NIHR | Policy Research Unit in Obesity

OPRU Briefing Paper – Modelling the impact of reductions in energy intake (estimated) on population prevalence of childhood overweight and obesity:

Energy intake estimates from BMI using Henry equations

April 2020

Authors

Simon J Russell, Steven Hope, Helen Croker, Jessica Packer, Russell M Viner

Key messages

This work replicated earlier modelling to simulate the potential impacts of reducing estimated energy intake on population prevalence and inequalities in childhood overweight and obesity. Unlike previous work that used dietary data, these analyses estimated energy intake from basal metabolic rate (BMR) using Henry equations.[1]

Analyses used Avon Longitudinal Study of Parents and Children (ALSPAC) cohort data with intake estimates at age 7 years and risk of overweight and obesity at age 11 years.

The simulation modelled the potential impact of an average 4.2% reduction in median intake based on estimated average requirements (EAR). This resulted in large reductions in prevalence of childhood overweight and obesity.

Reducing energy intake is likely to be effective in reducing childhood obesity.

Background

In the UK, rates of childhood obesity have been increasing[2] and evidence suggests that most children with obesity will subsequently have obesity in adolescence and adulthood.[3] Obesity is strongly linked to disadvantage and trends show that inequalities in obesity have widened in recent years.[2] Obesity is primarily the product of a positive energy balance and the consequence of a change in diet towards energy-rich foods, which often co-exist with poor nutrition.[4]

There is a clear rationale for effective public health policies and interventions that reduce children's dietary intake and improve dietary quality.[5] The Childhood Obesity Strategy (incorporating Chapters 1 and 2 of the Childhood Obesity Plan and DHSC's Prevention Green Paper 'Advancing Our Health: Prevention in the 2020s') seeks to address this need by reducing the amount of calories children consume and improving diet quality.

A simulation approach using longitudinal cohort data provided insights into the potential impacts of calorie-reduction programmes. This methodology is an approach to modelling the impact of reducing energy intake at a population level.

One key scenario was assessed: An average 4.2% reduction in estimated energy intake at age 7 years, reflecting the difference between estimated average requirements (EAR) and median intake estimated from BMI in the ALSPAC cohort.

Aim and objectives

The aim of this work was to model the impact of reducing estimated energy intake on prevalence and inequalities in overweight and obesity among UK children.

Research questions

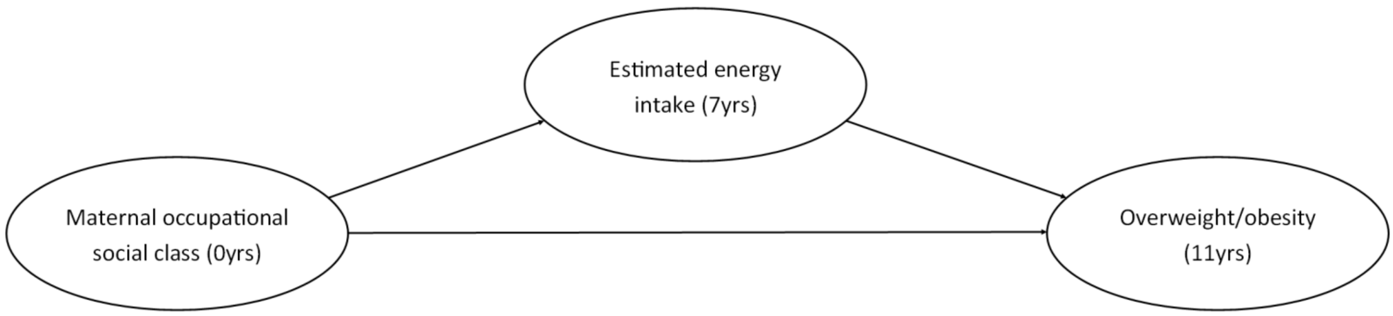
- What is the impact on population prevalence of childhood overweight and obesity of a reduction in estimated energy intake?
- What is the impact on inequalities in childhood overweight and obesity of a reduction in estimated energy intake?

What we did

Overview

A social determinants framework was adopted, with social class based on parental occupation used as the exposure. Estimated energy intake calculated from basal metabolic rate (BMR) at age 7 was used as a mediator of the exposure-outcome relationship (Figure 1). Z-scores for BMI at age 11 years using the UK90 reference data[6] and cut offs for overweight (>85th percentile) and obesity (>95th percentile) for epidemiological application[7] were used as outcomes.

Figure 1. Diagram showing hypothesised exposure, mediator and outcome relationship



We used data from the Avon Longitudinal Study of Parents and Children (ALSPAC). To estimate calorie intake at 7 years, we used the Henry equations.[1] A marginal structural modelling (MSM) framework was used to predict prevalence and inequalities in overweight and obesity. The MSM estimated the 'control direct effect' (CDE) (the association between social class and overweight/obese after controlling for confounding and holding the observed level of the mediator (estimated energy intake); risk ratios and risk differences of being overweight/obese were also calculated. The CDE is used as a reference point to gauge change resulting from the reduction in estimated energy intake. (See Appendices for further details on methods.)

Simulation

The mediator (estimated energy intake) was manipulated to simulate the impact of a reduction in energy intake (informed by EAR for children aged 7 years[8]) on overweight/obesity at 11 years. The median estimated intake in ALSPAC for children aged 7 years was 1,710.0kcal (or 7154.6kJ) for boys and 1,600.4 (or 6695.9kJ) for girls, while EAR was 1,649kcal (or 6899.4kJ) for boys and 1,530kcal (or 6401.5kJ) for girls.[8] To meet EAR, boys would need to consume 61.0kcal (or 255.2kJ) fewer and girls 70.4kcal (or 294.4kJ) fewer.

The overall reduction in estimated energy intake to meet EAR was 4.2% for girls and boys combined, and we used this figure to simulate the impact on obesity prevalence and inequalities of an average reduction in estimated intake to this level. Guided by the lower nutrient intake bound, a lower bound was set at 2SD below the mean energy intake to avoid reducing intake for children who already had low daily energy consumption.

The simulation was repeated with overweight and obese as a combined outcome.

Table 1. Scenario modelled

Scenario	**Energy reduction**	**Target**	**Uptake**
Universal reduction in estimated energy intake to meet EAR	-4.2% *(-3.6% boys, -4.4% girls)*	All children	100%

Results

The observed (CDE) prevalence of obesity was 19.0%; overweight and obesity prevalence was 35.2% (Table 2).

The simulated scenario (a universal reduction to meet EAR) reduced overall obesity prevalence by 5.3% (a reduction of 28.1% on the observed prevalence). With the combined overweight and obesity outcome, the simulation reduced prevalence by 8.8% (a reduction of 24.9% on the observed prevalence).

- Following this simulation, the proportion of children consuming equal to or less than EAR increased from 46.2% to 63.9% for boys and from 14.8% to 33.5% for girls.
- Reductions in overweight/obesity prevalence were similar across the social classes.
- There was no decrease in relative inequalities (risk ratio) but a small decrease in absolute inequalities (risk difference). This decrease was the result of large reductions in overweight/obesity prevalence across all social class groups.

Table 2. Prevalences and relative and absolute inequalities in child overweight/obesity at age 11 years, observed and after modelling the simulated scenario

Scenario	**% consuming <=RDI kcals (boys/girls)**	**Prevalence of obesity at 11 years (>=95th centile)**				**Inequalities in overweight/obesity[a]**	
		Overall (% change vs CDE)	**Maternal social class**			**Risk ratio (CIs)**	**Risk difference (CIs)**
			Lowest (% change vs CDE)	**Mid (% change vs CDE)**	**Highest (% change vs CDE)**		
Control Direct Effect[b]							
	46.2% / 14.8%	19.0%	21.0%	18.9%	17.3%	1.2 (1.1 – 1.3)	3.7 (1.6 – 5.8)
Simulation: Universal reduction of estimated intake to EAR (-4.2% overall average), 100% uptake							
	63.9% / 33.5%	13.6% (-28.1%)	15.1% (-28.3%)	13.5% (-28.3%)	12.6% (-27.5%)	1.2 (1.1 – 1.3)	2.5 (0.9 – 4.2)
Prevalence of overweight and obesity at 11 years (>=95th centile)							
Control Direct Effect[b]							
	46.2% / 14.8%	35.2%	37.8%	35.2%	33.0%	1.2 (1.1 – 1.2)	4.8 (2.2 – 7.5)
Simulation: Universal reduction of estimated intake to EAR (-4.2% overall average), 100% uptake							
	63.9% / 33.5%	26.4% (-24.9%)	28.6% (-24.5%)	26.3% (-25.3%)	24.8% (-24.8%)	1.2 (1.1 – 1.3)	3.8 (1.6 – 6.0)

[a] Risk ratios (prevalence in lowest social class *divided* by prevalence in highest social class) and risk differences (prevalence in lowest social class *minus* prevalence in highest social class) are likelihoods of being overweight/obese with reference to non-overweight/obese group.

[b] The effect of maternal social class on overweight/obesity prevalence at age 11 years, adjusted for baseline and Intermediate confounding with mediation of estimated energy intake held at observed level.

Discussion

Summary

Simulating a reduction in children's estimated energy intake resulted in a large decrease in population overweight and obesity prevalences. These analyses suggest that reducing estimated energy intake at age 7 could have profound implications for BMI at age 11.

Limitations

The ALSPAC cohort is not nationally representative and comprises children born in the early 1990s. Energy intake was estimated using BMI data recorded in 1998 and these data have less relevance to contemporary populations. Participants were also less deprived and likely to be leaner than their contemporary counterparts, meaning energy intake was likely to be underestimated.

Total daily energy intake for children age 7 years was calculated using the Henry equations (BMR estimated from BMI at age 7 with a physical activity multiplier applied). Given that energy intake was estimated using BMI, these analyses essentially show that reducing BMI at age 7 years is likely to reduce overweight/obesity at age 11 years. Using BMI to estimate BMR/energy intake is also problematic as there is no differentiation between lean and fat mass.

The physical activity multiplier in these equations was based on the median value from doubly labelled water (DLW) studies of a reference population, which is unrelated to the sample population. In addition, to acknowledged limitations of PAL estimates,[9] use of reference data for the ALSPAC cohort may also underestimate levels of physical activity, given the age of the cohort.

There are other, general limitations with estimating energy intake from BMR. The Henry equations are based on predictions for age bands (children aged between 3 and 10 years) and do not account for age differences within the bands or individual variations. These estimates do not have the granularity of data on energy intake or physical activity for individual children.

Implications for policy

Policy-makers have identified reducing energy intake and improving diet quality as key components of the Childhood Obesity Strategy. The findings from these analyses suggest that reducing estimated energy intake in children has the potential to lower obesity prevalence in mid childhood.

References

1. Henry, C.J.K. (2005). Basal metabolic rate studies in humans: measurement and development of new equations. Public Health Nutrition: 8(7A). 1133–1152.
2. National Child Measurement Programme. (2017). National Child Measurement Programme – England, 2016-17: Report. https://files.digital.nhs.uk/publication/j/n/nati-chil-meas-prog-eng-2016-2017-rep.pdf.
3. Simmonds, M., Llewellyn, A., Owen, C.G. et al. (2015) Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. Obesity Reviews. doi: 10.1111/obr.12334.
4. Rush, E.C. and Yan, M.R. (2017). Evolution not Revolution: Nutrition and Obesity. Nutrients. 9. 5: 519.
5. te Velde, S.J., van Nassau, F., Uijtdewilligen, L. et al. (2012). Energy balance-related behaviours associated with overweight and obesity in preschool children: a systematic review of prospective studies. Obesity Reviews. 13. S1: 56-74.
6. Cole, T.J., Freeman, J.V. and Preece, M.A. (1995). Body mass index reference curves for the UK, 1990. Archives of Disease in Childhood. 73: 25–9.
7. Troiano, R.P., Flegal, K.M., Kuczmarski, R.J. et al. (1995). Overweight prevalence and trends for children and adolescents: the National Health and Nutrition Examination Surveys, 1963 to 1991. Archives of Pediatrics and Adolescent Medicine. 149: 1085–1091.
8. SACN. (2011). Dietary Reference Values for Energy. Scientific Advisory Committee on Nutrition. London TSO. www.sacn.gov.uk
9. Goran, M.I. (2005). Estimating energy requirements: regression based prediction equations or multiples of resting metabolic rate. Public Health Nutrition. 8: 1184-1186.

Appendices

Methods

Analyses were undertaken using ALSPAC, a geographically-defined longitudinal birth cohort in the old administrative county of Avon in Southwest England. After restricting the total sample to children with completed data for maternal social class, multiple imputation was carried out to generate 50 datasets, which gave an analytic sample of 10,680.

Description of measures

Exposure (maternal social class) - Maternal occupational social class was used as a household measure of social inequalities. Reported at baseline (32 weeks gestation), classes were combined into three groups: higher social class (professional, managerial and technical), middle social class (skilled non-manual), and lower social class (skilled manual, part-skilled and unskilled).

Outcome (overweight and obesity) - Height and weight were recorded objectively at age 11 years. BMI was calculated and risk of overweight/obesity was defined using UK90 reference data and $85^{th}/95^{th}$ percentiles of BMI; these cut offs were used as they are policy-relevant and comparable to other data sets.

Mediator (estimated intake) - Children's total energy expenditure (TEE) at age 7 years was estimated using the Henry equations,[1] which are sex and age band specific (aged 3-10 years) and predict BMR from height and weight. BMR is then multiplied by physical activity level (PAL).

$$(TEE = BMR \times PAL)$$

The median value of PAL was estimated from measures of doubly labelled water (DLW) for children aged 3-10 years as per the SACN report.[8] The median value was adjusted for growth (1.58) and was applied with a small amount of random variation across the population (0.01 standard deviation).

Baseline confounding - Child ethnicity, categorised as 'white' and 'non-white', collected at enrolment was the only baseline confounder.

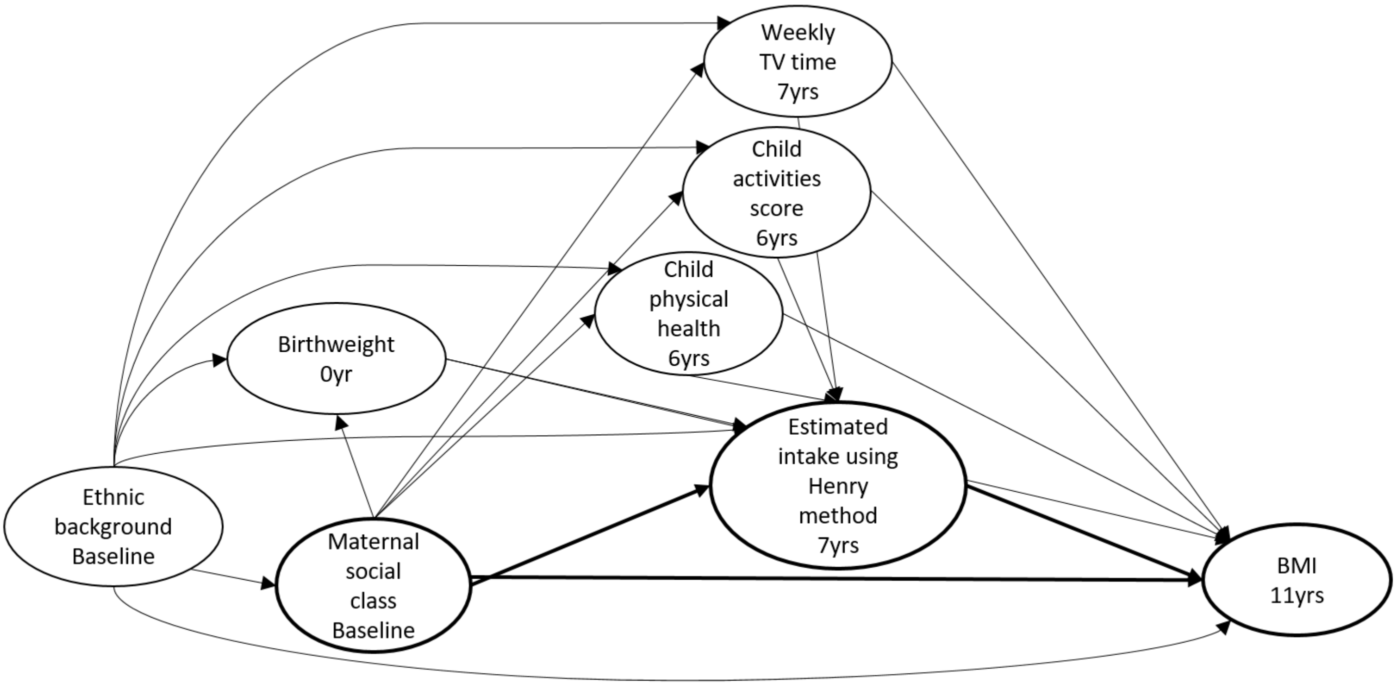
Intermediate confounding - These included: birthweight, and maternal reports of the child's physical health (6 years), physical activity (6 years) and daily TV time (7 years).

Modelling

The association between maternal social class (recorded during pregnancy) and BMI (age 11) was estimated using logistic regression within a marginal structural modelling (MSM) framework, accounting for estimated energy intake (age 7; the mediator) and confounding variables. The full theoretical model is indicated by a directed acyclic graph (Appendix Figure 1), which also shows the hypothesised confounding structure.

Descriptives and relationships between exposure, mediator and outcome and confounding variables have been included as Appendices tables 1 and 2.

Appendix Figure 1. Directed Acyclic Graph showing the theoretical model



This diagram can be understood in temporal terms, where the exposure (maternal occupational social class) was measured at pregnancy, the mediator (estimated energy intake) was measured at age 7 and the outcome (BMI) was measured at age 11. The confounding structure and hypothesised relationships are also shown; confounding variables were measured at appropriate time points.

Appendix Table 1. Descriptive statistics of ALSPAC for analytic sample

		Imputed sample (m=50) n=10,680
Sex	Male	51.9%
	Female	48.1%
Exposure		
Mother Social Class	Low	25.7%
	Mid	42.7%
	High	31.6%
Baseline confounding (0 years)		
Ethnicity	White	95.7%
	Non-white	4.3%
Mediator		
Estimated energy intake	Median kcal (SE)	1661.3 (1.85)
	Median kJ (SE)	6950.9 (7.74)
Time-varying confounding		
Birthweight	Low	13.2%
	Mid	72.3%
	High	14.5%
Child physical health	Very healthy/healthy	97.0%
	Sometimes/always unwell	3.0%
Child activities score	Low	7.3%
	Mid	66.4%
	High	26.4%
TV time	Low (<=14hrs)	7.6%
	Mid (>14hrs and <=26hrs)	80.9%
	High (>26 hours)	11.5%
Outcome		
BMI status (11 years)	Not obese	65.3%
	Overweight (85^{th}-95^{th})	16.3%
	Obese (>95^{th} centile)	18.5%

Appendix Table 2. Relationship between confounding and exposure, mediator and outcome variables (n=10,680)

	Maternal social class % in lowest social class	Estimated intake Median (SE)	zBMI 11 years % obese
Ethnicity			
White	25.6%	1660.5 (1.90)	18.9%
Non-white	26.3%	1680.1 (9.18)	21.6%
p-value	0.327	0.033	0.273
Birthweight			
Low	31.5%	1611.7 (5.20)	15.2%
Mid	29.2%	1657.7 (5.51)	18.4%
High	29.6%	1725.5 (7.10)	26.2%
p-value	0.188	<0.001	<0.001
Child physical health			
Sometimes/always unwell	32.6%	1679.0 (12.26)	23.3%
Very healthy/healthy	29.5%	1660.7 (1.89)	18.9%
p-value	0.532	0.137	0.435
Child activities score			
Low	30.9%	1657.7 (7.12)	18.0%
Mid	30.5%	1660.7 (7.56)	19.1%
High	26.5%	1664.0 (7.91)	19.4%
p-value	<0.001	=0.697	0.915
Weekly TV time			
Low (<=14hrs)	22.2%	1634.7 (6.97)	13.6%
Mid (>14hrs and <=26hrs)	29.4%	1661.1 (7.15)	18.5%
High (>26 hours)	34.1%	1679.9 (9.16)	25.5%
p-value	<0.001	<0.001	<0.001

P-values obtained from multinomial (maternal social class), linear (estimated energy intake), and logistic regressions (obesity at 11 years)