

Systematic Review

A comparison of British school meals and packed lunches from 1990 to 2007: meta-analysis by lunch type

Charlotte E. L. Evans^{1*}, Christine L. Cleghorn^{1,2}, Darren C. Greenwood² and Janet E. Cade¹

¹Nutritional Epidemiology Group, Centre of Epidemiology, University of Leeds, Room 8.01, Worsley Building, Clarendon Way, Leeds LS2 9JT, UK

²Division of Biostatistics, University of Leeds, Room 8.01, Worsley Building, Clarendon Way, Leeds LS2 9JT, UK

(Received 21 October 2009 – Revised 24 March 2010 – Accepted 25 March 2010 – First published online 26 May 2010)

Primary school children in the UK have the choice of a school meal provided by the school or a packed lunch provided from home. Currently, more than half of primary school children have a packed lunch. New food-based standards for school meals were introduced in English primary schools in 2006, followed by nutrient-based standards in 2008. No formal comparisons of primary school lunches by lunch type have been undertaken to date. The present review identified seven studies from 1990 to 2007 measuring lunchtime nutrient intake in children aged 5–11 years having a school meal and children having a packed lunch. Pooled estimates for each nutrient were as follows: energy intake was 543 (95% CI 233, 854) kJ higher in packed lunches; total sugar intake was 14.0 (95% CI 10.3, 17.7) g higher in packed lunches; non-milk extrinsic sugar intake was 11.7 (95% CI 7.3, 16.2) g higher in packed lunches; saturated fat intake was 4.7 (95% CI 2.4, 7.1) g higher in packed lunches and Na intake was 357 (95% CI 174, 539) mg higher in packed lunches. Differences between school meals and packed lunches were larger for all nutrients after the introduction of food-based standards compared with the period of no standards. However, differences between before and after standards did not reach statistical significance. The nutritional quality of packed lunches is poor compared with school meals. The introduction of food-based standards for school meals in 2006 has moderately improved the nutrient content of school meals, slightly widening the nutritional gap between school meals and packed lunches.

School children: School lunches: Packed lunches: Nutritional quality: Food-based standards

School lunches have experienced many upheavals in the last three decades. Prior to 1980 the vast majority of children had a school meal provided by the school which was required to meet basic standards⁽¹⁾, or went home for lunch. The 1980s saw the emergence of the packed lunch brought from home, which overtook school meals as the most popular lunch choice in the late 1990s⁽²⁾. Government standards for school meals were reintroduced in 2001, which specified that fruit and vegetables, low-fat starch and dairy food and protein-rich food must be offered to children every day⁽¹⁾. However, few checks were in place to ensure that these standards were routinely followed and surveys found little benefit to children's food choices at lunchtime as a result of introducing these standards⁽³⁾. More rigorous standards were recently introduced into English primary schools; first, food-based standards in September 2006 followed by nutrient-based standards in September 2008⁽⁴⁾. Restrictions were placed on certain foods including low-quality meat, savoury snacks and confectionery, in addition to fruit, vegetables, low-fat dairy and starch and protein-rich foods. The nutrient-based

standards provide maximum standards for fats, sugars and Na and minimum standards for vitamins and minerals. Currently about 44% of primary school children have a school meal in the UK^(4,5) and the vast majority of the remainder take a packed lunch which is not covered by these school-meal standards.

Differences between the types of foods in school meals and packed lunches are described in a number of surveys. However, comparisons between lunch types are made difficult by the fact that the contents of lunches vary widely between lunch types. The National Diet and Nutrition Survey (NDNS)⁽²⁾ found that, for 4- to 10-year-old children, school meals provided more than half the total consumption of fish, vegetables, chips and 'other' potatoes and puddings and over one-third of meat products. They also found that school meals provide a greater percentage of starchy foods and protein-rich foods than the rest of the daily diet but a lower percentage of milk and dairy foods and foods rich in fats and sugars. The most common food items in packed lunches are sandwiches, confectionery, savoury snacks and sweetened

Abbreviations: NDNS, National Diet and Nutrition Survey; NME, non-milk extrinsic.

* **Corresponding author:** Dr Charlotte E. L. Evans, fax +44 113 343 4877, email c.e.l.evans@leeds.ac.uk

drinks⁽⁶⁾. Although differences in the food content are well established, differences in the nutrient content of packed lunches compared with school meals are less clearly defined.

The importance of highlighting differences according to school lunch type is twofold. First, intake at lunchtime may be associated with overall nutrient intake. Studies measuring the impact of lunchtime intake on the total daily dietary intake of primary school-age children have found that high intakes of sugar at lunchtime result in higher levels over the whole day^(7,8). Therefore, highlighting differences in either lunch type could help to identify priorities for improvement to children's diets. Second, recent changes introduced to school meals could potentially have amplified or attenuated differences between school meals and packed lunches in terms of levels of specific nutrients. Any policy-dependent changes in the relationship between lunch types are key to evaluating success of existing policy in this area and determining future recommendations.

With the introduction in 2006 of school-meal standards⁽⁹⁾, it is an ideal time to review existing literature to assess the differences in the nutrient content of children's lunches both before, and since, the new standards were introduced. In the past, parents have viewed packed lunches as more nutritious than school meals⁽¹⁰⁾; however, a number of studies have not found this to be the case^(7,8). Furthermore, a study of teenagers aged 13–16 years reported a worse blood profile in young people usually having a packed lunch⁽¹¹⁾. The main aims of the present paper are to identify all UK-based cross-sectional studies that have measured a range of nutrients consumed in both school meals and packed lunches in primary school-age children aged 5–11 years since 1990, and to assess the nutritional differences between meal types, using meta-analysis where possible. The secondary aim is to compare the nutritional gap between school meals and packed lunches both before and after the introduction of food-based standards in 2006.

Methods

To compare packed lunches and school meals in British children aged 5–11 years a systematic literature review was carried out of all published and unpublished studies that collected data on both school meals and packed lunches between January 1990 and December 2009. Data on the fourteen nutrients included in the nutrient school-meal standards, plus total sugar, were considered for analysis.

Literature search

A search strategy was developed to identify all surveys measuring lunchtime intake in British primary school children (Table 1). Studies conducted from 1990 onwards were considered for inclusion. Electronic databases used were MEDLINE, EMBASE, BIOSIS and CAB Abstracts. Several websites were also searched using the search terms 'meal', 'pack', 'lunch' and 'mid-day' in conjunction with 'school' or 'children'. These were: <http://www.thecochranelibrary.com>, <http://catalogue.bl.uk> <http://apps.isiknowledge.com>, <http://lib.leeds.ac.uk/record=b1620056> (index to theses and dissertations) and <http://lib.leeds.ac.uk/record=b1617171> (index to theses and dissertations). In addition, all references

Table 1. Search strategy to identify surveys measuring food and nutrient intake at lunchtime in school children

Step ID	Description
1	EXP SURVEY or keyword survey
2	EXP CHILD or keyword child
3	EXP SCHOOL or keyword school
4	EXP DIET or keyword diet
5	1 and 2 and 3 and 4

included in the articles included in the present review were cross-referenced for any additional surveys.

Inclusion criteria

To be included in the review the surveys needed to satisfy the following criteria:

- (1) Study carried out in a British primary school in children aged no younger than 5 years and no older than 11 years;
- (2) Data collected from January 1990 up to December 2009;
- (3) Measurement of energy and nutrient intakes, not simply provision of these nutrients to children;
- (4) Intake assessed by weighing or observation at lunchtime, and not due to recall at a later time or date;
- (5) Study assessed both school meals and packed lunches using similar methods;
- (6) Published in the English language.

To be included in the meta-analysis the survey was required to provide additional information on the degree of variation such as standard deviation or standard error, to enable calculation of the difference and standard error of the difference between lunch types.

Outcome measures

The outcome measures obtained from the surveys were energy in kJ and weights of protein, total and saturated fat, carbohydrate, total sugar, non-milk extrinsic sugars (NME sugar), fibre (measured as NSP), Na (not including salt added to food), folate, Ca, Fe, Zn, vitamin A and vitamin C.

Statistical analyses

For each nutrient, two related sets of analyses were carried out. First, meta-analyses with all available studies, both published and unpublished, were performed to determine the pooled estimate of the difference between school meals and packed lunches over the whole time period and in two distinct time periods: January 1990 to August 2006 and September 2006 to December 2009. In the first time period no rigorous standards for school meals existed and in the second time period food-based school-meal standards were in place. Second, sensitivity analyses were carried out which included meta-analyses with published studies only in the two time periods. Comparisons were made with results from both analyses.

For each survey the effect size and standard error of the difference in effect size were extracted where available. If not reported, the mean, standard deviation and number in

each sample for those having a school meal and those having a packed lunch were extracted where possible and used to estimate the effect size and standard error of the difference. If no measures of mean and standard deviation were reported, the corresponding author was contacted to determine whether the information was available from unpublished sources. Pooled estimates were calculated by weighting each trial by the inverse of the variance and reported together with measures of heterogeneity using I^2 in Stata 10 (StataCorp LP, College Station, TX, USA)⁽¹²⁾. I^2 values of greater than 50% indicate that results need to be interpreted with caution. Forest plots are displayed for the primary analyses where surveys were stratified on time period. Results for nutrients where the pooled estimate was close to zero are described in the text. Results for the sensitivity analyses are reported in a table without forest plots. Meta-regression was used to determine the association of time period (before standards and after standards) on pooled estimates. Random-effects models were used to take account of differences in study design related to collection methods. Authors were contacted for extra information if necessary.

Results

Study information

After removal of duplicate articles, the electronic searching found 812 articles; 236 from MEDLINE, eighty-five from EMBASE, 392 from BIOSIS and ninety-nine from CAB Abstracts. Of these articles, two were deemed to be relevant to the scope of the present review. Three additional references were obtained from searching websites and contacting relevant organisations and authors directly. One additional article was obtained as a result of cross-referencing all references of obtained papers and one further paper was obtained from hand searching the most popular nutrition journals using the keywords 'meal', 'pack' and 'lunch'. Finally, two references were existing papers in file.

Seven studies were included in the meta-analyses, five of which contained either published data^(7,8,13,14) or data in the press⁽¹⁵⁾. Results reported by Gatenby⁽¹⁵⁾ included information from two populations of children, one in an affluent school

where no children had free school meals (labelled as 'affluent' in forest plots) and one in a school with high levels of free school meals (labelled as 'FSM' in forest plots). Two studies contained unpublished results. The first was secondary analysis of NDNS data analysed at the University of Leeds and in preparation for submission for publication in 2010 (CEL Evans, unpublished results). The second included unpublished results from the School Food Trust containing data from a 2007 survey submitted for publication in 2009 (J Pearce, unpublished results). Two studies lacked measures of variation such as standard deviation or standard error and were excluded from the meta-analysis^(16,17). Information on the seven studies used in the review is shown in Table 2. The studies utilised a variety of different methods to measure nutrient intake and varied in the age range sampled.

Six studies reported means and standard deviations for each nutrient. The NDNS data reported effect size and standard error of the difference using multilevel analysis to take into account that data was collected over a whole week and not 1 d only. The studies excluded from the meta-analysis reported means only. All seven studies reported results for energy, protein, total fat, carbohydrate, NSP, Fe and vitamin C. Six studies reported results for total sugar, saturated fat, Ca, folate and vitamin A. Five studies reported results for Na and two for NME sugars. Four studies reported results for Zn. Two authors (Ruxton⁽⁸⁾ and Rees⁽¹⁴⁾) provided extra unpublished information on fats and sugars. Mock⁽¹³⁾ could not be contacted for extra information on total sugar.

Nutrients

The nutrient levels in each study by meal type are detailed in Table 3. Pooled estimates and 95% CI for the difference in energy and fourteen nutrients, namely, energy, protein, total fat, saturated fat, carbohydrate, total sugar, NME sugar, NSP, folate, Ca, Na, vitamin A and vitamin C, between school meals and packed lunches were obtained. A positive pooled estimate indicates higher levels in packed lunches, and a negative pooled estimate indicates higher levels in school meals. The pooled estimates from the sensitivity

Table 2. Summary of surveys on school meals and packed lunches

Year data collected	First author	Year published	Subjects (n)	Age of children (years)	School meal (n)	Packed lunch (n)	Dietary assessment method used	Suitable for meta-analysis
1990	Ruxton ⁽⁸⁾	1996	136	7–8	333	251	7 d weighed intake	Yes
1990	Tilston ⁽¹⁷⁾	1992	n/a	5–7	100*	36	Food items recorded at one lunch	No
1995	Mock ⁽¹³⁾	1997	28	5–11	28	28	Food items recorded for five lunches	Yes
1997	NDNS†	n/a	630	4–11	1105	1510	7 d weighed intake	Yes
2000	Rogers ⁽⁷⁾	2007	621	7	211	410	Food items recorded for 3 d	Yes
2000	Burgess ⁽⁵¹⁾	2002	–	–	–	–	Food items recorded for five lunches	No
2006	Rees ⁽¹⁴⁾	2008	120	6–11	62	58	Food items recorded for one lunch	Yes
2006	Gatenby (affluent) ⁽¹⁵⁾	2010	75	8–11	37	38	Food weighed for five lunches	Yes
2006	Gatenby (FSM) ⁽¹⁵⁾	2010	71	8–11	39	32	Food weighed for five lunches	Yes
2007	School Food Trust‡	n/a	123	8	58	65	Food items recorded for one lunch	Yes

n/a, data not available; NDNS, National Diet and Nutrition Survey; FSM, free school meals.

* Estimated from percentages.

† CEL Evans, unpublished results.

‡ J Pearce, unpublished results.

Table 3. Summary data of surveys on school meals and packed lunches included in meta-analyses

Nutrient	Lunch type	Before introduction of school-meal standards				After introduction of food-based school-meal standards			
		Ruxton (1990) ⁽⁸⁾	Mock (1995) ⁽¹³⁾	NDNS (1997)*	Rogers (2000) ⁽⁷⁾	Rees (2006) ⁽¹⁴⁾	Gatenby (affluent) (2006) ⁽¹⁵⁾	Gatenby (FSM) (2006) ⁽¹⁵⁾	SFT (2007)†
Energy (kJ)	School meal	1780	2320	1972	1920	1860	1665	1537	1402
	Packed lunch	2120	2520	1814	2240	2060	2856	3181	2192
Total fat (g)	School meal	20.1	23.0	20.3	20.5	20.0	8.12	7.43	11.2
	Packed lunch	20.8	25.9	17.5	24.2	16.0	28.92	30.78	23.8
Saturated fat (g)	School meal	n/a	5.5	6.6	5.9	5.3	2.8	2.8	4.3
	Packed lunch	n/a	9.2	7.5	9.4	7.2	11.66	12.6	9.0
NSP (g)	School meal	1.58	3.0	3.5	3.17	3.0	3.21	2.8	3.6
	Packed lunch	2.62	3.5	2.7	2.81	4.0	3.72	3.9	2.4
Carbohydrate (g)	School meal	51.2	67.7	70.6	55.2	52	64.3	57.6	47.7
	Packed lunch	70.4	80.3	71.0	68.5	71	92.5	108.7	66.9
Sugar (g)	School meal	24.8	n/a	22.9	17	13	26.2	25.5	15.5
	Packed lunch	37.4	n/a	29.8	28.4	28	43.6	54.9	27.5
NMES (g)	School meal	n/a	21.6	15.5	n/a	n/a	11.9	7.0	9.1
	Packed lunch	n/a	30	20.2	n/a	n/a	25.7	35.9	19.8
Na (mg)	School meal	n/a	n/a	645	627	542	375	335	411
	Packed lunch	n/a	n/a	700	805	834	1010	1026	729
Ca (mg)	School meal	146	279	127	125	124	291	296	154
	Packed lunch	197	215	129	160	295	315	312	254
Folate (µg)	School meal	28.8	44.3	44.4	38.7	n/a	61.5	61.0	39
	Packed lunch	33.5	55.4	28.6	39.9	n/a	56.3	58.3	36.6
Protein (g)	School meal	12.5	18.5	15.6	16.4	18	20.8	21.0	13.7
	Packed lunch	12.8	16.1	11.2	14.7	18	18.9	18.9	13.6
Fe (mg)	School meal	1.79	2.8	1.8	1.9	1.8	1.93	1.5	1.7
	Packed lunch	2.23	2.8	1.6	2.10	2.2	2.42	2.8	1.9
Vitamin C (mg)	School meal	17.3	15.8	12.4	11.4	17	37.6	32.5	13.9
	Packed lunch	24.3	38.4	6.3	14.2	24	35.5	32.0	22.5
Vitamin A (µg)	School meal	102	220	107.6	149	n/a	129.0	96.0	188
	Packed lunch	144	241	83.2	157	n/a	162.9	172.0	152
Zn (mg)	School meal	n/a	n/a	1.7	1.5	n/a	1.8	1.8	1.6
	Packed lunch	n/a	n/a	1.2	1.3	n/a	2.0	2.0	1.5

NDNS, National Diet and Nutrition Survey; FSM, free school meals; SFT, School Food Trust; n/a, not available; NMES, non-milk extrinsic sugars.

* M Metsalaar, unpublished results.

† C Ruxton, G Rees and J Pearce, unpublished results.

analysis with CI and levels of heterogeneity for each nutrient are presented in Table 4.

Seven out of eight studies reported higher energy intakes in packed lunches compared with school meals. Based on all data, the pooled estimate for energy intake was 543 (95% CI 233, 854) kJ. Energy intake was similar in packed lunches and school meals before standards were introduced (see Fig. 1) and 950 kJ higher in packed lunches (95% CI 383, 1517 kJ) with food-based standards in place. I^2 was higher than 50% for both time periods. The sensitivity analysis with published data only indicated that energy intake was higher in packed lunches both before and after standards were introduced. I^2 was lower than 50% for earlier studies but higher than 50% for the period with standards in place (see Table 4). The difference in energy intake between school meals and packed lunches increased by 781 (95% CI -19, 1580) kJ after the introduction of food-based standards.

Six out of eight studies reported higher protein intakes in school meals compared with packed lunches. Based on all data (forest plot not shown), the pooled estimate for protein intake was -1.6 (95% CI -3.2, 0) g. Protein intake was similar in packed lunches and school meals before standards were introduced (pooled estimate 2.1 (95% CI -4.4, 0.3) g; $I^2 = 95%$) and after the introduction of standards (pooled estimate 0.8 (95% CI -2.1, 0.5) g; $I^2 = 0%$). The sensitivity

analysis with published data only confirmed that protein intake was similar in packed lunches and school meals both before and after the introduction of standards (see Table 4). The difference in protein intake between school meals and packed lunches increased by 1.1 (95% CI -2.2, 4.5) g after the introduction of food-based standards.

All eight studies reported higher carbohydrate intakes in packed lunches compared with school meals. Based on all data (forest plot not shown), the pooled estimate for carbohydrate intake was 18.1 (95% CI 10.9, 25.3) g. Carbohydrate intake was higher in packed lunches before standards were introduced (pooled estimate 11.3 (95% CI 2.0, 20.5) g; $I^2 = 96%$) and after the introduction of standards (pooled estimate 26.5 (95% CI 12.2, 40.9) g; $I^2 = 93%$). The sensitivity analysis with published data only indicated that carbohydrate intake was higher in packed lunches both before and after the introduction of standards (see Table 4). The difference in carbohydrate intake between school meals and packed lunches increased by 15 (95% CI -7.7, 37.7) g after the introduction of food-based standards.

Six out of eight studies reported higher total fat intakes in packed lunches compared with school meals. Based on all data (see Fig. 2), the pooled estimate for total fat intake was 7.0 (95% CI 1.5, 12.5) g. Total fat difference was close to zero before standards were introduced and 13.2 g higher in

Table 4. Pooled estimates of differences in nutrient intake in packed lunches compared with school meals (no standards v. food-based standards) using published surveys from 1990 to 2007 (excluding unpublished results)

Nutrient	No. of studies included in the meta-analysis	Pooled estimate (no standards)	95 % CI	Heterogeneity (I^2 ; %)	No. of studies included in the meta-analysis	Pooled estimate (food-based standards)	95 % CI	Heterogeneity (I^2 ; %)
Energy (kJ)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	323	256, 390	0	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	1008	146, 1870	95
Protein (g)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	- 1.1	- 2.8, 0.5	82	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	- 1.3	- 3.0, 0.4	0
Total fat (g)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	2.3	0, 4.7	79	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	13.4	- 3.7, 30.5	99
Saturated fat (g)	2: Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	3.5	2.9, 4.1	0	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	6.9	2.1, 11.7	97
Carbohydrate (g)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	15.5	10.9, 20.0	72	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	29.5	6.7, 52.4	95
Sugar (g)	2: Ruxton ⁽⁸⁾ ; Rogers ⁽⁷⁾	12.0	10.5, 13.50	0	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	20.2	12.5, 27.9	81
NMES (g)	2: Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	8.0	6.6, 9.5	0	2: Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	21.2	6.4, 36.0	94
NSP (g)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	0.4	- 0.6, 1.4	97	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	0.9	0.5, 1.3	17
Na (mg)	1: Rogers ⁽⁷⁾ ; Rees ⁽⁵⁰⁾	n/a	n/a	n/a	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	541	299, 782	93
Ca (mg)	2: Ruxton ⁽⁸⁾ ; Rogers ⁽⁷⁾	42.5	26.8, 58.1	47	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	72.9	- 35.7, 181.4	90
Folate (μ g)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	4.2	0.4, 7.9	62	2: Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	- 4.1	- 12.0, 3.8	0
Fe (mg)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	0.3	0, 0.5	77	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	0.7	0.2, 1.3	86
Zn (mg)	1: Rogers ⁽⁷⁾	n/a	n/a	n/a	2: Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	0.2	0, 0.4	0
Vitamin A (μ g)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	- 18.9	- 77.0, 39.1	88	2: Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	61.6	19.8, 103.4	0
Vitamin C (mg)	3: Ruxton ⁽⁸⁾ ; Mock ⁽¹³⁾ ; Rogers ⁽⁷⁾	8.9	1.7, 16.1	87	3: Rees ⁽¹⁴⁾ ; Gatenby (affluent) ⁽¹⁵⁾ ; Gatenby (FSM) ⁽¹⁵⁾	1.8	- 4.1, 7.6	37

FSM, free school meals; NMES, non-milk extrinsic sugars.

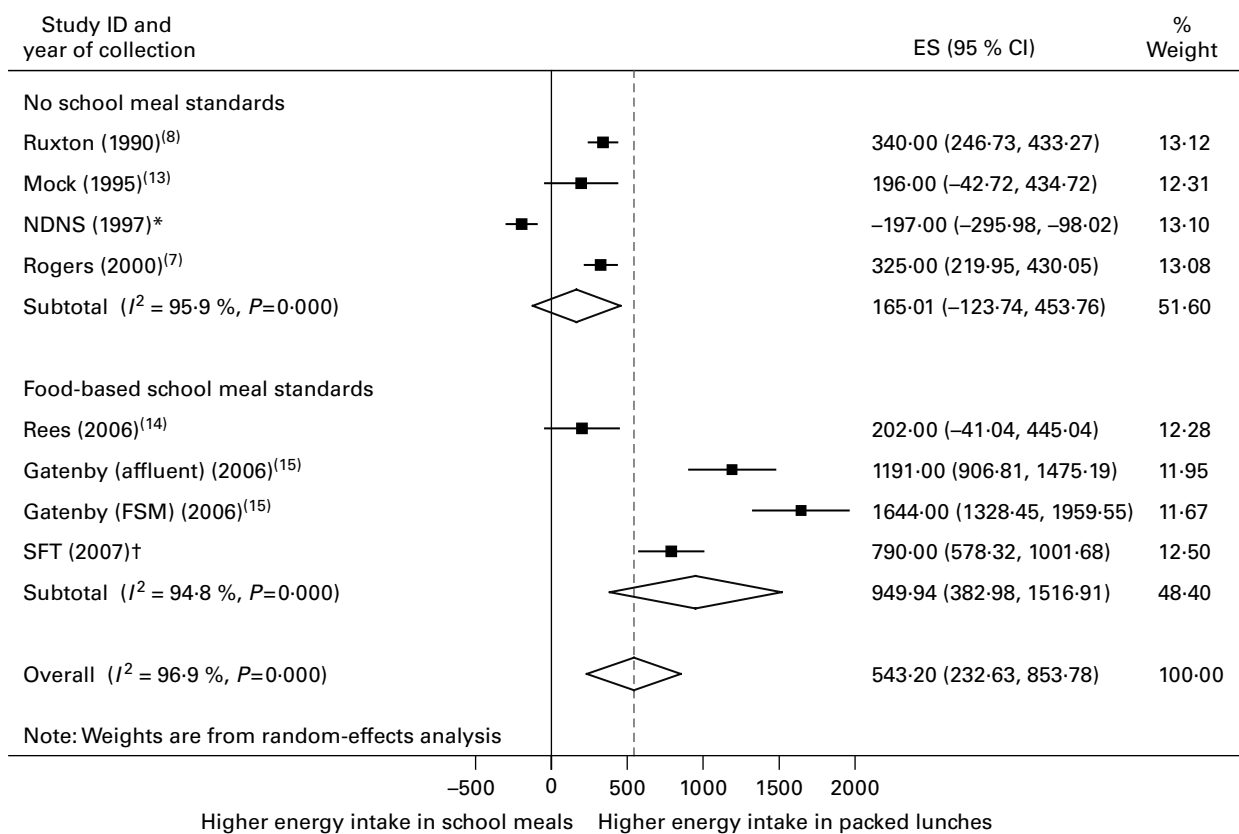


Fig. 1. Forest plot of pooled estimate (ES) of difference in energy intake (kJ) by lunch type in primary school children. NDNS, National Diet and Nutrition Survey; FSM, free school meals; SFT, School Food Trust. * M Metsalaar, unpublished results. † C Ruxton, G Rees and J Pearce, unpublished results.

packed lunches (95% CI 1.5, 24.9 g) with food-based standards in place. The sensitivity analysis with published data only indicated that total fat intake was similar in packed lunches and school meals both before and after standards were introduced (see Table 4). The difference in total fat intake between school meals and packed lunches increased by 12.2 (95% CI -3.3, 27.8) g after the introduction of food-based standards. I^2 was higher than 50% for both time periods.

Seven out of seven studies reported saturated fat intakes higher in packed lunches. Based on all data available (see Fig. 3), the pooled estimate for saturated fat intake was 4.7 (95% CI 2.4, 7.1) g. Saturated fat was 2.6 g higher in packed lunches (95% CI 0.5, 4.7 g) before standards were introduced and 6.4 g higher in packed lunches (95% CI 2.8, 9.9 g) with food-based standards in place. The sensitivity analysis with published data only confirmed that saturated fat intake was higher before and after standards were introduced (see Table 4). The difference in saturated fat intake between school meals and packed lunches increased by 3.7 (95% CI -2.2, 9.6) g after the introduction of food-based standards. I^2 was higher than 50% for both time periods.

Seven out of seven studies reported higher total sugar intakes in packed lunches compared with school meals. Based on all data available (see Fig. 4), total sugar intake was 14.0 (95% CI 10.3, 17.7) g. Total sugar was 10.1 g higher in packed lunches (95% CI 6.3, 13.9 g) before standards were introduced and 18 g higher in packed lunches (95% CI 11.7, 24.3 g) with food-based standards in place.

The sensitivity analysis with published data only confirmed that total sugar intake was higher both before and after standards were in place (see Table 4). The difference in total sugar intake between school meals and packed lunches increased by 7.8 (95% CI -3.4, 19) g after the introduction of food-based standards. I^2 was higher than 50% for both time periods.

Five out of five studies reported higher NME sugar intakes in packed lunches compared with school meals. Based on all data available (see Fig. 5), the pooled estimate for NME sugar intake was 11.7 (95% CI 10.3, 17.7) g. NME sugar intake was 6.7 g higher in packed lunches (95% CI 3.8, 9.6 g) before standards were introduced and 17.5 g higher in packed lunches (95% CI 8.2, 26.9 g) with food-based standards in place. The sensitivity analysis with published data only confirmed that NME sugar intake was higher both before and after standards were introduced (see Table 4). The difference in NME sugar intake between school meals and packed lunches increased by 10.5 (95% CI -4.9, 25.9) g after the introduction of food-based standards. I^2 was higher than 50% for both time periods.

Five out of eight studies reported higher fibre intakes in packed lunches compared with school meals. Based on all data (forest plot not shown), the pooled estimate for fibre intake was 0.2 (95% CI -0.5, 0.9) g. Fibre intake was similar in packed lunches and school meals before standards were introduced (pooled estimate 0.1 (95% CI -0.9, 1.1) g; $I^2 = 98\%$) and after the introduction of standards (pooled estimate 0.4 (95% CI -0.8, 1.5) g; $I^2 = 94\%$).

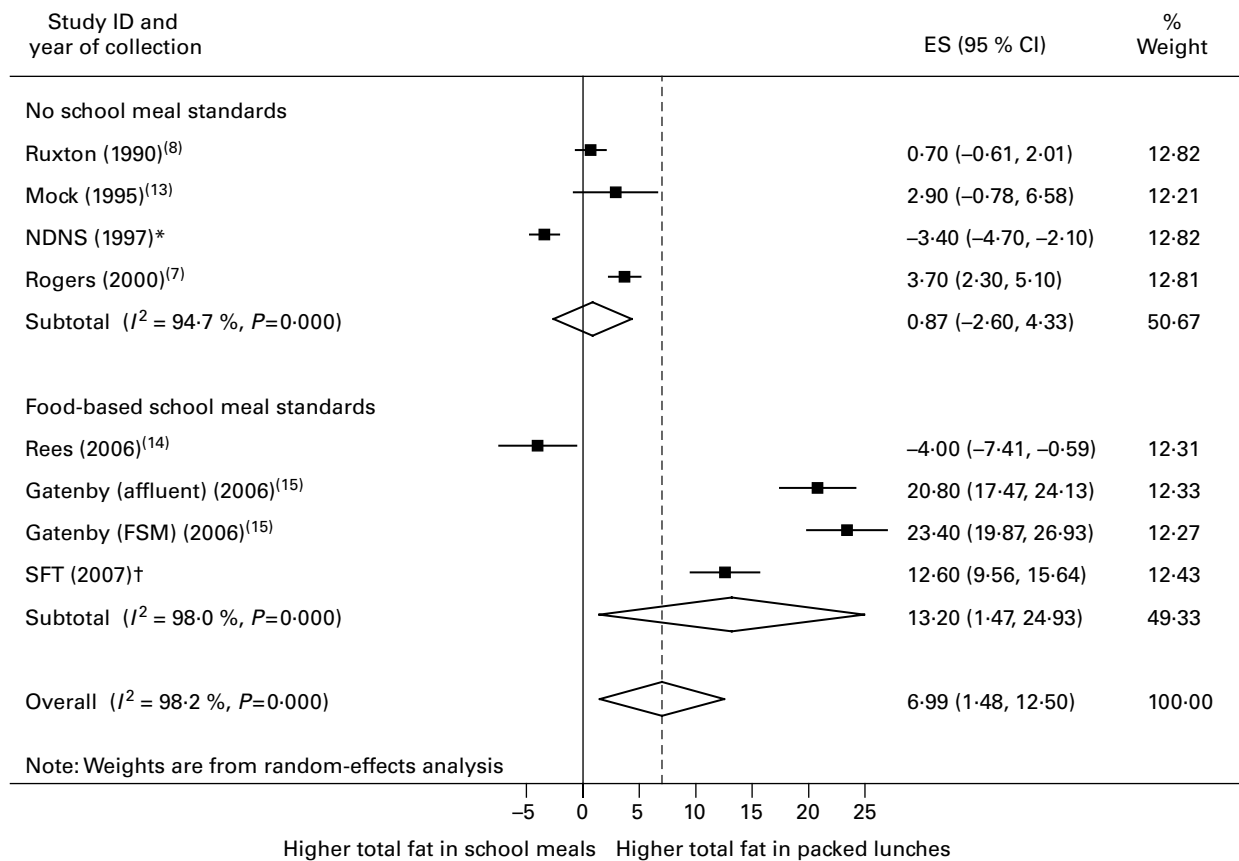


Fig. 2. Forest plot of pooled estimate of (ES) difference in total fat intake (g) by lunch type in primary school children. NDNS, National Diet and Nutrition Survey; FSM, free school meals; SFT, School Food Trust. * M Metsalaar, unpublished results. † C Ruxton, G Rees and J Pearce, unpublished results.

The sensitivity analysis with published data only indicated that fibre intake was similar in packed lunches and school meals before standards and slightly higher in packed lunches with standards in place (see Table 4). The difference in fibre intake between school meals and packed lunches increased by 0.3 (95% CI -1.4, 1.9) g after the introduction of food-based standards.

Six out of six studies reported higher Na intake in packed lunches compared with school meals. Based on all data available (see Fig. 6), the pooled estimate for Na intake was 357 (95% CI 174, 539) mg. Na intake was 114 mg higher in packed lunches (95% CI -11, 239 mg) before standards were introduced and 483 mg higher in packed lunches (95% CI 276, 690 mg) with food-based standards in place. The sensitivity analysis with published data only confirmed that Na intake was higher with standards in place (see Table 4); however, no analysis was carried out for the earlier time period, as only one study was available. The difference in Na intake between school meals and packed lunches increased by 369 (95% CI -69, 807) mg after the introduction of food-based standards. I^2 was higher than 50% for both time periods.

Six out of eight studies reported higher Fe intakes in packed lunches compared with school meals. Based on all data available (see Fig. 7), the pooled estimate for Fe intake was 0.3 (95% CI 0, 0.6) mg. Fe intake was similar in school meals and packed lunches before standards were introduced (pooled estimate 0.1 mg higher in packed lunches, 95% CI -0.3, 0.5 mg) and 0.6 mg higher in packed lunches

(95% CI 0.2, 1.0 mg) with food-based standards in place. The sensitivity analysis with published data only confirmed that Fe intake was similar in school meals and packed lunches before standards and higher in packed lunches with standards in place (see Table 4). The difference in Fe intake between school meals and packed lunches increased by 0.5 (95% CI -0.2, 1.2) mg after the introduction of food-based standards. I^2 was higher than 50% for both time periods.

Three out of five studies reported higher Zn intakes in school meals compared with packed lunches. Based on all data available (forest plot not shown), the pooled estimate for Zn intake was 0.1 (95% CI -0.1, 0.4) mg. Zn intake was higher in school meals before standards were introduced (pooled estimate -0.4 (95% CI -0.7, -0.1) mg; $I^2 = 95\%$) but similar with food-based standards in place (pooled estimate 0.1 (95% CI -0.1, 0.3) mg; $I^2 = 21\%$). The sensitivity analysis with published data only confirmed that Zn intake was similar in school meals and packed lunches with standards in place (see Table 4). Insufficient data were available in the earlier time period. The difference in Zn intake between school meals and packed lunches increased by 0.5 (95% CI -0.1, 1.1) mg after the introduction of food-based standards.

Seven out of eight studies reported higher Ca intakes in packed lunches compared with school meals. Based on all data available (forest plot not shown), the pooled estimate for Ca intake was 55.5 (95% CI 20.9, 90) mg. Ca intake was similar in school meals and packed lunches before

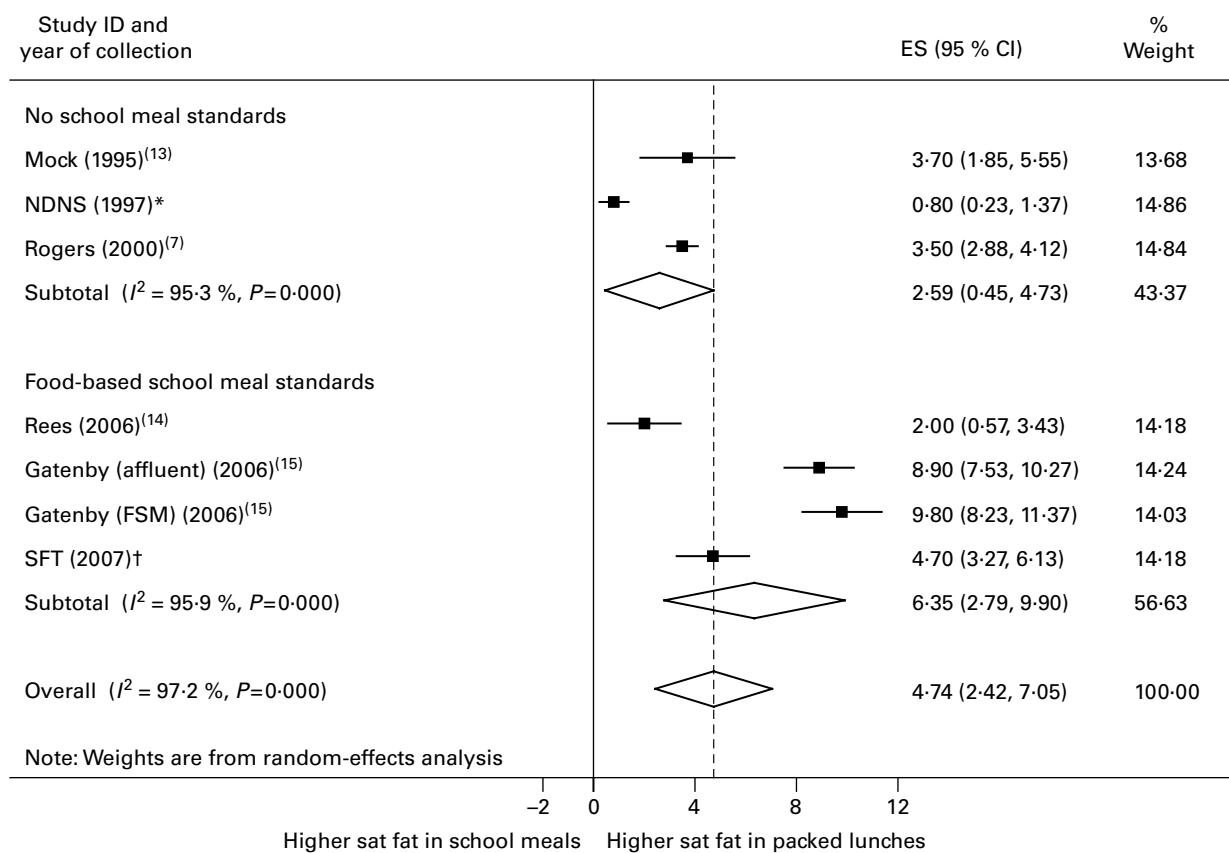


Fig. 3. Forest plot of pooled estimate (ES) of difference in saturated fat (sat fat) intake (g) by lunch type in primary school children. NDNS, National Diet and Nutrition Survey; FSM, free school meals; SFT, School Food Trust. * M Metsalaar, unpublished results. † C Ruxton, G Rees and J Pearce, unpublished results.

standards were introduced (pooled estimate 27.5 mg higher in packed lunches; 95 % CI -7.8, 62.8 mg; $I^2 = 97\%$) and higher in packed lunches after the introduction of food-based standards (pooled estimate 81.7 (95 % CI 12.8, 150.7) mg; $I^2 = 84\%$). However, the sensitivity analysis with published data only did not confirm this and indicated that Ca intake was higher in packed lunches before the introduction of standards and similar when standards were in place (see Table 4). The difference in Ca intake between school meals and packed lunches increased by 55.7 (95 % CI -52.4, 163.9) mg after the introduction of food-based standards.

Four out of seven studies reported higher folate intakes in school meals compared with packed lunches. Based on all data (forest plot not shown), the pooled estimate for folate intake was -1.5 (95 % CI -9.2, 6.3) μg . Folate intake was similar in packed lunches and school meals before standards were introduced (pooled estimate 0.1 μg higher in school meals; 95 % CI -11.1, 10.9 μg ; $I^2 = 97\%$) and after the introduction of standards (pooled estimate 3.0 μg higher in packed lunches; 95 % CI -9.2, 6.3 μg ; $I^2 = 0\%$). However, the sensitivity analysis with published data only indicated that folate intake was higher in packed lunches before the introduction of standards but similar when standards were in place (see Table 4). The difference in folate intake between school meals and packed lunches increased by 3.1 (95 % CI -22.3, 16.1) μg after the introduction of food-based standards.

Five out of eight studies reported higher vitamin C intakes in packed lunches compared with school meals. Based on

all data (forest plot not shown), the pooled estimate for vitamin C intake was 4.6 (95 % CI 0.2, 9) mg. Vitamin C intake was similar in packed lunches and school meals before standards were introduced (pooled estimate 5.8 (95 % CI -0.4, 12.0) mg; $I^2 = 93\%$) and after the introduction of standards (pooled estimate 3.4 (95 % CI -1.9, 8.6) mg; $I^2 = 39\%$). The sensitivity analysis with published data only indicated that vitamin C intake was higher in packed lunches before standards but similar when standards were in place (see Table 4). The difference in vitamin C intake between school meals and packed lunches increased by 2.9 (95 % CI -16.9, 11.2) mg after the introduction of food-based standards.

Five out of seven studies reported higher vitamin A intakes in packed lunches compared with school meals. Based on all data (forest plot not shown), the pooled estimate for vitamin A intake was -12.5 (95 % CI -55.7, 30.8) μg . Vitamin A intake was similar in packed lunches and school meals before standards were introduced (pooled estimate 39.9 μg higher in school meals; 95 % CI -87.5, 7.7 μg ; $I^2 = 91\%$) and after the introduction of standards (pooled estimate 25.9 μg higher in packed lunches; 95 % CI -42.2, 94.1 μg ; $I^2 = 73\%$). The sensitivity analysis with published data only indicated that vitamin A intake was similar before standards but higher in packed lunches when standards were in place (see Table 4). The difference in vitamin A intake between school meals and packed lunches increased by 65.3 (95 % CI -42.5, 173.0) μg after the introduction of food-based standards.

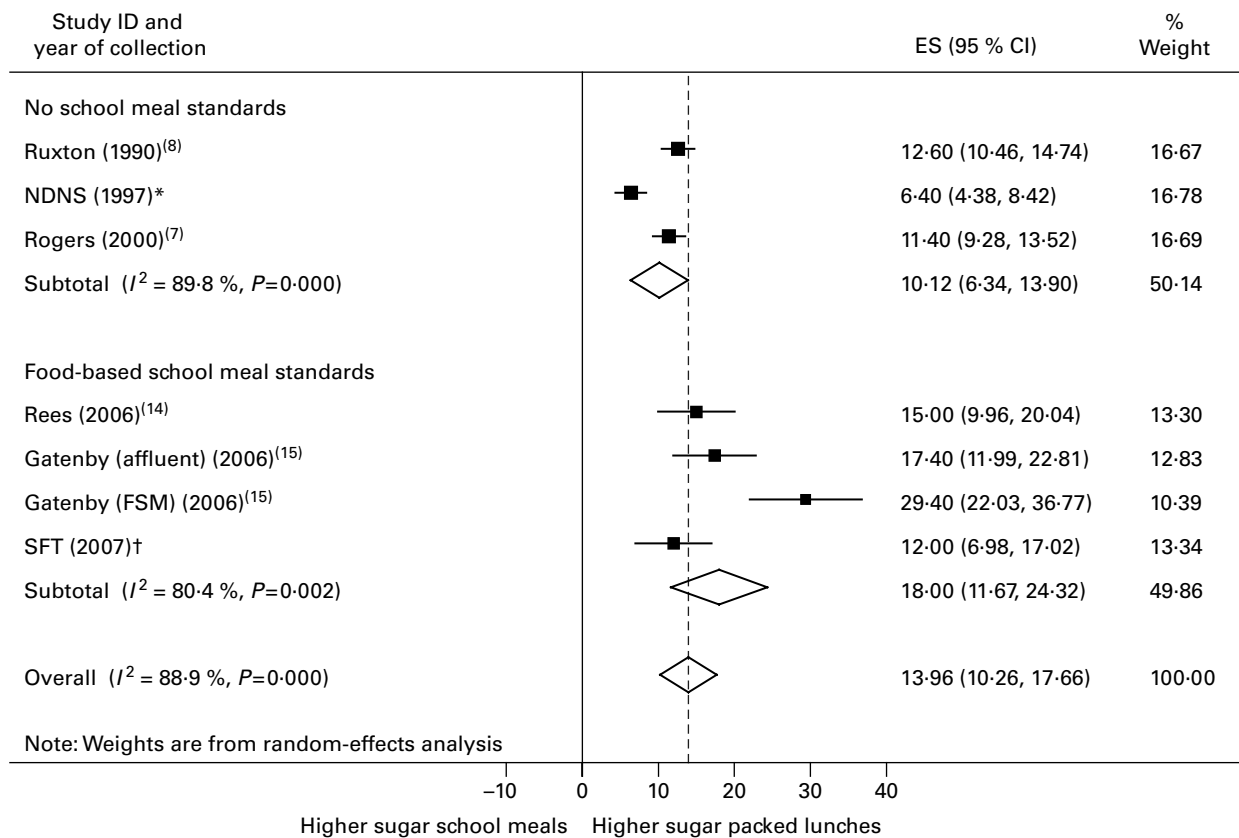


Fig. 4. Forest plot of pooled estimate (ES) of difference in total sugar intake (g) by lunch type in primary school children. NDNS, National Diet and Nutrition Survey; FSM, free school meals; SFT, School Food Trust. * M Metsalaar, unpublished results. † C Ruxton, G Rees and J Pearce, unpublished results.

Discussion

This meta-analysis is the first formal comparison of the nutrient content of packed lunches with school meals consumed by primary school children in the UK. The number of surveys that have measured both school meal and packed lunch nutrient intake over the last 20 years is small and heterogeneity between studies is high; however, some important findings were identified.

Intakes of carbohydrate, total sugar, NME sugar, saturated fat and Na were consistently reported to be higher in packed lunches compared with school meals by all studies. Energy and Fe levels were also higher in packed lunches in most studies.

Total sugar intake and NME sugar intake were estimated to be approximately 10 g and 7 g higher, respectively, for children having a packed lunch compared with those having a school meal before the introduction of school-meal standards. This gap widened to 18 g for both total and NME sugars after the introduction of school-meal standards. There is a suggestion that the gap between school meals and packed lunches in terms of sugars is widening although this was not significant when tested and heterogeneity was high for these analyses.

These results are consistent with the results from the largest UK study published on school meals by Nelson *et al.*⁽³⁾ and the largest published study on packed lunches by Evans & Cade⁽⁶⁾ where NME sugar levels were 29 g in packed lunches and 14 g in school meals. The difference between school meals and packed lunches was particularly dramatic in a school in a more deprived area collected by Gatenby⁽¹⁵⁾.

Children having school meals since 2006 to the present usually have water to drink, although they invariably consume a pudding⁽²⁾. Children having a packed lunch usually consume confectionery as well as a sweetened drink^(6,18,19). The main reason for the higher sugar levels in packed lunches is therefore most likely to be due to sweetened drinks and/or having more than one sweet snack. High sugar intakes from drinks are associated with higher body weights in children⁽²⁰⁾ and increased risk of impaired blood profile and diabetes mellitus⁽²¹⁾, although total sugar intakes from all sources are not associated with body weight in children⁽²⁰⁾.

Saturated fat intake was estimated to be approximately 2.6 g higher for children having a packed lunch compared with those having a school meal before the introduction of school-meal standards, increasing to 6.4 g after the introduction of school-meal standards. The food-based school-meal standards include improvements in the quality of meat served to children and in particular include restrictions on processed meat products, which may have contributed to the widening of the gap between lunch types. Surveys of children's diets in developed countries have generally concluded that saturated fat intake is too high^(2,22,23). High levels of fats, particularly saturated fats, are linked with higher levels of serum total and LDL-cholesterol^(24,25), higher blood pressure⁽²⁶⁾, atherosclerosis⁽²⁷⁾ and increased risk of obesity^(28,29). In turn, high cholesterol levels themselves are an established risk of CVD, due to the increased risk of atherosclerosis, which starts in childhood⁽³⁰⁾. Children with high serum cholesterol levels are also more at risk of having high serum cholesterol

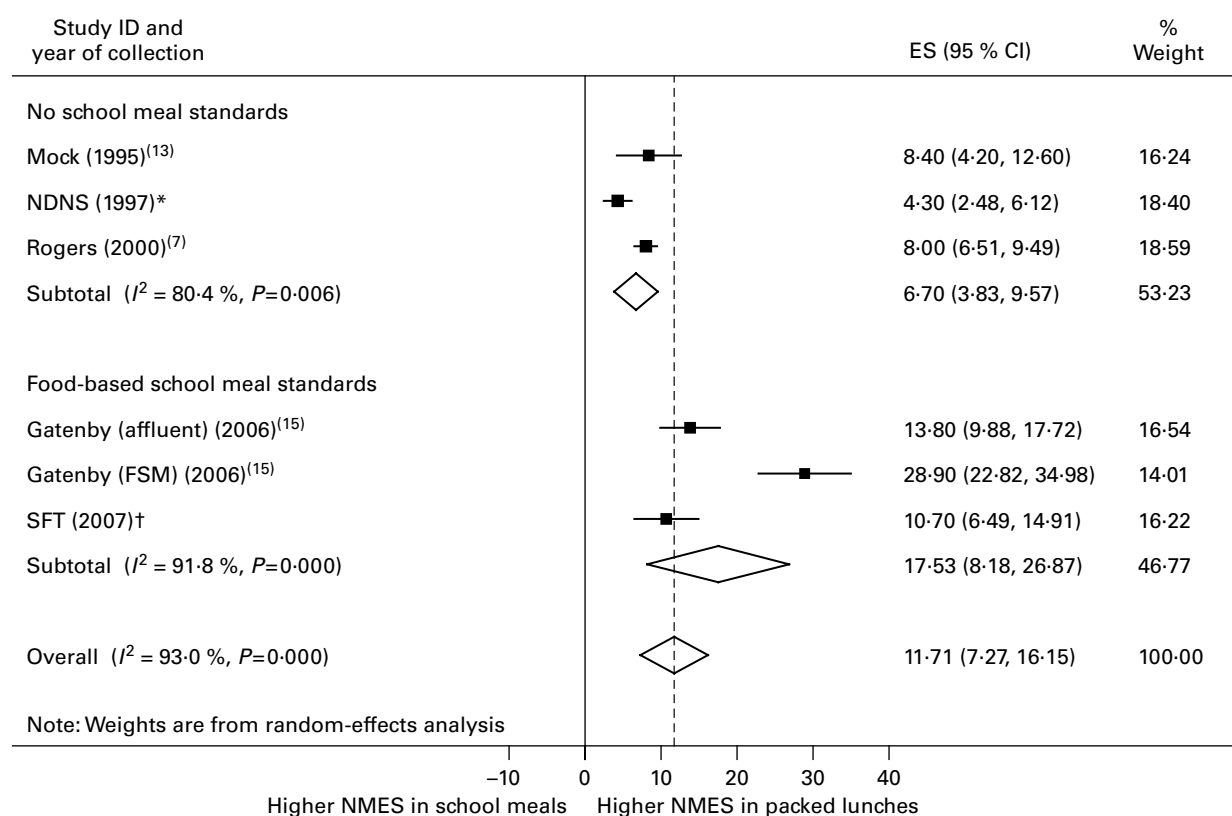


Fig. 5. Forest plot of pooled estimate (ES) of difference in total non-milk extrinsic sugar (NMES) intake (g) by lunch type in primary school children. NDNS, National Diet and Nutrition Survey; FSM, free school meals; SFT, School Food Trust. * M Metsalaar, unpublished results. † C Ruxton, G Rees and J Pearce, unpublished results.

levels as adults⁽³¹⁾. A recent review of trials has determined an association between CVD and high total fat intake⁽³²⁾. However, in this study, the evidence for higher total fat intakes in packed lunches was not consistent. At the time of the packed lunch survey, the profile of some foods popular in lunch boxes, such as savoury snacks, had recently been updated to reduce the saturated fat content⁽⁶⁾.

Na intake was estimated to be broadly similar in children having either lunch type before the introduction of school-meal standards. However, after the introduction of school-meal standards, Na intake was nearly 500 mg higher in packed lunches compared with school meals. This widening gap was not significant when tested but suggests that Na intake in school meals has reduced with the introduction of food-based standards. These standards restrict the use of savoury snacks and processed meats that are more likely to contain high levels of salt. Packed lunches generally contain foods high in Na such as sandwiches, savoury snacks and dairy products⁽³³⁾. Lower dietary Na intakes are associated with lower blood pressure^(34–37) and a reduction in CVD⁽³⁸⁾, therefore reductions in Na intake are beneficial to health.

Packed lunches were nutritionally superior to school meals in one respect, namely Fe. Children having packed lunches since the introduction of school-meal standards had higher Fe intakes at lunchtime. This is possibly a consequence of reducing processed meat products such as sausage rolls and burgers, which tend to be higher in Fe than poultry that has

now replaced these products. Many children are consuming lower Fe levels than recommended⁽²⁾.

Even small sustained higher levels of total sugar, saturated fat and Na intakes at lunchtime of children having packed lunches v. school meals could potentially have an impact on long-term health of young people. Indeed, there are reports that plasma insulin levels in young people aged 13–16 years who usually take a packed lunch are 7% higher than in those who usually take a school meal⁽¹¹⁾. This could be the result of slightly higher sugar intakes over extended periods of time. The same study also reported a 4.5% increase in the total:HDL-cholesterol ratio and a slightly higher systolic blood pressure in those regularly having a packed lunch, although differences were not statistically significant. The NDNS of young people⁽²⁾ reported that there were no significant differences by lunch type for blood cholesterol levels and haematological analytes in younger children aged 4–10 years. Therefore, differences in nutrient intake may not become apparent as effects on CVD risk markers until children are older.

Interventions to improve health may be successful with relatively minor decreases in fat, sugar and Na. A meta-analysis of interventions in adults concluded that a reduction in total fat intake of 2.5% is enough to reduce cholesterol levels by a useful amount⁽³⁹⁾. The benefits of reducing fat intake in children on risk of disease in adulthood are not as yet well understood. Some evidence exists of the benefit of

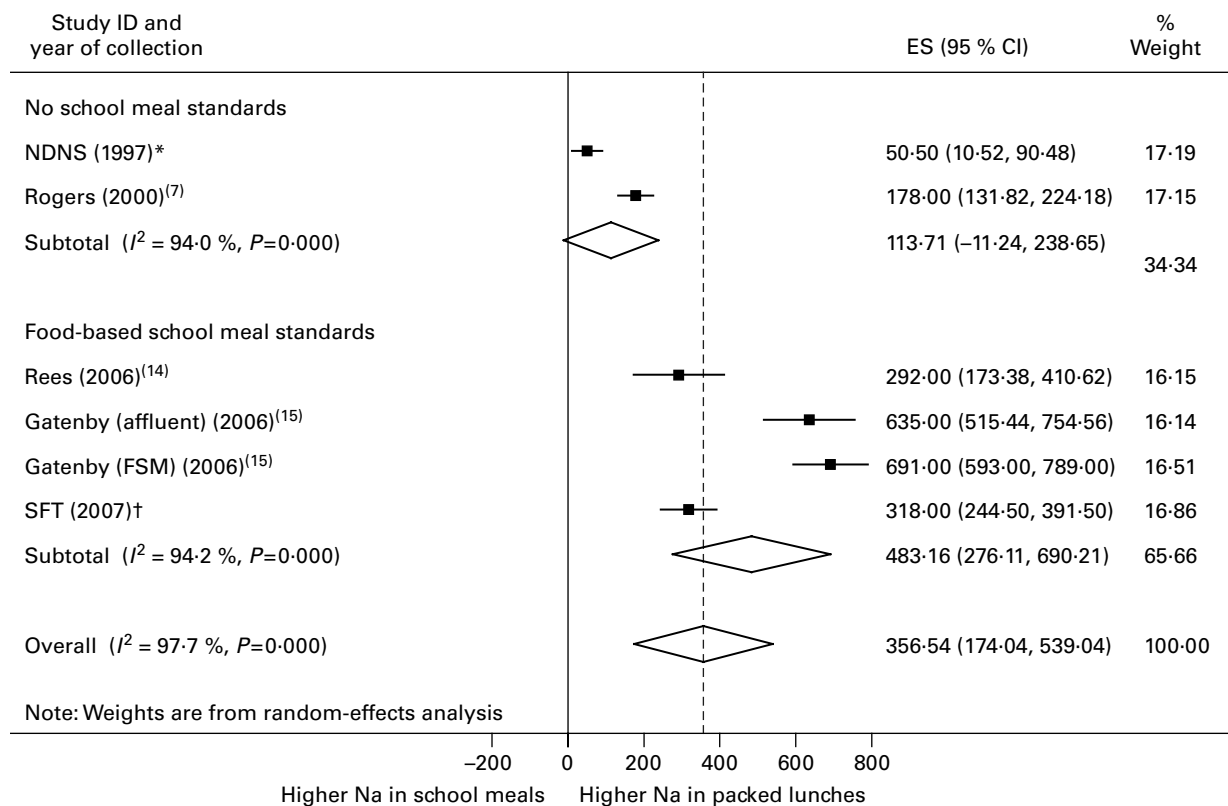


Fig. 6. Forest plot of pooled estimate (ES) of difference in Na intake (mg) by lunch type in primary school children. NDNS, National Diet and Nutrition Survey; FSM, free school meals; SFT, School Food Trust. * M Metsalaar, unpublished results. † C Ruxton, G Rees and J Pearce, unpublished results.

improvements in fat intake^(40,41); however, more work is necessary in this area.

The results for other nutrients were inconsistent. Levels of protein, folate, vitamin C and Zn were broadly similar in both lunch types. Results for remaining nutrients, namely, energy, total fat, fibre, Ca and vitamin A, were less consistent, with less evidence of differences by lunch type. Although there was evidence that energy intake is higher in packed lunches, particularly since the introduction of standards, this was at odds with the results of the national study (NDNS) which reported lower energy intakes for packed lunches while all the remaining studies (which were regional) reported higher energy intakes in packed lunches. This national survey looked at the whole day, not just lunchtime, and had a different focus for staff and parents at lunchtime than studies which just measured intake at lunch and therefore may be less biased towards changes in lunchtime intake due to the study. Unfortunately, the lack of focus on lunchtime meant that assumptions had to be made about which foods constituted lunch due to the methods of data collection. This may have led to packed lunch foods that were eaten at morning or afternoon break not being included in the lunchtime analysis and a reduction in the mean energy intake at lunchtime of children having packed lunches.

Weaknesses of the present study include the following points. Heterogeneity between studies was high for most analyses, making robust conclusions difficult. This is probably due to the different methodology used to collect nutritional data from each study. Sources of error are many. The most

recent edition of the Composition of Foods, which provides the nutrient content of a range of foods, does not include analysis of every food available in supermarkets and updates the results approximately once every 10 years, necessitating estimation. However, in the UK this information from the Royal Society of Chemistry is the only source of nutritional information. Some nutrients such as Zn and NME sugars intake were not collected in all studies, making it more difficult to make conclusions. An up-to-date review of school meals and packed lunches is further complicated by the fact that data take a number of years to publish. Unpublished results were used for this reason. The findings of the present report may change when the nutritional standards are implemented from September 2008.

Studies assessing differences between school meals and packed lunches are relatively rare; however, many recent changes have been made to school meals and therefore the authors recommend more regular data collection to determine differences in lunch type after the nutrient standards were introduced in September 2008. The present study provides some evidence that packed lunches are less nutritious than school meals. The widening of the gap between lunch types in recent years may be partly due to the improvement of school meals and partly due to the worsening of packed lunches in terms of fats, sugars and Na content. Efforts to increase the proportion of children having a school meal or improving the content of packed lunches, particularly in reducing added sugars and saturated fat, would be beneficial to children. The main sources of sugars in packed lunches are

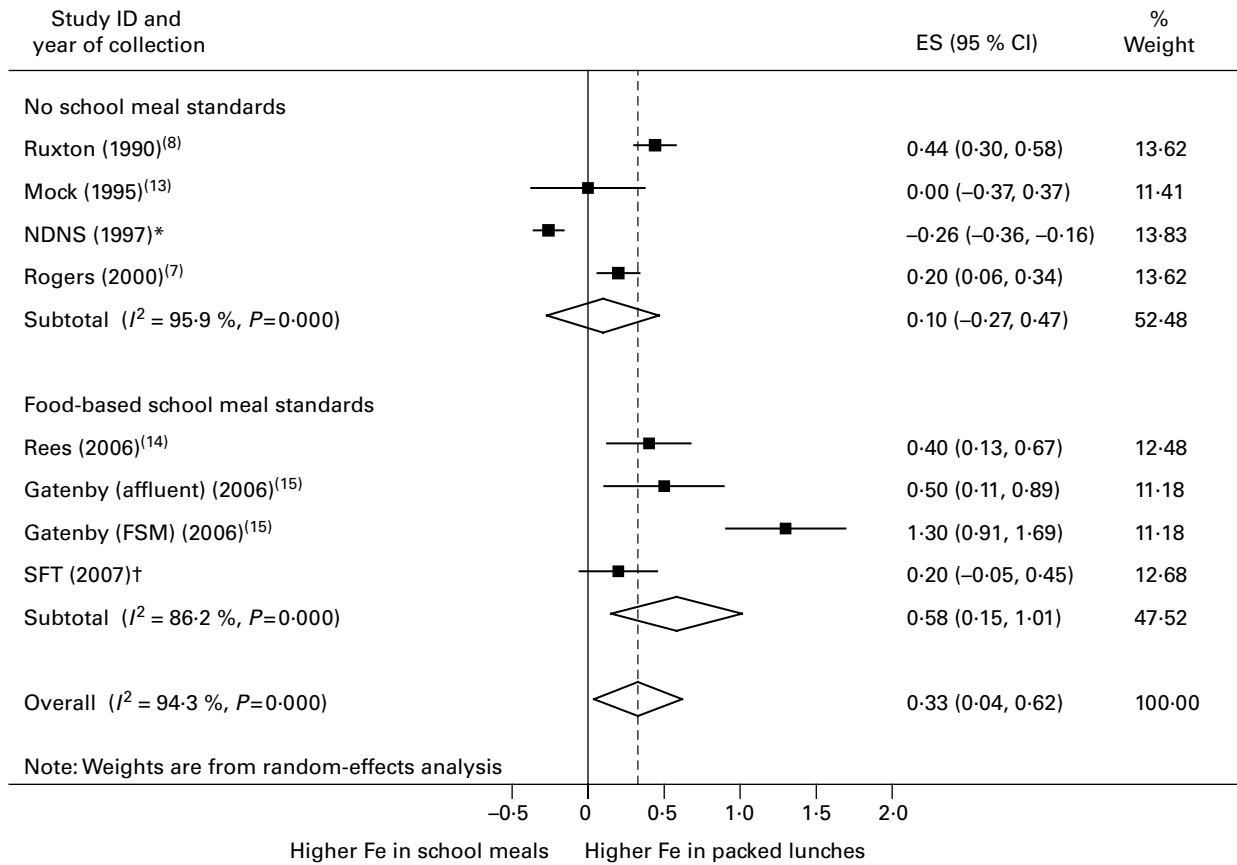


Fig. 7. Forest plot of pooled estimate (ES) of difference in Fe intake (mg) by lunch type in primary school children. NDNS, National Diet and Nutrition Survey; FSM, free school meals; SFT, School Food Trust. * M Metsalaar, unpublished results. † C Ruxton, G Rees and J Pearce, unpublished results.

sweetened drinks, confectionery and yoghurts⁽⁶⁾. The main sources of fats, including saturated fats, are confectionery and crisps. American multi-component school-based interventions that have reduced fat intake at lunchtime^(42,43) have mainly concentrated on lunches provided by schools, and recommend substituting other less-energy-dense foods such as fruit, vegetables or cereals^(44–46) or including more low-fat choices at lunchtime⁽⁴³⁾. However, encouraging young people to replace these energy-dense packed lunch foods provided from home with foods higher in starch and lower in fat and sugar is more challenging.

One recent intervention had some success in changing packed lunch food types such as fruit and vegetables but little impact on intake of fats and sugars⁽⁴⁷⁾. Schools are now strongly encouraged to have a packed lunch policy providing parents with clear guidelines on what to provide for their child's lunch. Reducing consumption of sweetened drinks, which are linked to increases in weight and risk factors for diabetes, may be the first step to improving children's food intake at lunchtime. The best solution may be to increase take-up of school meals by offering cheap or free meals. Recent pilot schemes in Scotland (Hungry for Success)⁽⁴⁸⁾ reported a doubling of take-up to 85% when free school meals were made available. Further pilots are now in place in Durham, Newham and Wolverhampton. Partial subsidy would still potentially be beneficial in terms of school meal uptake, as price is a strong predictor of take-up level⁽⁴⁹⁾.

Conclusion

Packed lunches had a worse nutrient profile compared with school meals for all nutrients considered. This was true even before the school meal food-based standards were introduced. The introduction of food-based standards for school meals in 2006 has moderately improved the nutrient content of school meals, slightly widening the gap between school meals and packed lunches. With no standards in place for packed lunches brought from home, nutrient-based standards introduced in 2008 may further widen this gap.

Acknowledgements

No specific funding was obtained for the present study. We are extremely grateful to Dr Carrie Ruxton, Dr Gail Rees and to Jo Pearce for providing additional unpublished results from their nutritional surveys of children's lunches. We would also like to thank Manon Metsalaar for carrying out the secondary analysis of the NDNS data used in the present review. C. E. L. E. carried out the statistical analysis and wrote the first draft. C. L. C. carried out the systematic review and contributed to the final draft. D. C. G. provided statistical guidance and support and contributed to the final draft. J. E. C. provided guidance for the analysis and contributed to the final draft.

There is no conflict of interest.

References

- Evans CEL & Harper CE (2009) A history and review of school meal standards in the UK. *J Hum Nutr Diet* **22**, 89–99.
- Gregory J, Lowe S, Bates CJ, *et al.* (2000) *National Diet and Nutrition Survey: Young People Aged 4 to 18 Years*. London: The Stationery Office.
- Nelson M, Nicholas J, Suleiman S, *et al.* (2005) *School Meals in Primary Schools in England*. London: Food Standards Agency.
- The School Food Trust (2007) Guide to the nutrient based standards. <http://www.schoolfoodtrust.org.uk/document.asp> (accessed 13 May 2010).
- School Food Trust (2008) Third annual survey of take up of school meals in England (provisional findings). <http://www.schoolfoodtrust.org.uk/UploadDocs/News/documents/mediabriefing2008.pdf> (accessed 19 July 2008).
- Evans CEL & Cade JE (2007) Packed Lunches in Primary Schools in the UK. A cluster randomised controlled trial of a 'Smart' lunch box, designed to improve the content of primary school children's packed lunches in the UK. Part 1: Results of baseline survey. <http://www.food.gov.uk/multimedia/pdfs/smartlunchbox> (accessed 13 May 2010).
- Rogers IS, Ness AR, Hebditch K, *et al.* (2007) Quality of food eaten in English primary schools: school dinners vs packed lunches. *Eur J Clin Nutr* **61**, 856–864.
- Ruxton CHS, Kirk TR & Belton NR (1996) The contribution of specific dietary patterns to energy and nutrient intakes in 7–8 year old Scottish schoolchildren. II. Weekday lunches. *J Hum Nutr Diet* **9**, 15–22.
- School Food Trust (2008) Revised guide to standards for school lunches. http://www.schoolfoodtrust.org.uk/doc_item.asp?DocId=8&DocCatId=9 (updated 3 April 2008).
- Cross M and MacDonald B (editors) (2009) *Nutrition in Institutions*. Oxford: Wiley-Blackwell.
- Whincup PH, Owen CG, Sattar N, *et al.* (2005) School dinners and markers of cardiovascular health and type 2 diabetes in 13–16 year olds: cross sectional study. *BMJ* **331**, 1060–1061.
- StataCorp LP (2008) *Stata 10*. College Station, TX: StataCorp LP.
- Mock J, Adams A, Snowden L, *et al.* (1997) Nutritional analysis of midday meals provided for 5–11 year old schoolchildren. *Br Food J* **99**, 12.
- Rees GA, Richards CJ & Gregory J (2008) Food and nutrient intakes of primary school children: a comparison of school meals and packed lunches. *J Hum Nutr Diet* **21**, 420–427.
- Gatenby LA (2010) A comparison of children's nutritional intake from packed lunches and school meals in two different socio-economic areas. *J Hum Nutr Diet* (In the Press).
- Department of Health (1989) *The Diets of British Schoolchildren*. London: H.M. Stationery Office.
- Tilston CH, Neale RJ, Gregson K, *et al.* (1992) A study of the nutritional composition of primary school children's packed lunches and school meals. *Int J Consum Stud Home Econ* **16**, 97–107.
- Jefferson A & Cowbrough K (2003) *School Lunch Box Survey 2003*. London: Food Standards Agency. <http://www.food.gov.uk/multimedia/pdfs/lunchsurvey.pdf> (accessed 13 May 2010).
- Jefferson A & Cowbrough K (2004) *School Lunch Box Survey 2004*. London: Food Standards Agency. <http://www.food.gov.uk/multimedia/pdfs/lunchbox2004report.pdf> (accessed 16 July 2008).
- Gibson S & Neate D (2007) Sugar intake, soft drink consumption and body weight among British children: further analysis of National Diet and Nutrition Survey data with adjustment for under-reporting and physical activity. *Int J Food Sci Nutr* **58**, 445–460.
- Vartanian LR, Schwartz MB & Brownell KD (2007) Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *Am J Public Health* **97**, 667–675.
- Biró L, Regöly-Mérei A, Nagy K, *et al.* (2007) Dietary habits of school children: representative survey in metropolitan elementary schools. Part two. *Ann Nutr Metab* **51**, 454–460.
- López-Frías M, Nestares T, Iañez I, *et al.* (2005) Nutrient intake adequacy in schoolchildren from a Mediterranean area (southern Spain). Influence of the use of the school canteen. *Int J Vitam Nutr Res* **75**, 312–319.
- Crowe FL, Skeaff CM, Green TJ, *et al.* (2006) Serum fatty acids as biomarkers of fat intake predict serum cholesterol concentrations in a population-based survey of New Zealand adolescents and adults. *Am J Clin Nutr* **83**, 887–894.
- Mensink RP & Katan MB (1989) Dietary fat guidelines for men and women. *Lancet* **i**, 790–791.
- Mensink RP, Janssen MC & Katan MB (1988) Effect on blood pressure of two diets differing in total fat but not in saturated and polyunsaturated fatty acids in healthy volunteers. *Am J Clin Nutr* **47**, 976–980.
- Merchant AT, Kelemen LE, de Koning L, *et al.* (2008) Interrelation of saturated fat, *trans* fat, alcohol intake, and subclinical atherosclerosis. *Am J Clin Nutr* **87**, 168–174.
- Gibson SA (2007) Are diets high in non-milk extrinsic sugars conducive to obesity? An analysis from the Dietary and Nutritional Survey of British Adults. *J Hum Nutr Diet* **20**, 229–238.
- Berenson GS, Wattigney WA, Tracy RE, *et al.* (1992) Atherosclerosis of the aorta and coronary arteries and cardiovascular risk factors in persons aged 6 to 30 years and studied at necropsy (The Bogalusa Heart Study). *Am J Cardiol* **70**, 851–858.
- Berenson GS, Srinivasan SR, Bao W, *et al.* (1998) Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart Study. *N Engl J Med* **338**, 1650–1656.
- Webber LS, Harsha DW, Phillips GT, *et al.* (1991) Cardiovascular risk factors in Hispanic, white, and black children: the Brooks County and Bogalusa Heart studies. *Am J Epidemiol* **133**, 704–714.
- Hooper L, Summerbell CD, Higgins JP, *et al.* (2001) Dietary fat intake and prevention of cardiovascular disease: systematic review. *BMJ* **322**, 757–763.
- Evans C, Greenwood D, Thomas J, *et al.* (2010) A cross-sectional survey of children's packed lunches in the UK: food and nutrient based results. *J Epidemiol Community Health* (epublication ahead of print version 20 January 2010).
- Sacks FM, Svetkey LP, Vollmer WM, *et al.* (2001) Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH – Sodium Collaborative Research Group. *N Engl J Med* **344**, 3–10.
- Law MR, Frost CD & Wald NJ (1991) By how much does dietary salt reduction lower blood pressure? I – Analysis of observational data among populations. *BMJ* **302**, 811–815.
- Frost CD, Law MR & Wald NJ (1991) By how much does dietary salt reduction lower blood pressure? II – Analysis of observational data within populations. *BMJ* **302**, 815–818.
- He FJ & MacGregor GA (2002) Effect of modest salt reduction on blood pressure: a meta-analysis of randomized trials. Implications for public health. *J Hum Hypertens* **16**, 761–770.
- Cook NR, Cutler JA, Obarzanek E, *et al.* (2007) Long term effects of dietary sodium reduction on cardiovascular disease outcomes: observational follow-up of the trials of hypertension prevention (TOHP). *BMJ* **334**, 885.
- Brunner E, White I, Thorogood M, *et al.* (1997) Can dietary interventions change diet and cardiovascular risk factors? A meta-analysis of randomized controlled trials. *Am J Public Health* **87**, 1415–1422.

40. Brunner E, Shipley MJ, Blane D, *et al.* (1999) When does cardiovascular risk start? Past and present socioeconomic circumstances and risk factors in adulthood. *J Epidemiol Community Health* **53**, 757–764.
41. Caballero B (2001) Early nutrition and risk of disease in the adult. *Public Health Nutr* **4**, 1335–1336.
42. Greenwald P, Clifford CK & Milner JA (2001) Diet and cancer prevention. *Eur J Cancer* **37**, 948–965.
43. Arbeit ML, Johnson CC, Mott DS, *et al.* (1992) The Heart Smart cardiovascular school health promotion: behavior correlates of risk factor change. *Prev Med* **21**, 18–32.
44. Epstein LH, Gordy CC, Raynor HA, *et al.* (2001) Increasing fruit and vegetable intake and decreasing fat and sugar intake in families at risk for childhood obesity. *Obes Res* **9**, 171–178.
45. Swain JF, Rouse IL, Curley CB, *et al.* (1990) Comparison of the effects of oat bran and low-fiber wheat on serum lipoprotein levels and blood pressure. *N Engl J Med* **322**, 147–152.
46. Heald AH, Golding C, Sharma R, *et al.* (2004) A substitution model of dietary manipulation is an effective means of optimising lipid profile, reducing C-reactive protein and increasing insulin-like growth factor-1. *Br J Nutr* **92**, 809–818.
47. Evans C, Greenwood D, Thomas J, *et al.* (2010) SMART lunch box intervention to improve the food and nutrient content of children's packed lunches: UK wide cluster randomised controlled trial. *J Epidemiol Community Health* (In the Press).
48. The Scottish Government (2003) Hungry for Success – A Whole School approach to School Meals in Scotland. <http://www.scotland.gov.uk/Publications/2003/02/16273/17566> (accessed 13 May 2010).
49. Rona RJ & Chinn S (1984) Parents' attitudes towards school meals for primary school children in 1981. *Hum Nutr Appl Nutr* **38**, 187–198.
50. Rees GA, Richards CJ & Gregory J (2007) Nutrient intakes at lunchtime of primary school children in Cornwall: a comparison of school meals and packed lunches. *Proc Nutr Soc* **66**, 101A.
51. Burgess AL & Bunker VW (2002) An investigation of school meals eaten by primary schoolchildren. *Br Food J* **104**, 705–712.