention (3 to 5 home visits with face-to-face-counselling, support) plus a structured sports programme were offered to families with overweight or obese children and to families with obese parents. Follow-up at 1,4 and 8 yrs, here reported data of 4 yr-follow-up		pronounced in girls. Compared with the control group the intervention tended to have a small effect on physical activity and media time (not significant).
Eliakim et al. (2007); Israel	101 children (INT=54, CON=47), 5–6 yr; Four preschool classes; Group RCT	Obesity: 6 x 45-min sessions/wk, 2 d/wk led by professional youth coach and other days by preschool staff; used exercise circuit (indoors and outdoors) with endurance and some coordination and flexibility activities (also nutrition education) Intervention for 14 wk	PA (Pedometer), fitness (600m field test), BMI, fat %, Skinfold-thickness	PA significantly greater in INT compared to CON on daily basis ($p<.003$) as well as during ($p < .001$) and after-school ($p < .04$); improvements in fitness endurance (shorter run times)significant ($p<.017$) vs. CON
Trost et al. (2008); United States;	42 children (I: 20, C:22), age 3–5 yrs; One preschool with four classes (2 a.m. and 2 p.m.) Group randomised controlles study	PA: Collection of activities integrating PA into all aspects of the curriculum: combining of e.g. maths, language arts, nutrition education with PA in one activity 3-h teacher training before: goal was to provide two 10-min lessons per preschool-session, 2 sessions a day, 4d/wk Duration of Intervention: 8 weeks	PA (accelerometer), measured 2 wk prior to start, then weekly throughout the 8-wk program Characterisation of PA-levels during specific learning contexts (direct observation OSRAC-P)	MVPA classroom / outdoor combined was greater for intervention group for weeks 7–8 ($p < .05$); intervention group had higher classroom MVPA and VPA during weeks 5–6 and weeks 7–8 ($p < .05$ respectively)
Bayer et al. (2009); Germany; „Tigerkids"	Baseline 1329 children (I: 866, C: 463 at 12 month-follow-up) 64 Kindergartens, randomly assigned for intervention; Cluster-RCT	Nutrition, Obesity, Motor skill: PA-related: Offering kindergarten-teachers a folder with information material and ready-for-use-materials for daily kindergarten activities; three day training and motivating workshops for teachers; telephone hotline for counselling teachers; for parents newsletters and „Tipp cards" with simple messages on health related behaviour of parents,e.g..	Fruit, vegetable, high caloric drink consumption (parent questionnaires); overweight, obesity, dietary habits; motoric testing	Higher reported proportions of healthy food; Prevalence of overweight and obesity as well as motoric testing results not statistically different between INT and CON

		physically active leisure activities for families; Internet platform for teachers and parents		
Jasmund (2009); Germany;	Baseline 274 children, 212 children after one yr (end of longitudinal study) 11 Kindergartens (E: 7, C: 4); Longitudinal study with three times of measuring	Children´s Development: No Intervention; relation between childcare environment / policy and development aspects, especially motor development, of the child, experiment group („Bewegungskindergärten“) are distinguished by play environment, activities, staff qualification and policy specialised on motor activity	Motor Development (Test MOT 4-6) Socio-emotional development (diverse rating questionnaires)	No significant differences between experimental and control group
Niederer et al. (2009); Switzerland; „Ballabeina“	655 Children (I: 343, C: 312) at baseline, ages 4-6yrs, ‚high migrant population‘ (73%),up to now no systematic dates available for post-intervention 40 (I: 20, C: 20) preschool classes Partially blinded Cluster RCT	PA, nutrition, media use: Multi-disciplinary, multilevel lifestyle intervention: Specially trained physical education teachers (HP) to coach teachers and to intervene on different levels (children, etc.) Children: PA lessons 45min, 4 times/wk, in the beginning by HP with regular preschool teacher, with ongoing intervention decreasing contribution of HP, PA lessons prepared by an exercise physiologist, in / around preschool, once weekly in gym, focus on coordination and endurance; additional portable play material; Weekly 45 min nutrition lessons One additional extracurricular PA lesson Teachers: two afternoon workshops on PA, nutrition, media use, sleep) prior to start of intervention, Parents/families: PA and nutrition home activities (21 cards with specific tasks, music CD), information evenings, information booklets Duration of Intervention: 1 year	BMI, Aerobic fitness (20m shuttle run test), total (skinfolds) and central body fat (waist circumference), motor abilities (tests), PA and sleep duration (accelerometry, questionnaires) and others	Up to now findings not systematically published. First findings shown on conferences: Compared with controls, children in the intervention group had no difference in BMI, but a more favorable improved performance in aerobic (p=0.01) and overall (p=0.009) fitness and significant relative decreases in body fat (p=0.003), % body fat (p=0.017) and waist circumference (p=0.001). There were siginificant differences in reported, but not in measured PA, in media use and some aspects of nutritional behavior, but not in sleep duration. (ENDO 2010)
Roth et al. (2010); Germany; „PAKT“	709 children (I: 368, C: 341) at baseline, age 4.0 to 5.9 yrs 41 Kindergartens (I: 21, C: 20) Cluster RCT	PA, motor skills, media use multilevel lifestyle intervention: Children: daily 30-min sessions of physical education (theoretical base: psychomotor education), instructed by kindergarten	PA (accelerometry), motor skill performance (diverse tests), BMI, skinfolds, media use (questionnaire), and others	Up to now findings not systematically published. First findings shown on conferences: statistically significant improvements in LPA (p<.05), MPA (p<.01), MVPA (p<.01) during the intervention, in

		teachers under supervision of the research team, based on collection of games and exercise tasks (predetermined structure, individual focus), structure of lessons: initial ritual and introduction, main activity part with focus on perception and coordinative skills, additional endurance etc., final cool down game and feedback Teachers:Training in workshops and during intervention (supervision), written instructional materials Parents: 52 physical activity homework cards (activity games, motor tasks), information evenings, written information Duration of Intervention: 1 year Follow-up 3 months after intervention		selected aspects of motor skills (balancing, standing long jump, jump coordination) during and at the end of the intervention in intervention vs. control group; statistically significant improvements in body fat (skinfolds). No effects were found for BMI and other selected aspects of motor skills (flexibility, complex motor performance)
Environment				
Dowda et al. (2004); United States	266 children in the final sample with complete data, age 3-5 yrs 9 preschools Cross-sectional, randomly assigned for intervention	PA and sedentary behaviour: No Intervention; relation between preschool practices / policies and overall quality of preschools and PA-levels of children	PA (direct observation with OSRAC-P), school policies / practices (interview), assessment of preschool-quality (ECERS-R)	Number of field trips and college-educated teachers were significant ($p<.001$ respectively $p=.03$) positively associated with playground MVPA in children. Quality of preschool assessed with ECERS-R: scores were inversely associated ($p=.05$) with sedentary activity (Mixed-Model-ANOVAS)
Alhassan et al. (2006); United States	33 Latino children (I: 18, C: 15), age 3–5 yr; 1 Head Start center; one class randomly assigned for intervention	Physical activity: intervention class received 30 min of outdoor time in morning and afternoon additionally, for two consecutive days	PA (accelerometer)	No significant difference in PA between CON and INT for total PA time, at-school PA, after-school PA, or percent time MVPA
Benjamin et al. (2007); United States	19 child care centers (I: 15, C: 4); randomly assigned for intervention; pilot study, pre-post-design	Obesity: NAP SACC programme in intervention centers with components: self-assessment instrument of PA-related practices and environment at baseline, action planning with at least 3 areas for improvement, workshops, assistance from special consultants; self-assessment intervention period 6 month	Teacher-reported Changes pre-post-intervention scores and descriptions in self-assessment-instrument	PA-related: Intervention Centers physical activity score improved from baseline 34.23 to 41.00 after intervention ($p <.001$)

Ward et al. (2008); United States	84 child care (I: 58, C: 26) centers, Randomized controlled study	Obesity: NAP SACC programme in intervention centers with components: self-assessment instrument of PA-related practices and environment at baseline, action planning with at least 3 areas for improvement, workshops, assistance from special consultants; self-assessment intervention period 6 month	PA- and Nutrition-Environment (direct observation with EPAO-instrument: 75 items)	No significant difference between intervention and control centers for intention-to-treat or per protocol for the whole environment; for individual EPAO items intervention had +3.6 change score compared with -0.2 for controls (p<.05)
Bower et al.(2008); United States	20 child-care-centers; Cross-sectional, centres randomly selected	PA: No Intervention; association between childcare environment and PA-behaviour of children	PA (direct observation OSRAC-P at center level); environment (direct observation with EPAO instrument)	Centres with higher physical activity environment scores had children who were more physically active and less inactive while in child care; the active opportunities subscale was related most strongly to all measures of PA.
Hannon, Brown (2008); United States	64 children (final sample with completed data), age 3–5 yrs, One university preschool; Pre-post-design	PA: added additional equipment (~$1000) to the outdoor playground; research staff set up (10 min) equipment every day for 5 d; play area designed by an early childhood movement specialist into a course; equipment was placed in an irregular circle, following the natural contours of the play area, with enough space between stations so that children were unlikely to be crowded; equipment chosen to support multiple locomotor (running, jumping, crawling) and manipulative activities (basketball shooting, target kicking, throwing) Duration of Intervention: 5 days No follow-up	PA (accelerometer), measured for 5 d during each outdoor time before and after intervention	Increases were noted in VPA (p<.001), MPA (p<.001), and light PA (p<.001), whereas sedentary time decreased by 16% (p<.001). Consistent increases in PA were observed across all 5 d of monitoring
Cardon et al. (2008); Belgium	783 children in the final sample, mean age 5.3 ± 0.4 yrs old 39 preschools Cross-sectional, random sample	PA: No intervention; influence of childcare environment on PA-levels of children in outdoor recess	PA (pedometry), playground factors (observed and measured by the research team)	Less children per square meter of play space and shorter recess periods were significantly (p<.05 boys, p<.01 girls resp. p<.001 boys and girls) associated with higher step counts per minute. Hard play surfaces were borderline significant (p<.07) predictor for higher PA in boys only. The number of supervisors was significantly (p<.05), inversely associated with PA in girls. No association was found between PA and ground markings, vegetation or toys.

Cardon et al. (2009); Belgium	636 children (I1: 150, I2: 161, I3: 161, C: 162) at baseline, age 4-5, 583 at post-intervention (equal dropout) 40 preschools (I1: 10, I2: 10, I3: 10, C: 10) Cluster RCT	PA: 3 Intervention groups: 1. portable play equipment was provided: different balls, throwing discs and rings, bean bags, hoops, wipes, jumping bags (costs: ~$370) 2. markings were painted on the playground of the preschool („trail“, „river with crossings“, hopscotch) 3. portable play equipment was provided and markings were painted Recommendation to preschool teachers to introduce new material to children for 1 hour min. and to set up material every recess Duration of intervention: 4 to 6 weeks Follow-up at end of intervention	PA (accelerometry) during recess at baseline and 4 to 6 weeks after implementation of intervention	No effect in increasing the average activity levels or the percentages of engagement in moderate or vigorous activity, or in decreasing sedentary time between any of the intervention groups and the control group
Brown et al. (2009); United States; “Children´s Activity and Movement in Preschools Study (CHAMPS)”	476 children observed inside, 372 children observed outside, age 3-5yrs 24 preschools Cross-sectional study design with two waves of data collection separated by 13-19 months;. Stratified randomly selection	PA: No Intervention; description of physical activity behaviours and the accompanying social and environmental events and determine which contextual conditions were predictors of PA	PA and accompanying social and environmental contextual conditions (direct observation with two simultaneously recording observers using OSRAC-P)	Assessment with Logistic Regressions showed that MVPA was connected with specific outdoor contexts (e.g. 26.9% with children playing with balls and objects vs. 13.9 % with fixed equipment and 13.5% with wheel toys, odds ratio 3.21 respectively 1.31 resp. 1.29), depending on the Initiator of activities and the group composition (e.g. 28.5% solitary play vs. 11.2 % adult present, odds ratio 3.55 vs. 1.00)
Dowda et al. (2009); United States; “Children´s Activity and Movement in Preschools Study (CHAMPS)”	299 children in the final sample, age 3-5 yrs 20 preschools Cross-sectional study design with two waves of data collection separated by 13-19 months	PA: No Intervention; examination of policies and characteristics of different preschools and the influence on children´s PA	PA (accelerometry), school policies / practices (interview), assessment of preschool-quality (ECERS-R)	Children spent fewer minutes per hour in sedentary activity and more minutes per hour in MVPA in preschools with higher quality ($p=.01$), with less fixed playground equipment ($p<.01$ respectively $p=.02$), more portable playground equipment ($p=.05$ respectively $p=.03$), lower use of electronic media ($p=.05$ respectively $p=.03$) and larger playgrounds ($p=.02$). Children in preschools with all of these characteristics had significantly more MVPA ($p=.001$) and fewer sedentary time ($p<.001$) compared with children in other preschools.

Brown, Googe et al. (2009); United States	5 children, Age 4 yr, in 2 preschools; Single-case withdrawal of intervention research design, formative	PA: Implementation of two teacher-led PA-activities that consisted of the components: teacher-guided discussion of PA, „Plan, Do and Review"-Process with children, teacher pep-talk, teacher participation in PA, teacher encouragement and acknowledgement of PA	PA and teacher-arranged activities (direct observation using OSRAC-P)	Observations during teacher-implemented activities indicate increased MVPA on intervention days compared to non-intervention days, teacher enthusiasm and participation critical for reaching efforts

Abbreviations: PA: Physical Activity; RCT: Randomised Controlled Trial; SES: socioeconomic status; EPAO: Environment and Policy Assessment; OSRAC-P: Observational System for Recording Activity in Children; NAP SACC: Nutrition and Physical Activity Self-Assessment for Child Care; E: experiment group