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Associations between caries levels and BMI measures among five-year-old children. Analysis and cross-sectional multi-variable analysis at an individual child level

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Objectives: To establish the existence and directions of any associations between measures of body mass index (BMI) with caries levels using individual measures of each as derived from national surveys in England. ***Methods:*** The BMIs of five-year-old children calculated from the 2017 National Child Measurement Programme and caries measures from the 2016-17 Public Health England (PHE) National dental epidemiology survey were securely linked at a child level. Comparison at individual level of caries levels and BMI z scores was done using multivariable regression. ***Results:*** Records for 67,033 children were linked and allocated a deprivation quintile. An association between BMI Z score categories and caries levels was established. Caries prevalence was higher among overweight (24.4%) and very overweight (27.6%) children compared with those of average BMI (22.5%). Odds ratios were statistically significant at 1.08 and 1.14 for prevalence among overweight and very overweight children. Children of low BMI were found to have higher caries severity (1.2 $d_3$mft) and extent (4.4 $d_3$mft among those with any caries) compared to children of healthy BMI (0.7 $d_3$mft, 3.3 $d_3$mft) with statistically significant Incidence Rate Ratio of 1.24. Underweight children were more likely to have caries experience and more severe attack compared with children of healthy weight. Deprivation and ethnicity were confounding factors. ***Conclusions:*** There is some association between child BMI status and caries levels whereby caries prevalence among children of higher BMI is increased. The associations are over and above those of deprivation, ethnicity and water fluoridation individually, but these factors impact on the strength of the link between BMI and caries.

Keywords: *caries, height and weight measurements, BMI, associations, children*

Introduction

The common risk factors of the ingestion of foods and drinks containing sugars affect both body mass index (BMI) and caries. Therefore it might reasonably be expected that an association would exist between BMI and caries. A summary of the current relevant evidence found a variety of individual and systematic reviews of studies, which gave conflicting results (PHE, 2015). This summary found that the current evidence was of low quality and often based in low income developing countries. Any associations were predicted to be stronger in developed countries, such as the UK. Previous efforts to establish the strength, direction and nature of such an association have usually worked on data about groups of children, often relying on self-reporting of caries status or weight. On this basis it has not been possible to say whether an individual who is of an unhealthy weight is at higher risk of dental caries or vice versa. The summary also noted that any association was probably moderated by a range of other factors.

An opportunity arose in the PHE Dental Public Health Epidemiology Programme to collect caries data from individual five-year-old children and link it to their individual height and weight data, which had been collected as part on the National Child Measurement Programme using standardised measures. Thus, the analysis for association could be run using individual level data, controlling for other known risk factors.

The aims of this study were: To establish the existence, strength and directions of any associations between measures of child BMI with caries levels using individual measures of each as derived from national survey programmes in England.

Method

Ethical opinion was sought from the Health Research Authority which oversees research within the National Health Service in the UK. The opinion was that ethical approval was not required for this study that involved linkage of two existing datasets.

National caries surveys using standardised methods of sampling, and clinical examination (PHE, 2016) are undertaken across the country, which produce estimates of caries levels for every local government area in England. The survey which took place during 2016 to 2017 was used to provide data on caries levels for a population of five-year-old children who were randomly sampled to take part using a stratified sampling method (PHE, 2016, Pine *et al.*, 1997). For those children for whom explicit consent was provided by their parents, standardised examinations took place in schools, using visual means of recording caries at the dentinal threshold level (d_3). Parents were also asked to consent to their child's information being linked to another database. The arising data were

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collated and analysed for caries severity, extent (severity among those with any caries experience) and prevalence (PHE, 2018). During the same survey home postcodes were collected and ethnic background was recorded using parental responses when asked at the time of their children being first registered at their primary school. Postcodes were used to assign deprivation scores using Office for National Statistics data (Ministry of Housing Communities and Local Government, 2015) and exposure to optimally fluoridated water using information on the geographical coverage of community water fluoridation schemes as held by PHE.

The National Child Measurement Programme (NCMP) involves weighing and measuring the height of all children aged 4 – 5 and 10 – 11 (NHS Digital, 2018) according to standardised procedures and calibrated devices, in schools. Responsibility for doing this lies with local authorities who give parents the opportunity to opt out of having their child measured. Body mass index (BMI) scores are calculated by dividing children's weight (in kilograms) by the square of their height (in metres). The resulting scores are used to classify each child by calculating the child's BMI z-score which approximates closely to centiles, taking into account age and sex as well as height and weight to allow for different growth patterns in boys and girls at different ages. The approximated classification is based on the 1990 growth reference dataset and identifies children as underweight if they are in the 2nd centile or below, overweight if in the 91st to 98th centiles and very overweight if in the 98th centile or above. All other children were classed as being of healthy weight (NHS digital, 2018).

Partnership working between the Public Health England dental public health epidemiology team and the NHS Digital team and other colleagues who deal with the NCMP meant that procedures could be followed to ensure secure and successful data linkage between the caries data set and the child height and weight data at an individual child level. To achieve this each child's date of birth, postcode and school were electronically matched across the two databases so that the data could be linked. Once this was done all identifiable data was stripped out. This resulted in a database showing caries experience and severity, ethnic code, deprivation score, geographic location, height, weight and clinical BMI category and fluoride status of the local authority of the child residence. Four multivariable regression models were fitted. Two of these looked at the outcome of prevalence of decay using the full sample of children and used logistic regression to reflect the binary outcome (decay/no decay). The other two models examined the outcome of severity of decay using the subsample of children with any decay. These models used zero-truncated negative binomial regression as the value zero does not occur in this subsample (all children had some decay) and the negative binomial is able accommodate the skewness present in the data. One model of each type included BMI z score as a continuous covariate term, while the other model included instead the clinical categories of BMI. Other covariates included in all models were child ethnic group, England deprivation quintile, government office region and fluoride status.

The multivariable regression approach allows for all potential determinants of the outcomes to be considered together in the same model, producing estimates of the effect size of each potential determinant, which are adjusted for the other determinants in the model. The five determinants of interest were included in the models as main effects, while two- and three-way interaction terms between ethnicity, deprivation and water fluoridation status were added by forward selection to test for any moderating effects on the outcomes. Interaction terms were only retained in the final models if they were significant at the 5% level and main effects also remained significant. Variables were tested for significance by examining deviance differences between pairs of nested models. All statistical analysis was performed in R. The prevalence models were fitted using the R glm function and the severity models were fitted using the glmmADMB package (Fournier *et al.*, 2012).

After model fitting the R emmeans package was used to obtain adjusted estimates of the marginal predicted probabilities of any decay, and the predicted number of $d_3$mft, averaging over the other model variables as necessary (Length, 2018).

Results

Out of 96,005 five-year-old children examined for caries status, 67,033 were linked on the NCMP dataset for height and weight and could be allocated a deprivation quintile and geographic location so were available for analysis (Table 1).

The prevalence of caries was statistically higher among those classed as overweight and very overweight than those of healthy weight (Figure 1). As BMI classifications increased so did the prevalence of caries (Figure 3). Children who were classified as underweight (N=675, 1%) had a significantly higher mean severity ($d_3$mft) and extent of caries than those of other weight status (Table 1 and Figure 2). An underweight child with caries experience has a mean $d_3$mft of 4.4 compared to a mean $d_3$mft of 3.3 in a healthy weight child (Table 1).

These associations are maintained even after multivariable analysis, which found that consideration of other factors, deprivation, exposure to fluoridated water and ethnicity mediated the strength of association. Table 2 gives the odds ratios (OR) and the incidence rate ratios (IRR) estimated by each of the four fitted multivariable models. The marginal predicted probabilities of decay and extent of decay obtained from two of these models are shown in Figures 3 and 4 for BMI z score and BMI category respectively. After adjustment for the other model covariates, Figure 3 indicates that, prevalence of caries increases linearly with BMI z score. However, this effect is smaller than the estimated effect of either water fluoridation or deprivation on caries prevalence. In children with caries experience, Figure 4 confirms that decay is more severe in underweight children compared to healthy weight, overweight and very overweight children.

In analysis by ethnic group the results for Asian children showed greater variation in comparison with white children than among the other, less well represented, sub-groups (Table 2). Both underweight and very overweight Asian children had significantly higher odds ratios of caries prevalence than their same BMI group White peers and extent was notably higher.

Table 1. Descriptive statistics of the sample overall and the subset of children with $d_3$mft>0

	n	*% of overall sample*[a]	*Mean $d_3$mft*	*n*	*$d_3$mft>0*[a]	*mean*	*25th percentile*	*median*	*75th percentile*
Total	*67,033*		*0.75*	*15,420*	*23.0*	*3.3*			
Ethnicity									
White	53,281	79.5	0.6	11,219	72.8	3.1	1	2	4
Mixed	2,942	4.4	0.8	702	4.6	3.2	1	2	4
Asian / Asian British	6,084	9.1	1.5	2,184	14.2	4.0	2	3	6
Black / Black British	2,138	3.2	0.7	425	2.8	3.3	1	3	4
Other Ethnic Group	1,250	1.9	1.7	515	3.3	4.1	2	3	6
Eastern European	352	0.5	2.2	160	1.0	4.9	2	4	7
Ethnic group not provided	986	1.5	0.8	215	1.4	3.8	1	3	5
IMD national quintile									
Most deprived 1	15,949	23.8	1.3	5,458	35.4	3.7	1	3	5
2	14,133	21.1	0.9	3,759	24.4	3.4	1	3	5
3	12,199	18.2	0.6	2,471	16.0	3.0	1	2	4
4	12,231	18.2	0.4	2,037	13.2	2.7	1	2	4
Least deprived 5	12,521	18.7	1.2	1,695	11.0	2.5	1	2	3
*Exposure to fluoridated water**									
No	59,202	88.3	0.8	13,775	89.3	3.3	1	2	4
Yes	7,831	11.7	0.6	1,645	10.7	2.8	1	2	4
BMI clinical category									
Underweight	675	1.0	1.2	183	1.2	4.4	2	3	6
Healthy weight	57,024	85.1	0.7	12,845	83.3	3.3	1	2	4
Overweight	5,821	8.7	0.8	1,422	9.2	3.3	1	2	4
Very overweight	3,513	5.2	0.9	970	6.3	3.2	1	2	4
Region									
North East	13,272	19.8	0.8	3,229	20.9	3.2	1	2	4
North West	5,892	8.8	1.1	1,879	12.2	3.5	1	3	5
Yorkshire and The Humber	3,243	4.8	0.9	841	5.5	3.4	1	2	5
East Midlands	8,884	13.3	0.7	2,070	13.4	3.2	1	2	4
West Midlands	6,807	10.2	0.8	1,747	11.3	3.1	1	2	4
East	8,549	12.8	0.6	1,492	9.7	3.2	1	2	4
London	7,323	10.9	1.0	1,930	12.5	3.7	2	3	5
South East	7,891	11.8	0.6	1,241	8.0	3.1	1	2	4
South West	5,172	7.7	0.0	991	6.4	3.0	1	2	4

* children living in areas known to have tap water containing fluoride at a level of 0.7 to 1.0 ppm during the five years prior to the survey compared to those who were not living in such areas

[a] percentages may not add to 100 due to rounding

Table 2. Distribution of caries by BMI categories among White and Asian children

	N	*Prevalence of caries experience (%)*	*Severity - mean $d_3$mft (95% CI)*	*Severity - $d_3$mft 1st quartile*	*Severity - d3mft median*	*Severity - $d_3$mft 3rd quartile*	*Extent - mean $d_3$mft among those with caries experience (95% CI)*	*Odds ratio for prevalence compared to White healthy weight (95% CI)*[a]
All White children								
Underweight	339	20%	0.74 (0.53 - 0.94)	0	0	0	3.62 (2.97 - 4.27)	1.01 (0.79 - 1.27)
Healthy weight	45,679	21%	0.62 (0.61 - 0.64)	0	0	0	3.03 (2.98 - 3.08)	ref
Overweight	4,736	23%	0.74 (0.69 - 0.80)	0	0	0	3.19 (3.04 - 3.34)	1.08 (0.99 - 1.18)
Very overweight	2,527	27%	0.82 (0.75 - 0.89)	0	0	1	3.08 (2.90 - 3.27)	1.14 (1.03 - 1.27)
All Asian children								
Underweight	249	37%	1.86 (1.45 - 2.27)	0	0	2	5.09 (4.32 - 5.85)	1.82 (1.43 - 2.32)
Healthy weight	5,008	36%	1.46 (1.38 - 1.53)	0	0	2	4.03 (3.89 - 4.17)	1.81 (1.67 - 1.97)
Overweight	380	34%	1.34 (1.08 - 1.60)	0	0	2	3.95 (3.41 - 4.49)	1.96 (1.74 - 2.22)
Very overweight	447	34%	1.22 (1.01 - 1.43)	0	0	2	3.59 (3.18 - 3.99)	2.07 (1.81 - 2.36)

[a] From adjusted model

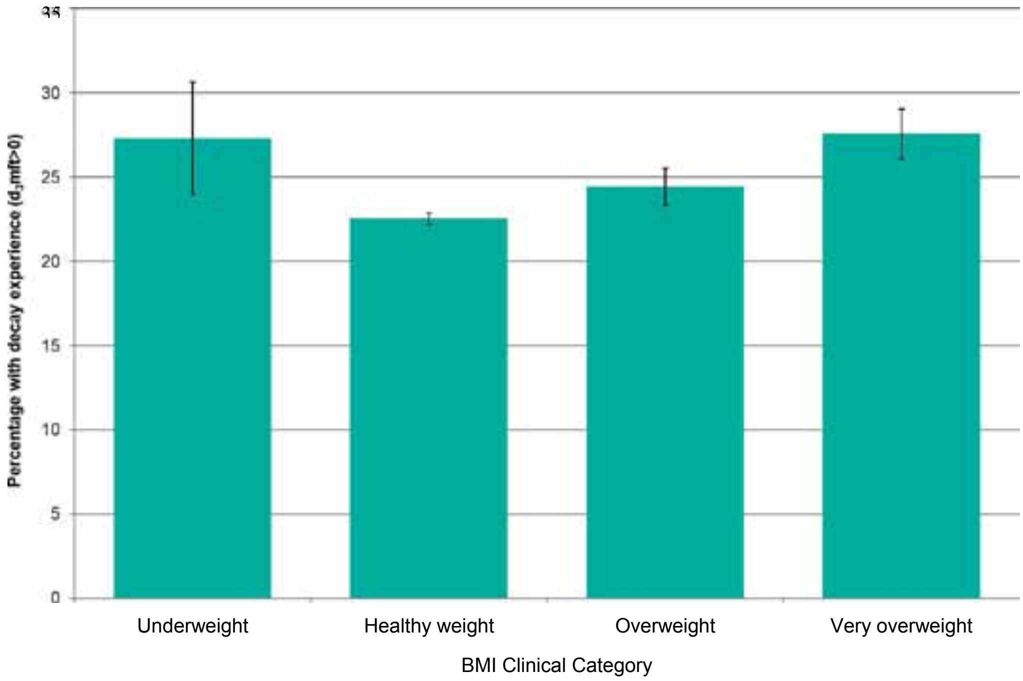

Figure 1. Percentage of five-year-old children with decay experience ($d_3mft>0$) by BMI clinical category, 2017

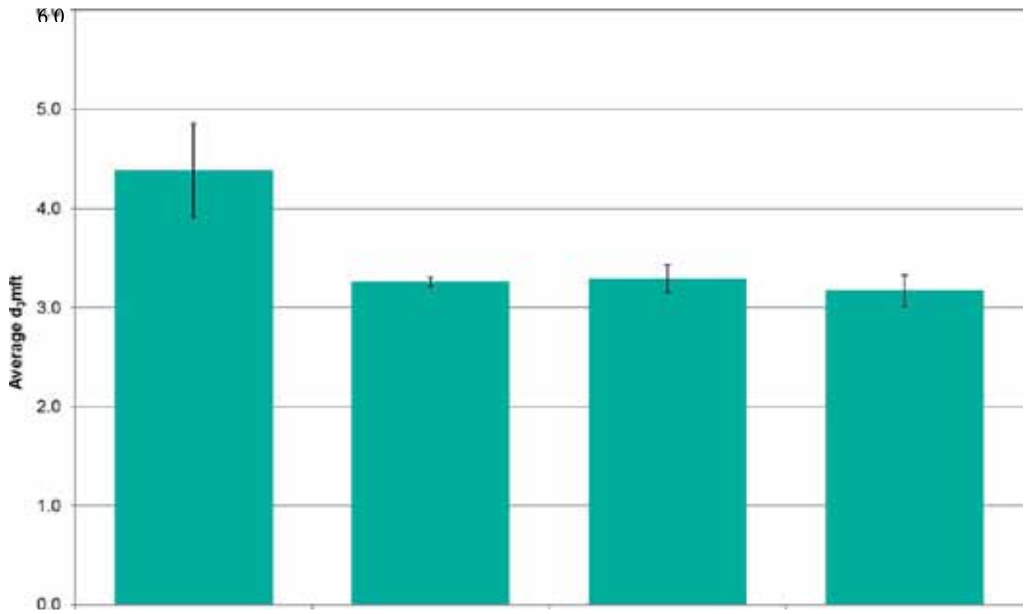

Figure 2. Average decayed, missing (due to decay) and filled teeth in five-year-old children with decay experience ($d_3mft>0$) by BMI Clinical Category, 2017

Discussion

A strength of this study lies in the connection of two high quality, routinely collected data sets allowing the analysis of associations that have been of interest for some time. Unlike some previous work the availability of data on individual children in an England population representative sample has allowed the relevant associations to be investigated (PHE, 2014). A degree of consent bias is present in the caries data whereby children with caries activity are under-represented as consent is less likely to be provided by their parents. This cannot be measured or corrected, beyond multivariable adjustment (Monaghan *et al.*, 2011; Davies *et al.*, 2014). The sub-groups were unevenly represented in this population representative sample; 80% of the children were white, 88% had not been exposed to optimally fluoridated water and 85% were of a healthy weight. None of the sub-groups under scrutiny had fewer than 350 individuals in it.

The associations that might have been predicted between caries and weight-for-height in children are

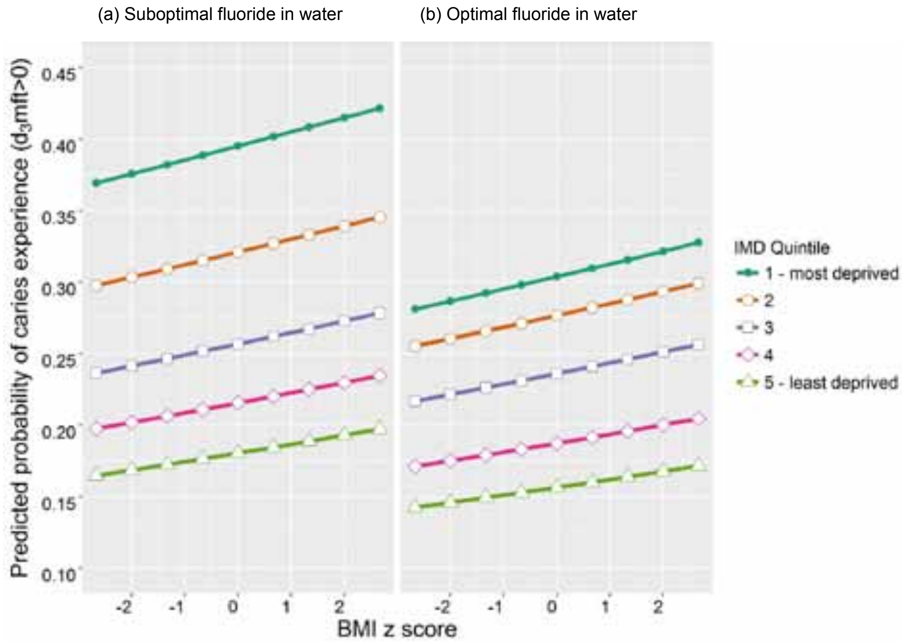

Figure 3. Predicted prevalence of caries by BMI z score, deprivation quintile and exposure to optimally fluoridated water status. Adjusted for other model covariates. (a) Suboptimal fluoride in water (b) optimal fluoride in water.

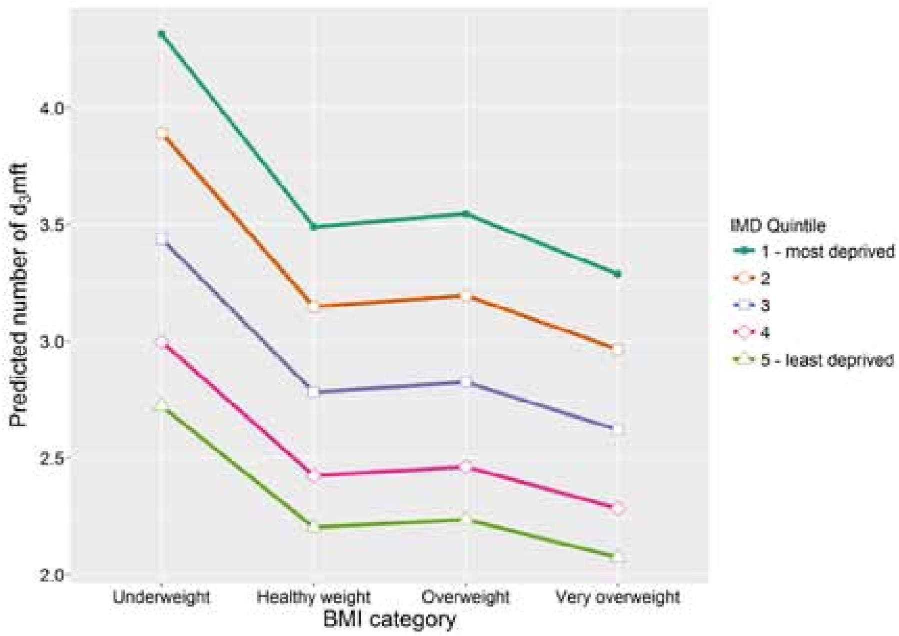

Figure 4. Predicted severity of decay in five-year-old children with decay experience ($d_3$mft>0) by clinical BMI category. Adjusted for other model covariates.

relevant for underweight, overweight and very overweight children. The very large dataset of individual records showed these associations with certainty and overcame the problems of working with grouped data found in previous investigations (PHE, 2014).

The associations between BMI scores and categories and caries prevalence and severity occur over and above the association with deprivation and were seen in all deprivation quintiles. However, these associations are not as strong as those reported between deprivation and caries, and between deprivation and increased BMI (PHE, 2014; 2018).

The association is not as simple as might have been predicted as there are many modifying risk factors for both conditions beyond sugar intake that may not occur in the same cases. Height-to-weight ratios are affected by many complex behavioural and societal factors, including overall calorie intake, physical activity levels and genetic background. Caries is also affected by frequency of exposure to fluoride, frequency of sugar intake as well as overall intake, oral bacteria, salivary composition and flow rates, and quality of tooth enamel.

Several explanations may be hypothesised for the findings of this study. The high level of extent among underweight children may be explained by them receiving a very poor diet, which provides insufficient calories, and possibly essential nutritional elements, but features high frequency sugar containing drinks and food, for example in sweets and confectionary. The increased risk of caries prevalence in children with higher BMI scores and categories could be explained by consumption of amounts of food that provide more calories than are needed and that are high in sugar. The frequency of sugar intake may be lower among these children compared with underweight children, so the severity of caries attack is lower.

The public health issues raised here are complex and require in-depth understanding of the psychology, sociology, and wider influences at play on families and communities. It is well-known that the consumption of sugar containing drinks, sweets and confectionary contributes to the burden of tooth decay and obesity. The Scientific Advisory Committee on Nutrition (2015) recommends that for all age groups from age two years upwards, the average intake of free sugars should not exceed 5% of total dietary energy intake. Younger children should have even less than this. The main message, to reduce both the amount and frequency of consuming foods and drinks that contain free sugars, is only part of the strategies required to tackle these linked problems.

The role of fluoride in toothpaste in the various sub-groups of children was not measured in this study nor was exposure to other preventive interventions such as fluoride varnish. The information about exposure to fluoridated water may have resulted in a potential bias due to misclassification of some children and limited certainty over the consistency of supply over their lifetime.

The findings in this study relate to a very large sample taken from a representative population of multi-racial school-children in a developed, industrialised country with wide variability of income, education and opportunities. The degree to which the results can be generalised to differing populations cannot be predicted.

Conclusions

There is a clear association between children's BMI and caries severity and prevalence, even when other potential influences such as deprivation are taken into account. Children who are overweight and very overweight are more likely to have caries experience than those of healthy weight.

Further investigation is indicated into the habits and behaviours of households with underweight and overweight children to better understand the relationships of these two important health problems.

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References

Davies, G.M., Robinson, M., Neville, J. and Burnside, G. (2014): Investigation of bias related to non-return of consent for a dental epidemiological survey of caries among five-year olds. *Community Dental Health* **31**, 21-26

Fournier, D., Skaug, H.J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M., Nielsen, A., and Sibert J. (2012): AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optimization Methods and Software,* 233-249.

Ministry of Housing Communities and Local Government (2015): English indices of deprivation 2015. From www.gov.uk/government/statistics/english-indices-of-deprivation-2015

Monaghan, N.P., Jones, S.J. and Morgan, M.Z. (2011): Do parents of children with caries choose to opt out of positive consent dental surveys in Wales? *British Dental Journal* **210**, E1 Published online: 21 January 2011, doi:10.1038/sj.bdj.2011.26

NHS Digital, 2018. The National Child Measurement Programme. https://digital.nhs.uk/services/national-child-measurement-programme/

NHS Digital. NCMP IT System frequently asked questions. https://digital.nhs.uk/binaries/content/assets/website-assets/services/national-childhood-measurement-programme/frequently-asked-questions.pdf Accessed 14/03/2019

Pine, C.M., Pitts, N.B. and Nugent, Z.J. (1997b): British Association for the Study of Community Dentistry (BASCD) guidance on sampling for surveys of child dental health. A BASCD coordinated dental epidemiology programme quality standard. *Community Dental Health* **14** (Supplement 1), 10 - 17

Public Health England. Child obesity and socioeconomic status data factsheet [Internet]. PHE Gateway; 2014. Available from: http://www.noo.org.uk/NOO_about_obesity/inequalities

Public Health England (2015): *The relationship between dental caries and obesity in children: an evidence summary*. https://www.gov.uk/government/publications/dental-caries-and-obesity-their-relationship-in-children

Public Health England (2016): *Dental public health epidemiology programme. Oral health survey of five-year-old children 2016–17. National protocol*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774469/Oral_health_survey_protocol_5_year_olds_2016.pdf

Public Health England (2018): *Report National Dental Epidemiology Programme for England: oral health survey of five-year-old children 2017. A report on the inequalities found in prevalence and severity of dental decay.* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/768368/NDEP_for_England_OH_Survey_5yr_2017_Report.pdf

Length, R. (2018): 'emmeans: Estimated Marginal Means, aka Least-Squares Means' R package version 1.1.

Scientific Advisory Committee on Nutrition (2015): Carbohydrates and health report. https://www.gov.uk/government/publications/sacn-carbohydrates-and-health-report