Title:

Identifying the most important energy balance behaviours among 10-12 year olds, and their parents, that are associated with excessive weight gain and overweight

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Declarations:

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

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1 Introduction

The aim of this comprehensive systematic review was to identify the most important energy balance behaviours among children aged 10 to 12 years - and their parents - that are associated with excessive weight gain and overweight, with the resulting intention of developing an intervention in this particular grouping. In the most general sense, there are two energy balance behaviours: energy intake (dietary behaviour), and energy expenditure (basic metabolic rate and physical activities). However, more specific behaviours within these general categories were central to the review to select more specific goals for obesity prevention interventions (such as snack consumption or television viewing) as well as differences in such behaviours across the European regions in order to select specific behaviour change goals tailored to specific regional and cultural circumstances.

Relevant exposures of interest included patterns of diet, food and drink consumption, food preparation, constituents of dietary intake, physical activity and inactivity, energy intake, energy density of diet, energy expenditure, body composition and weight in fetal life (including birthweight) and growth, body composition and weight in infancy/childhood. Outcomes of interest included markers of weight gain; overweight; obesity; markers of body composition; markers of distribution of fat.

2 Methodology

Studies that included either baseline (predictors) and/or outcomes in children aged 10, 11 and 12 years old and/or their parents were incorporated into the review.

In accordance with the original protocol, the intention was to explore two defined levels of evidence, namely *epidemiological studies* and *exploratory ideas trials* relevant to the research question. Time constraints in terms of the review ensured the former was prioritised, with ideal studies for inclusion being prospective cohort studies with at least one exposure (listed previously) measured at baseline and at endpoint at least 9 months later. This timeframe was to accommodate the inclusion of potentially useful evidence from studies that lasted for an academic year.

Studies using a randomised controlled trial design were not included as the remit of this work package was to look at what typically happens over a period of time with regards to energy balance behaviours associated with excessive weight gain and overweight in children aged 10-12 years old and/or their parents, not what happened to these particular energy balance behaviours because a specific intervention was introduced.

Only studies published in English were included.

Systematic reviews

Potentially relevant systematic reviews (from 1995 onwards) were examined for studies which may fit the preset inclusion criteria; these reviews can be found in Appendix 3.

Quality issues

Quality issues (e.g. ascertainment of outcome, population studied, sample size, and adjustment for potential confounding) were assessed to explore the reasons for heterogeneity in study results, to guide interpretation of findings, to aid determination of the strength of inferences and to guide recommendations for future research.

Quality issues that were deemed important for interpretation of the evidence, where reported, are included in this review at the end of each exposure section.

3 Results of the search

Searching was conducted in May 2009, with relevant literature included in the review up to and including the search date.

The overall aim of the data synthesis is to collate and summarise the results of the studies included in the review. Although we stated that formal meta-analyses would be attempted where sufficient data existed, it was not possible to run any meta-analytic comparisons from the included studies due to insufficient data (i.e. the availability of adequate information in an appropriate format and at identical points in time). Therefore, only narrative approaches to data analysis have been employed in this review.

Databases

The following databases were searched as part of the searching process: MEDLINE, EMBASE, CINAHL, Web of Science, Cochrane library incorporating: DARE database, Systematic review database, HTA database.

Search strategy

The search was designed to identify all types of evidence except for case series and case control studies. Other observational studies, trials and ecological studies were included at the searching stage.

A systematic search of the literature was conducted to identify relevant primary studies. Only primary studies reported from 1990 were included, as behaviour patterns have been subject to change since then.

A systematic search of the literature was also conducted to identify relevant systematic reviews; as with primary studies, only recent reviews of potential relevance were considered, from 1995 onwards.

The search strategy itself was designed by combining search terms relating to obesity and overweight with the search terms for diet, nutrition and physical activity. The search strategy was adapted for each database where appropriate. There is an enormous amount of literature around diet, nutrition and physical activity and obesity and the search strategy was refined a number of times in order to optimise the selectivity of the search while maintaining sensitivity.

The full list of search terms for this review can be found in Appendix 4.

The search hits from MEDLINE, EMBASE, CINAHL, ISI Web of Science, and the Cochrane Library were downloaded and entered into Endnote reference management software, combined and duplicates were removed. These searches resulted in the identification of 9,755 articles.

Table 1. Summary of the literature search

Database	**No. of hits from search**
MEDLINE	5,370
EMBASE	3,810
CINAHL	1,035
Web of Science	3,533
Cochrane Library	10
TOTAL (combined and de-duplicated)	**9,755**

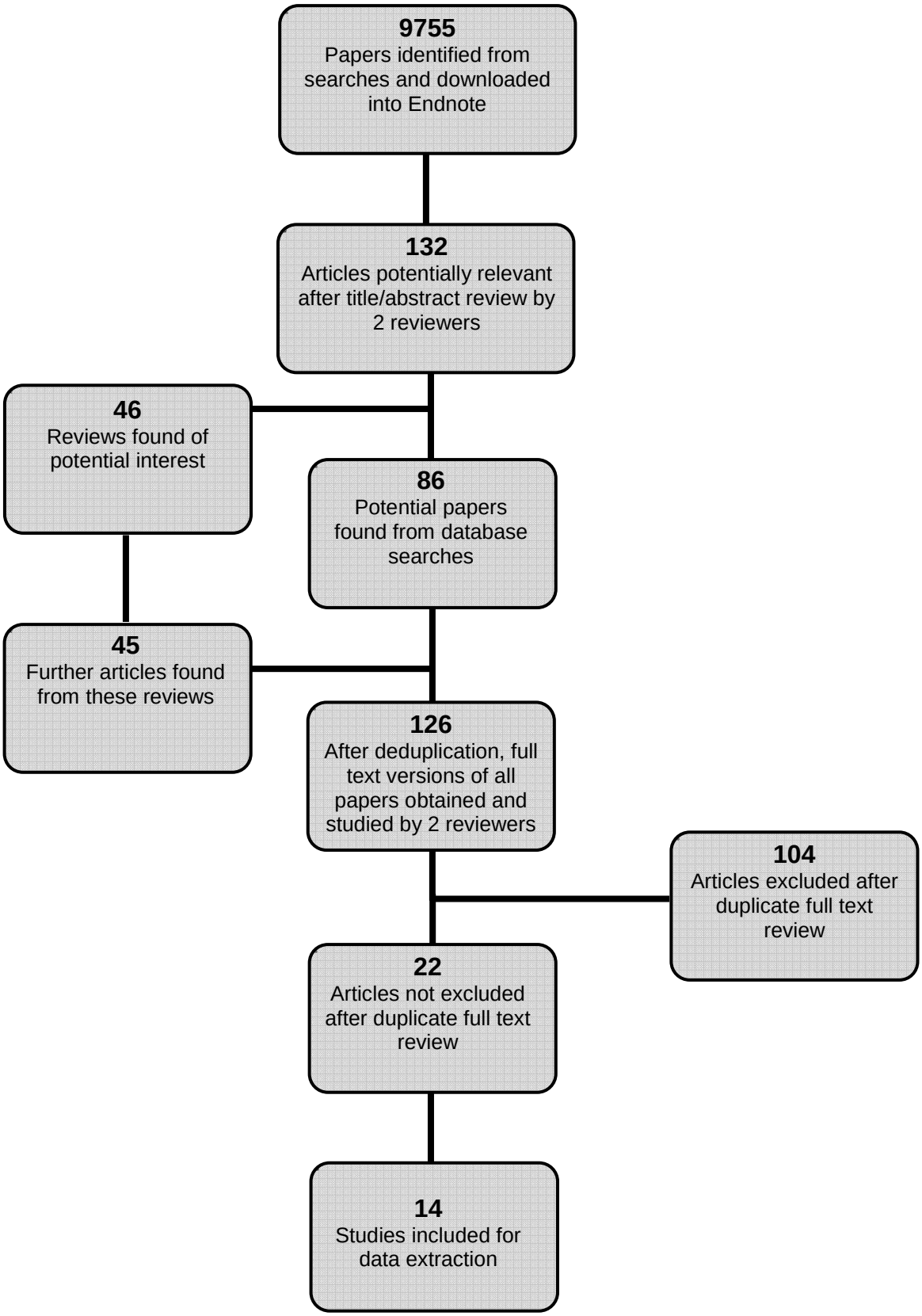
The articles identified from the searches (in Endnote) were initially screened – on the basis of titles and abstracts – by one reviewer (WD) to remove any articles that were clearly not relevant. Hand searching of systematic reviews and key reviews was also undertaken.

From the remaining list, 132 articles were identified as being 'potentially relevant for the review'; 86 original papers and 46 systematic reviews. From these reviews, a further 45 papers were identified, and after a final de-duplication of the 131 remaining articles, 126 were put forward for possible inclusion. Full text versions of all of these papers were obtained. Inclusion or exclusion of articles into the review was carried out in duplicate (WD, HM) and any disagreements resolved by a third reviewer (CS).

22 papers remained after the duplicated full text review stage, with all papers included for data extraction. A number of these papers were publications based on the same study, which meant a total of 14 individual studies formed part of this review.

Each of the studies included in the review can be comprised of single or multiple papers. We have ensured simple identification of each study by allocating a reference which is usually composed of the surname of the first author and the year of the primary reference for the study (e.g. Libuda 2008). One reference for each study has been awarded the status of the 'primary reference'.

Figure 1. Flowchart of search



4 Description of studies

4.1 Amount of data and study types

Numbers of study types:

14 prospective cohort studies (22 papers) with relevant data were identified.

Amount of data extracted:

Within the 14 included studies, a number of different exposures may have been assessed e.g. some studies may have reported physical activity AND physical inactivity. For each exposure within the study, several different weight-related outcomes were often reported e.g. some studies may have reported outcomes related to BMI, weight and waist circumference. Results were extracted for each exposure and outcome.

4.2. Populations studied

Table 2 shows the number and percentage (to one decimal place) of studies reported in the review by country:

Table 2. Number and percentage of studies by country

Country of Study	No of studies	Percentage Studies (%)
France	2	14.3
Italy	2	14.3
Netherlands	2	14.3
Denmark	1	7.1
England	1	7.1
Finland	1	7.1
Germany	1	7.1
Greece	1	7.1
Northern Ireland	1	7.1
Spain	1	7.1
Wales	1	7.1
Total results	**14**	**100.0**

4.3 Outcomes

Several different weight-related outcomes with relevant exposures were identified in the studies included in this review e.g. outcomes related to measures of weight, BMI, waist circumference, skinfolds etc. This wide range of outcomes is one of the reasons why it was not possible to combine studies in meta-analyses. The outcomes are reported more fully in the text.

4.4 Length of follow-up

All studies included in the review have length of follow-up greater than nine months. The length of follow-up for each study is further discussed in the text.

5 Results by determinants

5.1 Reported determinants that may protect from developing excess overweight

5.1.1 Higher physical activity levels

Three prospective cohort studies were found (Elgar et al., 2005), (Mamalakis et al., 2000) and (Vogels et al., 2006).

A Welsh cohort study (Elgar et al., 2005) examined the effect of hours per week spent playing sport or exercising upon changes in body mass in a cohort of 355 adolescents of mean age 12.3 years, with a follow-up of four years. Regression analyses showed that increased levels of physical activity predicted change in BMI over 4 years (Reg coeff = -0.08, $p<0.05$). However, the number of hours per week spent playing sports or exercising at baseline did not predict BMI at follow-up.

As part of the Greek-based Health and Nutrition Education programme, (Mamalakis et al., 2000) conducted a follow-up study reporting on obesity indices in a cohort of Cretan children, measured prospectively at ages 6, 9 and 12 years. At baseline, 1046 first-grade pupils were examined, with a sample of 831 re-examined six years later. Five physical fitness assessments were carried out on the cohort – sit and reach tests, sit-ups, hand-grip tests, a standing broad jump test and an endurance 20m shuttle run test (ERT – see quality section for further details). The latter test demonstrated an association between higher ERT levels – presuming increased physical activity levels – and lower obesity amongst participants ($P<0.0001$).

(Vogels et al., 2006), studying a Dutch cohort of 105 children, examined the effects of early development, parental and genetic variables, and behavioural determinants on overweight at the age of 12 years, having previously followed the cohort from birth to age 7 years. Physical activity was estimated using the Baecke Questionnaire, assessing school, sports and leisure activity. Using this tool, the study reported that a high physical activity score – and therefore energy expenditure – was associated with low percentage body fat ($P < 0.05$). No significant correlation was found with BMI.

Important quality issues for the interpretation of the evidence

- Nature of definition of exposure

  Physical activity was assessed using the Baecke Questionnaire in the Vogels study, and via the HBSC questionnaire in the Elgar study. In the Mamalakis study, physical fitness was assessed using five specific tests, including an endurance 20m shuttle run (ERT); a standard test of cardiovascular fitness where speed is gradually increased, and participants withstanding a greater number of these gradual increases achieved a higher ERT score.

- Ascertainment of outcome

  Body weight and height were measured in each of the three studies.

- Populations studied

  One study was based in Wales, one in Greece, and one in the Netherlands.

- Sample size

  Each of the three studies were cohort studies (n=105 to 831).

- Adjustment for appropriate confounders

  All studies adjusted for some potential confounders.

5.1.2 Three hours a week (or more) of extra-curricular sports activities

One prospective cohort study was found (Ara et al., 2006).

In a Spanish cohort of 42 male children (mean age: 9.4±1.4 years), (Ara et al., 2006) aimed to analyse the effect of extra-curricular physical activity on both fat mass accumulation and physical fitness at baseline, and at the 3.3 year follow-up stage. From these 42 participants, two groups were formed, namely the 'PA' group (26 participants) and 'non-PA' group (16 participants); the former being physically active for at least three hours per week across the three-year study. Without any dietary intervention, the authors concluded that children who regularly participate in sports activities for a minimum of three hours per week have improved protection against total and regional fat mass accumulation.

Important quality issues for the interpretation of the evidence

- Nature of definition of exposure

  Physical fitness variables (dynamic and isometric force, anaerobic capacity and maximal aerobic power) were determined in all subjects, while each participant also completed questionnaires based around personal data and sports record (including number of hours training per week).

- Ascertainment of outcome

  Body weight and height were measured in the Ara study, while body circumferences and skinfolds were also measured by the research team.

- Populations studied

  The study population were based in Spain.

- Sample size

  42 male children formed the cohort in this longitudinal study.

- Adjustment for appropriate confounders

  Any adjustment for potential confounders was not reported in the study.

5.1.3 Having a 'healthier lifestyle'

One prospective cohort study was found (Boreham et al., 1999).

The Young Hearts Project, based in Northern Ireland, is a long-term study of coronary heart disease (CHD) factors in young people. As part of the study, (Boreham et al., 1999) examined the relationships between the longitudinal development of biological risk factors for CHD and the development of lifestyles considered to be atherogenic. Repeated measurements were conducted at both 12 and 15 years of age in a sample of 459 adolescents (229 boys, 230 girls). The authors concluded that the development of biological risk factors for CHD over the adolescent period is related to certain lifestyle behaviours, particularly physical activity, smoking and dietary intake.

Important quality issues for the interpretation of the evidence

- Nature of definition of exposure

  In the Boreham study, a physical activity score and smoking status for each subject was derived using a confidential recall questionnaire, while dietary intake was assessed using dietary history via an open-ended interview and a photographic food atlas to determine portion sizes.

- Ascertainment of outcome

  Anthropometrics were measured by the research team in the Boreham study.

- Populations studied

  The study population were based in Northern Ireland.

- Sample size

  In terms of the (Boreham et al., 1999) study, 459 adolescents participated.

- Adjustment for appropriate confounders

  The study adjusted for some potential confounders.

5.2 Reported determinants that may promote excess weight gain

5.2.1 Parental obesity

Three prospective studies were found (Maffeis et al., 1998), (Verduci et al., 2007), (Vogels et al., 2006).

In a cohort of 112 Italian children studied initially aged nine years of age and followed up over a period of four years, (Maffeis et al., 1998) aimed to assess the complex relationships between diet, body composition, physical activity, parents' obesity and adiposity. Parental obesity was seen to be the main risk factor of obesity within this particular cohort at baseline and at the age of 12 years, in both male and female subjects.

(Verduci et al., 2007) assessed dietary and macronutrient intakes during the first ten years of life in a sample of 61 healthy Italian children (28 females, 33 males), with measurements taken at 1, 5, 8 and 10 years of age. Although the rate of overweight

at 10 years of age was almost three times higher in children with than without parental overweight, the relatively small sample size ensured the association was not statistically significant.

In a Dutch cohort of 105 children (60 boys, 45 girls), (Vogels et al., 2006) examined the effects of early development, parental and genetic variables, and behavioural determinants on overweight at the age of 12 years, having previously followed the cohort from birth to 7 years. Using linear regression analyses, a high BMI of the child's father was found to be significantly associated with child overweight at the age of 12 years ($P<0.05$). No similar association with the mother of the child was found.

Important quality issues for the interpretation of the evidence

- Nature of definition of exposure

  Overweight for parents and children in the Vogels study was defined using specific cut-offs described elsewhere, while the Verduci study used the same method for children (if BMI was above the age and sex-adjusted curve passing through the cut-off of 25 kg/m^2 at 18 years), yet defined parental overweight if BMI $\geq$ 25kg/m^2. Obesity in the Maffeis study was defined as relative BMI > 120%, where relative BMI = (BMI/BMI at 50th centile for age and gender) x 100.

- Ascertainment of outcome

  Both parent and child height/weight measurements were recorded by the research team in the Maffeis and Verduci studies. In the Vogels study, both parents reported their actual body weight, which was measured at home using standard instructions given by the research team. Height, which was originally measured, was obtained from the passports of parents. Similar anthropometric

measurements of children participants were measured in the study.

- Populations studied

  Two studies were based in Italy, and one in the Netherlands.

- Sample size

  Each of the three studies were cohort studies (n=61 to 112).

- Adjustment for appropriate confounders

  All studies adjusted for some potential confounders.

5.2.2 Higher levels of sedentary behaviours

Two prospective cohort studies were found (Elgar et al., 2005), (Maffeis et al., 1998).

(Elgar et al., 2005) examined the effect of sedentary behaviour on changes in body mass in a Welsh cohort of 355 adolescents of mean age 12.3 years, with a follow-up of 4 years. Sedentary behaviours included the hours spent each week either watching television or playing computer or video games. Regression analyses showed that sedentary behaviour at baseline predicted BMI at follow-up (reg coeff = 0.19, $p<0.01$). However, there was no significant association between sedentary behaviour and change in BMI over 4 years. TV viewing was self-reported by questionnaires administered by trained reviewers. Weight and height were measured by the research team.

In a cohort of Italian children studied initially aged nine years of age and followed up over a period of four years (n = 112), (Maffeis et al., 1998) found that TV viewing (self-reported using an interview) was not associated with change in relative BMI over the following four years. The study reports a number of cross-sectional and

longitudinal analyses and it is not always clear which analyses are longitudinal. No further relevant data was reported in the paper. Weight and height outcomes were measured by the research team.

Important quality issues for the interpretation of the evidence

- Nature of definition of exposure

  TV viewing or physical inactivity was self-reported in the (Elgar et al., 2005) and (Maffeis et al., 1998) studies.

- Ascertainment of outcome

  Weight-related outcomes were measured in both studies in this section.

- Populations studied

  One study was based in Italy, while the other was based in Wales.

- Sample size

  Both studies were cohort studies (n=112 to 355).

- Adjustment for appropriate confounders

  Both studies adjusted for some potential confounders.

5.2.3 Obesity at baseline

Two prospective studies were found (Raitakari et al., 2005), (Lake et al., 2001).

The Young Finns Study is a longitudinal study from childhood to adulthood, with the baseline study of 1980 including 3,596 children and adolescents aged 3-18 years. In a 2001 follow-up (n=2283, ages 24-39 years), (Raitakari et al., 2005) assessed relationships between risk factors identified in childhood, including obesity, and adulthood. Longitudinal data indicate that obesity in youth (BMI>90th percentile) is a

risk factor for obesity in adulthood (r=0.45, P<0.0001), with obesity in adolescence between the ages of 12 and 18 years carrying an approximate four-fold increased risk of being obese in adulthood 21 years later at ages 33-39 years.

The ASH30 study originally recruited a group of 405 adolescents (aged 11-13 years) based in north-east England in 1979/80, followed-up in 2000/01 aged 30-32 years. (Lake et al., 2001), examining 196 subjects (115 female, 81 male) at the follow-up stage, aimed to assess body mass index from young adolescence to adulthood. Using Pearson correlation to measure the strength of association between BMI in young adolescence and in adulthood, a highly significant correlation was identified across the 20-year study period (P<0.001, R = +0.532).

Important quality issues for the interpretation of the evidence

- Nature of definition of exposure.

  In terms of the Raitakari study, obesity in youth was given as BMI > 90th percentile, while adult obesity was defined as BMI > 30kg/m^2. Adult overweight was described in the Lake study as BMI > 25 with obese classification as BMI > 30.

- Ascertainment of outcome.

  Weight and height related outcomes were measured in both studies in this section.

- Populations studied

  One study was based in Finland, while the other was based in England.

- Sample size

  Both studies were cohort studies (n=196 to 2283).

- Adjustment for appropriate confounders.

  The Young Finns study adjusted for some potential confounders, while the ASH30

study did not report such information.

5.2.4 Higher energy intake at age 1 (higher protein / lower CHO intake)

Two prospective cohort studies were found (Hoppe et al., 2004), (Verduci et al., 2007).

In a cohort of male and female Danish children, (Hoppe et al., 2004) studied the children (n=142) initially at nine months of age, and followed them up for nine years when they were 10 years old. (Hoppe et al., 2004) found that protein intake (g/day) at 9 months of age (assessment 5-day weighed food record) was positively associated with body weight (reg coeff=0.16, 95% CI (0.29 ,0.37), p<0.012 at 10 years of age. Similar results were seen for protein intake (%energy) and body weight (reg coeff =0.44, 95% CI (0.12, 0.76), p<0.01). Protein intake (g/day and %energy) at nine months of age was not associated with BMI or % body fat at 10 years of age.

(Verduci et al., 2007) studied 61 healthy Italian infants (28 females, 33 males) from birth until 10 years of age, assessing dietary and macronutrient intakes across this period. Children overweight at the age of 10 years ingested at 1 year a higher percentage of proteins than non-overweight children, and also a lower percentage of carbohydrates ($P < 0.05$).

Important quality issues for interpretation of the evidence

- Nature of definition of exposure

  A 7-day food record was used to assess nutritional intake in the study by Hoppe, while a standardised food frequency questionnaire was used by Verduci.

- Ascertainment of outcome

  Body weight and height were measured in both of the studies included in this section.

- Populations studied

  One study was from Denmark, while the other was based in Italy.

- Sample size

  Both studies were prospective cohorts (n=61 to 142).

- Adjustment for appropriate confounders

  Both studies adjusted for some potential confounders.

5.2.5 Rapid increase in body weight before age 1 year

One prospective cohort study was found (Vogels et al., 2006).

In a Dutch cohort of 105 children, (Vogels et al., 2006) studied the effects of early development, parental and genetic variables, and behavioural determinants on overweight at the age of 12 years, having previously followed the cohort from birth to 7 years. Linear regression analyses showed that a rapid increase in body weight during the first year of life was significantly associated with overweight at the age of 12 years ($P < 0.05$).

Important quality issues for the interpretation of the evidence

- Nature of definition of exposure

  Overweight for parents and children in the Vogels study was defined using specific cut-offs described elsewhere.

- Ascertainment of outcome

  Anthropometric measurements of children participants were measured in the study.

- Populations studied

  The study was based in the Netherlands.

- Sample size

  The cohort study had a sample size of n=105.

- Adjustment for appropriate confounders

  The Vogels study adjusted for some potential confounders.

5.2.6 Dietary restraint practised by mother

One prospective cohort study was found (Vogels et al., 2006).

Studying a 105-strong Dutch cohort, (Vogels et al., 2006) examined the effects of early development, parental and genetic variables, and behavioural determinants on overweight at the age of 12 years, having previously followed the cohort from birth to 7 years. Linear regression analyses demonstrated that a high dietary restraint score for the mother of the child was significantly associated with child overweight at the age of 12 years ($P < 0.05$).

Important quality issues for the interpretation of the evidence

- Nature of definition of exposure

  Eating behaviour was assessed using a validated Dutch version of a 'Three-Factor Eating Questionnaire'.

- Ascertainment of outcome

  Both parents reported their actual body weight, which was measured at home using standard instructions given by the research team. Height, which was originally measured, was obtained from the passports of parents. Similar anthropometric measurements of children participants were measured in the study.

- Populations studied

  The study was based in the Netherlands.

- Sample size

  The cohort study had a sample size of n=105.

- Adjustment for appropriate confounders

  The Vogels study adjusted for some potential confounders.

5.2.7 Decrease in moderate physical activity in girls

One prospective cohort study was found (Kettaneh et al., 2005).

(Kettaneh et al., 2005) evaluated the association between the level of moderate or vigorous physical activity (hours / week) and BMI over 2 years in a cohort of 436 French children. At follow-up, BMI was predicted by the level of moderate physical activity in girls but not in boys (High level of moderate physical activity: BMI 19.7 (95% CI (19.5, 20.0)); Low level of moderate physical activity: BMI 19.4, 95% CI

(19.2, 19.6); p for difference = 0.03). Data for boys was not reported in the paper. However, BMI was not predicted by the level of vigorous physical activity (High level of vigorous physical activity: BMI 19.5, 95% CI (19.3, 19.7); Low level of vigorous physical activity: BMI 19.6, 95% CI (19.4, 19.9); p for difference= 0.14).

Important quality issues for interpretation of the evidence

- Nature of definition of exposure

  Physical activity was assessed using a Modifiable Activity Questionnaire, while moderate activity was defined in the study as activity which was 'not hard enough to make participants breathe heavily and make their heart beat fast'.

- Ascertainment of outcome

  Body weight and height were measured in the (Kettaneh et al., 2005) study.

- Populations studied

  The study population in this section was from France.

- Sample size.

  The sample size involved in the Kettaneh study was n=436.

- Adjustment for appropriate confounders

  The (Kettaneh et al., 2005) study adjusted for some potential confounders.

5.2.8 Increase in sugar-sweetened soft drinks and fruit juices

One prospective cohort study was found (Libuda et al., 2008).

Established in 1985, the DONALD (Dortmund Nutritional and Anthropometric Longitudinally Designed) Study collected information on the nutrition, development, metabolism and health status of subjects between infancy and early adulthood. As

part of this longitudinal study, (Libuda et al., 2008) investigated the relationship between the consumption of soft drinks (regular and diet) and fruit juices and body weight across five years in German adolescents. Complete anthropometric and dietary data was available for 244 subjects (125 boys, 119 girls), mean age at baseline 11.9 years. In girls, an increase in energetic beverage consumption over the study period was associated with an increased in BMI-SDS (+0.070 SDS/MJ increase in energetic beverage consumption; P=0.01). Also, analyses of regular soft drinks and fruit juices showed that, in girls, BMI-SDS increased with increased fruit juice consumption (+0.096 SDS/MJ increase in fruit juice consumption; P=0.01), and to a lesser extent with regular soft drink consumption (+0.055 SDS/MJ increase in regular soft drink consumption; P=0.08). In boys, however, energetic beverage consumption was not associated with BMI-SDS or percentage body fat.

Important quality issues for interpretation of the evidence

- Nature of definition of exposure

  Three-day weight dietary records were used in the study, with energy and nutrient intakes calculated on this basis. Energetic beverages were defined as ‘a combined variable, made up of both regular soft drinks and fruit juices’.

- Ascertainment of outcome

  Body weight, height and skinfolds were measured in the (Libuda et al., 2008) study.

- Populations studied

  The study population in this section was based in Dortmund, Germany.

- Sample size.

  The sample size involved in the Libuda study was n=244.

- Adjustment for appropriate confounders

  The Libuda study adjusted for some potential confounders.

5.2.9 Increase in snack consumption

One prospective cohort study was found (Elgar et al., 2005).

A recent Welsh cohort study (Elgar et al., 2005) examined the effect of snacking on body mass in a cohort of 355 adolescents of mean age 12.3 years, with a follow-up of 4 years. Regression analyses showed that the number of snacks per day at baseline predicted BMI at follow-up (Reg coeff = 0.13, $p<0.05$). However, there was no significant association between snacks per day and change in BMI over 4 years. Weight and height were measured by the research team.

Important quality issues for interpretation of the evidence

- Nature of definition of exposure

  The HBSC questionnaire was used in the Elgar study, administered by trained interviewers to collect information on dieting and meal skipping amongst other variables analysed in the study.

- Ascertainment of outcome

  Weight and height were measured by the research team in the (Elgar et al., 2005) study.

- Populations studied

  The population studied was based in Wales.

- Sample size

  The size of the cohort was n=355.

- Adjustment for appropriate confounders

  The Elgar study adjusted for some potential confounders.

5.2.10 Skipping breakfast

One prospective cohort study was found (Elgar et al., 2005).

A Welsh cohort study (Elgar et al., 2005) examined the effect of skipping breakfast on body mass in a cohort of 355 adolescents of mean age 12.3 years, with a follow-up of 4 years. Regression analyses showed that there was an association between skipping breakfast at baseline and BMI at follow-up (Reg coeff = 0.13, $p<0.05$). However, there was no significant association between skipping breakfast and *change* in BMI over 4 years. There was also no significant relationship between skipping lunch or dinner and BMI or change in BMI over 4 years. Weight and height were measured by the research team.

Important quality issues for interpretation of the evidence

- Nature of definition of exposure

  The HBSC questionnaire was used in the Elgar study, administered by trained interviewers to collect information on dieting and meal skipping amongst other variables analysed in the study.

- Ascertainment of outcome

  Body weight and height were measured by the research team in the Elgar study.

- Populations studied

  The Elgar study was conducted in Wales.

- Sample size

  The cohort size was n=355.

- Adjustment for appropriate confounders

  The Elgar study adjusted for some potential confounders.

5.3 Included studies without definitive conclusions regarding determinants of overweight/obesity

As part of the French longitudinal study of growth and nutrition, (Deheeger et al., 2002) assessed nutritional intake, growth parameters, physical activity and television viewing in 94 French adolescents (55 boys, 39 girls) examined at 10, 14 and 16 years of age. The authors concluded that during adolescence, some nutritional variations could be adequately explained by normal, individual growth processes. Despite this, low intake of calcium in girls and a sedentary lifestyle were highlighted as areas of particular concern.

The ENDORSE (Environmental Determinants of Obesity in Rotterdam SchoolchildrEn) Study is a longitudinal study assessing a cohort of Dutch adolescents aged 12-15 years (van der Horst et al., 2008), with data collected at baseline (2005/06) and two years later (2007/08). The study aims focused upon the identification of individual and environmental determinants of behaviours related to overweight and obesity, and the complexities and relationships between these determinants and subjects. At the time of writing, no published results or conclusions regarding this study were available.

Important quality issues for interpretation of the evidence

- Nature of definition of exposure

  The Deheeger study used a dietitian-led dietary history method to assess food intake, while physical activity and inactivity was recorded using a questionnaire. The study protocol sourced from the ENDORSE study reported that physical activity and inactivity was assessed using an adapted version of the Activity Questionnaire for Adolescents and Adults (which was also used to assess parental behaviour), while dietary intake was recorded via a food frequency questionnaire and a 24-hour recall method.

- Ascertainment of outcome

  Body weight, height and waist circumference was measured in the ENDORSE study, while body height and weight was measured in the Deheeger study.

- Populations studied

  The Deheeger study was based in France, while the ENDORSE study population was based in the Netherlands.

- Sample size

  The cohort size in the Deheeger study was n=94.

- Adjustment for appropriate confounders

  Any adjustment for potential confounders was not reported in the study.

6. Discussion and Conclusions

6.1 Interpretation of the evidence

Energy balance and body composition

Measuring energy intake and expenditure in free-living participants taking part in prospective cohort studies is complex. Interpretation of measures of energy intake per se is problematic, both because of the inaccuracies in assessment and the complexity of its relationships with body mass and physical activity. Against a background of much higher levels of total energy intake and expenditure, current techniques are not sufficiently precise to reliably detect the small imbalances that lead to weight gain. Several of the studies that contributed data to this review used self-reported body weight, which correlates well with measured body weight, although under-reporting is common, particularly among more overweight subjects. Self-reported information on food consumption has also been used; this is prone to similar bias. Consumption of foods or drinks regarded as 'unhealthy', for instance those containing fat, sugars and alcohol, tends to be underreported more than others. Reporting methods vary between studies, making it difficult to combine data. For most of the exposures assessed, many different measures are used. Study results can and have been compared, but meta-analysis was not usually possible.

Physical activity

Measurement of physical activity is complex. When exposure measurement is less precise than outcome measurement, the apparent effect is attenuated. Most cohort studies used subjective assessment methods. Although all studies are prospective, some do not allow reverse causality to be excluded. That is, a high BMI at the start of the study may be a cause of decreasing physical activity and may also be

independently associated with an increased risk of weight gain. Although many studies adjusted for potential confounders, the complexity of this area makes residual confounding difficult to exclude. Cohort studies that investigated the effects of physical activity on weight gain vary greatly in size, length and follow-up, making comparisons problematic and precluding meta-analysis. More recent studies report an inverse relationship between physical activity and weight gain. Although this could be explained by improvements in study design, publication bias may be present.

6.2 Evidence and judgements

A total of 14 studies were included in this systematic review identifying the most important energy balance behaviours among children aged 10 to 12 years and/or their parents that are associated with excessive weight gain and overweight.

The interpretation of the results of this review requires careful consideration, given the problem of correlation versus causation. Although this review has identified some exposures as being associated with subsequent excess weight gain and obesity, this does not prove that that they are causative. There is a certain degree of uncertainty inherent in the evidence reviewed, given that it is impossible to determine if there are uncontrolled variables, including genetic variations.

6.2.1 Diet and dietary restraint

The epidemiological evidence reviewed identified that the consumption of sugar-sweetened soft drinks and fruit juices (girls only), as defined in the literature, are associated with slightly higher levels of subsequent excess weight gain and obesity, although limited in terms of the body of evidence reviewed (one study). No

association between the consumption of snack foods or skipping breakfast and subsequent excess weight gain and obesity was identified. Two studies identified higher levels of protein intake at one year of age was associated with higher levels of subsequent excess weight gain and obesity. High levels of dietary restraint in a mother was found to be significant associated with child overweight at the age of 12 years (one study).

6.2.2 Body weight

Rapid increase in body weight before the age of one year was found to be significant associated with child overweight at the age of 12 years (one study). Evidence from three studies showed that parental obesity was significantly associated with child overweight, although this association only held true for paternal obesity in one study. As expected, obesity at baseline was associated with higher levels of subsequent excess weight gain and obesity (two studies).

6.2.3 Physical activity

The epidemiological evidence shows that higher levels of physical activity, or participation in sport, and lower levels of sedentary behaviour, are generally associated with lower levels of subsequent excess weight gain and obesity.

6.3 Conclusions

The epidemiological evidence reviewed here shows that the only diet and physical activity exposures that are associated with subsequent excess weight gain and obesity are the consumption of sugar-sweetened soft drinks and fruit juices (girls only), higher levels of protein intake at one year of age, and high levels of dietary

restraint in the mother. Higher levels of physical activity, or participation in sport, and lower levels of sedentary behaviour, are generally associated with lower levels of subsequent excess weight gain and obesity.

The substantial evidence reviewed suggests that the levels of consumption of other foods, energy and nutrient intake, are not associated with subsequent excess weight gain or obesity in the age group assessed. This is not what would be expected, given our understanding of energy balance. This lack of association is likely, at least in part, to be an artefact of the well documented under- and mis-reporting of foods and drinks that is greater in participants of dietary surveys, particularly in those who are overweight and obese, who are more likely to avoid reporting foods and drinks that contribute to a high total energy intake. Conversely, it is well documented that participants in studies are likely to over-report levels of physical activity. There is good evidence that people who are overweight and obese are more likely to subsequently gain excess weight over time, compared with those who are within the ideal weight range.

The interpretation of the results from all studies reviewed suffers from significant problems involved with measurement error of the exposure, analytic design, confounding and publication bias.

Appendices

Appendix 1 – References to included studies

Fourteen studies have been included in this review. Where more than one paper was used to supply information about a study, all papers have been referenced but one *'primary reference'* has been chosen as an overall identifier for the study. These primary references are listed below with bold font and an asterisk (*). Papers that also belong to the same study follow underneath the primary reference.

Ara 2006

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Deheeger 2002

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Elgar 2005

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Hoppe 2004

*****Hoppe C, Molgaard C, Thomsen BL, Juul A, Michaelsen KF. Protein intake at 9 mo of age is associated with body size but not with body fat in 10-y-old Danish children. American Journal of Clinical Nutrition 2004; 79(3):494-501.

Kettaneh 2005

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Lake 2001

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Libuda 2008

*****Libuda L, Alexy U, Sichert-Hellert W, Stehle P, Karaolis-Danckert N, Buyken AE, Kersting M. Pattern of beverage consumption and long-term association with body-weight status in German adolescents – results from the DONALD study. British Journal of Nutrition 2008; 99:1370-79.

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Appendix 4 - Search strategies adopted

Medline search (Original search)

1 exp Weight Gain/
2 exp Weight Loss/
3 obesity.ab,ti.
4 obese.ab,ti.
5 adipos$.ab,ti.
6 weight gain.ab,ti.
7 weight loss.ab,ti.
8 overweight.ab,ti.
9 over weight.ab,ti.
10 overeat$.ab,ti.
11 over eat$.ab,ti.
12 weight change$.ab,ti.
13 ((bmi or body mass index) adj2 (gain or loss or change)).ab,ti.
14 body fat$.ab,ti.
15 body composition.ab,ti.
16 body constitution.ab,ti.
17 or/1-16
18 exp Diet Therapy/
19 nutrition.mp.
20 diet$.ab,ti.
21 eat$.ab,ti.
22 (intake and (diet$ or food$)).ab,ti.
23 nutrient$.ab,ti.
24 vegetarian$.ab,ti.
25 vegan.ab,ti.
26 exp FOOD/
27 exp BEVERAGES/
28 food$.ab,ti.
29 vegetable$.ab,ti.
30 fruit$.ab,ti.
31 breakfast.ab,ti.
32 lunch.ab,ti.
33 dinner.ab,ti.
34 tea.ab,ti.
35 supper.ab,ti.
36 snack$.ab,ti.
37 meal.ab,ti.
38 (water and (consumption or diet$ or drink$)).ab,ti.
39 drinks.ab,ti.
40 drinking.ab,ti.
41 coffee.ab,ti.
42 caffeine.ab,ti.
43 juice.ab,ti.
44 beverage$.ab,ti.
45 (fizzy and drink$).ab,ti.
46 (soft and drinks).ab,ti.
47 soda.ab,ti.
48 exp COOKERY/
49 cook$.ab,ti.
50 or/18-49
51 exp Physical Fitness/
52 exertion.mp.
53 exp Physical Endurance/
54 exp WALKING/
55 recreational activit$.ab,ti.

56 household activit$.ab,ti.
57 occupational activit$.ab,ti.
58 physical activit$.ab,ti.
59 physical inactivit$.ab,ti.
60 sedentary.ab,ti.
61 exercise.ab,ti.
62 exercising.ab,ti.
63 energy intake.ab,ti.
64 energy expenditure.ab,ti.
65 energy balance.ab,ti.
66 (active and transport).ab,ti.
67 (leisure and time).ab,ti.
68 recreation$.ab,ti.
69 (domestic and activit$).ab,ti.
70 ((television or tv or tele) and viewing).ab,ti.
71 (computer and game$).ab,ti.
72 internet.ab,ti.
73 (game$ and console$).ab,ti.
74 game$.ab,ti.
75 read$.ab,ti.
76 play$.ab,ti.
77 advert$.ab,ti.
78 magazine$.ab,ti.
79 or/51-78
80 50 and 79
81 exp GROWTH/
82 exp ANTHROPOMETRY/
83 exp Body Composition/
84 exp Body Constitution/
85 birth weight.ab,ti.
86 anthropometry.ab,ti.
87 birthweight.ab,ti.
88 child development.ab,ti.
89 height.ab,ti.
90 body mass.ab,ti.
91 bmi.ab,ti.
92 skinfold measurement$.ab,ti.
93 skinfold thickness.ab,ti.
94 bio impedance.ab,ti.
95 bioimpedance.ab,ti.
96 waist circumference.ab,ti.
97 hip circumference.ab,ti.
98 waist hip ratio$.ab,ti.
99 or/81-98
100 17 and 99
101 80 and 100
102 Animals/
103 101 not 102
104 exp Evaluation Studies/
105 exp Follow-Up Studies/
106 exp Prospective Studies/
107 exp Cross-Over Studies/
108 exp Cohort Studies/
109 exp Cross-Sectional Studies/
110 or/104-109
111 exp INCIDENCE/
112 incidence.tw.
113 exp PREVALENCE/
114 prevalence.tw.
115 exp Risk Factors/

116 risk.tw.
117 exp Time Factors/
118 exp Epidemiologic Studies/
119 exp Population Surveillance/
120 etiology.mp.
121 cohort$.tw.
122 (prospectiv$ adj5 (stud$ or trial$ or design$)).tw.
123 (longitudinal adj5 (stud$ or trial$ or design$)).tw.
124 (follow up adj5 (stud$ or trial$ or design$)).tw.
125 (experimental$ adj5 (stud$ or trial$ or design$)).tw.
126 (evaluat$ adj5 (stud$ or trial$ or design$)).tw.
127 (observation$ adj5 (stud$ or trial$ or design$)).tw.
128 (volunteer$ adj5 (stud$ or trial$ or design$)).tw.
129 or/111-128
130 110 or 129
131 exp Case-Control Studies/
132 (case adj3 control$).tw.
133 (case adj3 series).tw.
134 case study/
135 letter.pt.
136 or/131-135
137 103 and 130
138 137 not 136
139 limit 138 to (english language and humans and yr="1990-2009")