The dental health of three-year-old children in Greater Glasgow, Scotland

A. D. McMahon,¹ Y. Blair,² D. R. McCall³ and L. M. D. Macpherson⁴

IN BRIEF

- The three-year-old age group has never been researched in such detail before.
- The sample size is very large (over 4,000 children), which creates accurate results that are useful for other researchers to use.
- Sets a baseline for government targets.
- Readers will be able to assess how much prevention will be required in the future.
- Includes the effects of deprivation on dental health.

Objective To report on the dental health of three-year-old children in Greater Glasgow, and to examine the amount of dental caries associated with deprivation in this young age group. **Design** Dental inspections in nursery schools. **Subjects and methods** The national inspection programme using BASCD criteria was extended to include an additional group of nursery attending three-year-olds in Greater Glasgow in 2006/7 and 2007/8. Caries experience was analysed by logistic regression models and ROC plots. **Results** Fourteen percent of this population was sampled in 2006/7 and 19% in 2007/8 (usable data $n = 1,711$ in 2006/7, 2,428 in 2007/8). Mean d_3mft was 1.1 in 2006/7 and 1.0 in 2007/8. The prevalence of caries experience was 26% in 2006/7 and 25% in 2007/8 (33% and 32%, respectively, for children in deprived areas). The adjusted odds-ratio for caries experience for children living in the most deprived areas was 2.90 (2.31, 3.64), $p < 0.001$. There was a high rate of caries in the upper anterior teeth. **Conclusion** It was feasible to conduct large scale caries surveys of three-year-olds in a nursery setting. Poor dental health and inequality commence early in life. Caries prevention should be targeted toward deprived families from birth.

INTRODUCTION

Dental caries remains one of the most prevalent chronic diseases of childhood.^{1–3} The World Health Organization estimates that caries affects between 60–90% of school age children in developed countries and the vast majority of adults.⁴ In spite of dental health improvements, marked gradients in the distribution of caries towards socio-economically disadvantaged groups and recent immigrants have remained evident.^{2,3} Additionally, a reversal in the decline of caries in young children was being reported by some countries by the late 1990s.^{5,6} Studies controlling for socio-economic status in childhood and adulthood have found that adult oral health could be predicted by childhood dental health.⁷ There is therefore a need for

continuity of population surveillance and development of existing epidemiological programmes to include groups as young as possible. This will enhance the ability of dental public health strategists to respond swiftly by modifying interventions in the population.

The Scottish Dental Epidemiological Programme (SHBDEP) and successor National Dental Inspection Programmes (NDIP) have, since 1987, applied standardised British Association for the Study of Community Dentistry (BASCD) methodology to successive comparative caries prevalence surveys among school children in their first (Primary 1) and, from 2005,⁸ last (Primary 7) elementary school years using dentists trained and calibrated to 'substantial agreement' in the diagnosis of dental caries.⁹ These permit valid comparisons of geographic and longitudinal data from these surveys. The NDIP programme protocols allow for local NHS Boards to carry out further supplementary dental inspections for additional discretionary year groups as they feel necessary within their populations. Following publication of the Scottish Dental Action Plan,¹⁰ the Childsmile National Oral Health Demonstration Programme was initiated

to develop an appropriate caries preventive programme for children in Scotland commencing from earliest childhood.¹¹ Further strategic direction within Scotland emphasised the need to develop models of anticipatory preventive care instead of traditional reactive approaches if poor health due to chronic diseases is to be overcome.¹² Dental caries is one such chronic disease.

While much historical and contemporary data had been accumulated describing the incidence and prevalence of caries among the five-year-old school age group in Scotland, there was little reliable information available with respect to the pre-school age groups.¹ Thus, in the Greater Glasgow and Clyde NHS Board area (NHSGGC) an additional discretionary year group, ie the ante-pre-school group of three-year-olds attending nursery, was added to the standard NDIP schedule of dental inspections in 2006/7. The exercise was repeated in 2007/8.

The NHSGGC area comprises the largest population group in Scotland, amounting to *circa* 25% of Scotland's annual birth cohort. In addition to a metropolitan core, the NHSGGC area extends to suburban and rural communities and towns which provide ample access to a representative

¹Reader in Epidemiology, ²NDIP Co-ordinator Greater Glasgow and Clyde, ³Consultant in Dental Public Health, ⁴Professor of Dental Public Health, Community Oral Health, Level 8, University of Glasgow Dental School, 378 Sauchiehall Street, Glasgow, G2 3JZ
*Correspondence to: Dr Alex McMahon
Email: a.mcmahon@dental.gla.ac.uk; Tel: + 44 (0)141 211 9750

Refereed Paper

Accepted 25 March 2010

DOI: 10.1038/sj.bdj.2010.723

©British Dental Journal 2010; 209: E5

cross-section of socioeconomic groups and districts. Use of the Carstairs Index,^{13,14} which comprises four area-based indicators of SES aggregated at postcode sector level, has demonstrated a pervasive positive relationship between poor dental health and socio-economic disadvantage within Scotland's child population.^{15,16} The updated Scottish Index of Multiple Deprivation (SIMD) (2006) contains 37 indicators of SES deprivation¹⁷ and is considered to have improved discrimination potential for some health outcomes when compared to the Carstairs Index. Furthermore, the geographic aggregation level for SIMD at the data-zone level is far smaller than that for the Carstairs Index. This type of measure has been developed in parallel to similar indices of multiple deprivation for use in England, Wales and Northern Ireland, respectively the IMD, Welsh IMD¹⁸ and the 'Noble Index'.¹⁹ These contemporary composite indices provide measures which incorporate many dimensions of contemporary social circumstances and are considered to reflect the totality of living-conditions better than the historic indices for application at small area level within the different UK territories. While these types of measures have been the subject of debate in the medical literature, the SIMD has been recommended for all prospective analyses of Scottish health statistics.²⁰

The reasons for NHSGGC undertaking a NDIP caries epidemiological survey in the additional discretionary three-year-old age group were:

1. To demonstrate the feasibility of carrying out large scale dental epidemiological surveys in this age group while conforming to BASCD criteria
2. To inform on the potential health opportunities which could arise from timing anticipatory interventions early in life to maximise their effectiveness
3. To identify any need for and to facilitate targeting of interventions differentially to those groups and districts with the greatest dental health needs
4. To provide baseline information for the Childsmile programme which addresses *inter alia* caries incidence and prevalence in this pre-school group
5. To prompt infants' routine attendance

at primary care general dental practitioner services by providing information and advice to parent and carers.

The cohort from 2007/08 will be five years old in 2010 when the national target of 60% of children with no obvious caries will be assessed. The aim of this particular study is to report on the dental health of three-year-old children in NHS Greater Glasgow and Clyde, and to examine the amount of dental caries associated with deprivation in this young age group.

SUBJECTS AND METHODS

Children in the Greater Glasgow area in the ante-pre-school year were inspected in the school years of 2006/07 and 2007/08. Sampling of nurseries was undertaken using standard BASCD criteria modified for the age group, as described by Hinds and Gregory.²¹ Training and calibration of the three dentist examiners and their dental nurse scribes took place immediately before each survey. The agreement rates among the three examiners varied from 96% to 99% (using number of teeth as the denominator). Once the cohorts were assembled we excluded children whose third birthday fell before the beginning of March of 2007 and 2008 respectively or after the end of February of the following years, in order that this inclusion criterion matched that for entry to primary school at the age of 4.5-5.5 in the following August. This was done so that we could be certain of the number of similar children in the population at large. The age of the children at the date of their NDIP examination was calculated.

The amount of caries experience was calculated for each tooth and subsequently the summary measures of d_3mft , d_3t , mt , and ft were calculated for each child. The d_3mft threshold of caries diagnosis includes only those lesions which have obviously penetrated dentine, with or without pulpal involvement. With respect to diagnosis of d_3mft at epidemiological survey, this follows the visual inspection of cotton wool dried teeth by a trained and calibrated dentist under standardised lighting conditions. Using each child's home postcode, we assigned a Scottish Index of Multiple Deprivation (SIMD) score to the data. As this is a key field in the

analyses we excluded children from the cohort who did not have sufficient post-code information to enable this. We used the standard SIMD 'quintiles' (which are more accurately called 'fifths' or 'scores') where '1' represents the most deprived areas and '5' represents the most affluent areas. The overall size of the respective sample populations was obtained from the Information Support Services Department of NHS Greater Glasgow and Clyde. These population denominators were further broken down by SIMD scores.

Statistical methods

Population weights were calculated by the inverse of the probability of being sampled. The probability of being sampled is the number of children examined, divided by the equivalent number of children in the population in each of the five SIMD scores. Mean d_3mft and the percentage of children with no caries were calculated in both un-weighted and weighted survey analyses, together with the attendant 95% confidence intervals. The odds of caries experience were further analysed in a logistic regression model including parameters for age, SIMD and year of survey.

A Receiver Operating Characteristic (ROC) plot was produced with separate lines for models including year and age only, and also for year/age/SIMD together. The ROC plot is derived from the operational research field and is used in the analyses of diagnostic tests in medicine.²² The y-axis plots sensitivity, while the x-axis plots '1-specificity' and the resulting curve is a measure of coincidental sensitivity and specificity. The greater the distance of the curve from the diagonal line, the greater the predictive potential of the explanatory variable under investigation (in this instance SES deprivation) for the outcome of interest ($d_3mft > 0$). The c-index, which is the area under the curve of the lines of the ROC plot, was calculated. Note that a variable with no predictive ability has a c-index of 0.5 and a variable with perfect predictive power has a c-index of 1.

Survey analyses of the percentage of children with decayed teeth (dt), missing teeth (mt) and filled teeth (ft) for each tooth type and position were undertaken and are presented in a graphical format. All analyses were carried out using SAS version 9.1 (SAS, Cary, NC), with

Table 1 Sampling fraction in each Scottish Index of Multiple Deprivation (SIMD) category

SIMD	2006/7				2007/8			
	n sampled	(%)	n in population	(% sampled)	n sampled	(%)	n in population	(% sampled)
1 (most deprived)	655	(38%)	5,106	(13%)	1,068	(44%)	5,327	(20%)
2	259	(15%)	1,863	(14%)	414	(17%)	2,044	(20%)
3	247	(14%)	1,512	(16%)	296	(12%)	1,546	(19%)
4	194	(11%)	1,700	(11%)	237	(10%)	1,710	(14%)
5 (least deprived)	356	(21%)	2,449	(15%)	413	(17%)	2,423	(17%)
Total	1,711	(100%)	12,630	(14%)	2,428	(100%)	13,050	(19%)

Table 2 Weighted and un-weighted mean d_3 mft, and mean d_3 mft for those with d_3 mft >0

SIMD	2006/7			2007/8		
	Mean d_3 mft	Mean d_3 mft if >0 (n)		Mean d_3 mft	Mean d_3 mft if >0 (n)	
1 (most deprived)	1.5	4.5	(n = 216)	1.4	4.4	(n = 343)
2	1.4	4.4	(n = 81)	0.9	3.3	(n = 114)
3	0.9	4.1	(n = 56)	0.9	3.8	(n = 68)
4	0.7	3.2	(n = 42)	0.5	3.2	(n = 35)
5 (least deprived)	0.3	2.6	(n = 46)	0.5	3.1	(n = 65)
Un-weighted	1.1	4.1	(n = 441)	1.0	3.9	(n = 625)
Weighted (95% CI)	1.1	(1.0, 1.2)		1.0	(0.9, 1.1)	

survey analyses carried out using the SURVEYMEANS procedure.

RESULTS

There were 2,030 children inspected with usable data in 2006/7, and 2,797 in 2007/8. This represents a coverage of 71% and 76% (respectively) of the rolls of the schools that were chosen for inspection. In 2007/08 for example, 657 (18%) of the children were absent on the day, 196 (5%) of the children refused to take part, and 18 (0.05%) of the parents did not wish their children to take part (the pattern was similar in 2006/07). After the children with missing SIMD information were excluded and the birthday filter was applied there were 1,711 and 2,428 in the two cohorts, respectively. In both of the school years sampled the average age of the children was 3.7 years with a standard deviation of 0.3 years, ranging from a minimum of 3.0 years to a maximum of 4.3 years. The distribution of relative deprivation of the sampled subjects is shown on Table 1. In 2006/7 there were 655 (38%) in the most deprived areas, and there were 1,068 (44%) in 2007/8. In 2006/7 14% of the population

Table 3 Weighted and un-weighted % with no obvious experience of caries

SIMD	2006/7	2007/8
	d_3 mft = 0 (%)	d_3 mft = 0 (%)
1 (most deprived)	439 (67%)	725 (68%)
2	178 (69%)	300 (72%)
3	191 (77%)	228 (77%)
4	152 (78%)	202 (85%)
5 (least deprived)	310 (87%)	348 (84%)
Un-weighted	1270 (74%)	1803 (74%)
Weighted (95% CI)	74% (72%, 76%)	75% (73%, 77%)

were sampled and a greater proportion of 19% in 2007/8.

Mean d_3 mft changed little from year to year (1.1 in 2006/7 and 1.0 in 2007/8, Table 2). As expected, mean d_3 mft was lower in the least deprived areas (0.5 in 2007/8) than it was in the most deprived areas (1.4 in 2007/8). In terms of the proportion of children with no obvious caries experience, the figures were 74% in 2006/7 and 75% in 2007/8 (Table 3).

Adjusting by age and SIMD, the odds of caries experience were similar in 2007/8

versus 2006/7 with an odds-ratio of 0.92, 95% confidence interval = (0.80, 1.06), $p = 0.256$ (Table 4). However, the gap between those with d_3 mft >0 residing in the most deprived and the least deprived communities reduced slightly from 67% *vs* 87% in 2006/7 to 68% *vs* 84% in 2007/8. The odds-ratio for caries experience in the most deprived children *versus* the least deprived children, adjusting for age and year, was 2.90 (2.31, 3.64), $p < 0.001$. The ROC plot is shown in Figure 1. The curvature of the lines is clear, and the extra effect

of deprivation in predicting caries is demonstrated by the gap between the dotted and solid lines. The c-index of the model with just age and year is 0.58, rising to 0.64 when SIMD is added to the model.

The breakdown of decayed (d_3t), missing (mt) and filled teeth (ft) is presented for each tooth type and position separately in Figures 2 and 3 for the two year cohorts. In three-year-old children in Greater Glasgow there is a pronounced trend for the upper anterior teeth to be decayed (in addition to the molars). For example, in 2006/7 the upper right central incisor was decayed in 10% of the children studied, 95% CI = (9%, 11%), and in 2007/8 it was 8%, 95% CI = (7%, 9%). The decrease from 10% to 8% was statistically significant with an odds-ratio of 0.79, 95% CI = (63%, 98%), $p = 0.031$ (adjusted by age and SIMD).

DISCUSSION

While we have known the caries status of children in Primary 1 since the first NDIP/SHBDEP surveys in 1987,¹ little was known about the prevalence of caries at the age of three years old. It was feasible to conduct large scale caries surveys in nursery settings, using multiple examination teams calibrated with the age group and applying the standardised BASCD methodology. The three-year-old population examined was thus representative of the background SES distribution of three-year-olds. As expected, there was little overall change in d_3mft metrics over a period as short as one year. Overall the levels of caries were very high, with 26% and 25% of children already experiencing some decay into the dentine or beyond by the age of three years in the 2006/7 and 2007/8 cohorts, respectively. For children living in the most deprived areas (SIMD = 1), the prevalence of caries experience at the d_3 level was 33% and 32%, respectively.

Levels of childhood caries in other communities worldwide are also a concern. A large cohort study of Italian four-year-olds found that 22% of the children suffered caries experience.²³ A similar rate was found in an urban Brazilian pre-school population (23%).²⁴ Similarly in the USA (using older data) it was found that for children aged two to five years old the percentage of caries experience was 24% for whites, 29% for blacks and a much higher 40% for Mexicans.²⁵ Another US study found

Table 4 Results of logistic regression model for risk of caries (variables are adjusted by each other)

Variable	Contrast	Odds-ratio	95% CI	p
Age*	1 year risk	2.65	(2.04, 3.44)	<0.001
Year	2007/8 vs 2006/7	0.92	(0.80, 1.06)	0.256
SIMD	1 vs 5	2.90	(2.31, 3.64)	<0.001
	2 vs 5	2.46	(1.89, 3.20)	<0.001
	3 vs 5	1.75	(1.31, 2.32)	<0.001
	4 vs 5	1.31	(0.95, 1.81)	0.096

* Odds-ratio gives the extra risk associated with one year's increase in age

Fig. 1 ROC plot for models of dental decay in three year old children

Fig. 2 dt, mt and ft for each tooth separately - 2006/7

Fig. 3 dt, mt and ft for each tooth separately – 2007/8

a rate of 28% for pre-school children in Arizona.²⁶ However, a national dataset from the NHANES cohort found that 42% of US children aged two to six years had caries experience.²⁷ A study of low SES Brazilian children reported the caries experience for children at ages one, two, three, four and five years, with the results given as 4%, 15%, 29%, 40% and 50%, respectively.²⁸ Some communities worldwide are reported to have extreme problems with caries experience, with prevalence rates as high as 85% in the Republic of Belarus for six-year-olds,²⁹ and over 90% for Canadian aboriginal minority group children living on one reserve.³⁰

While historically much dental health education coincided with children starting at school, in recent years there has been an emphasis on oral health promotion programmes based in the nursery setting. The information from the present study helps to establish the possibility of improving dental health at five years of age from the initiation of intervention strategies before three years of age, as the foundation of a whole life-course approach. There are strong indications that for a sizable minority it is necessary that interventions commence before the age of three years, as *circa* 25% of children already had d_3mft

experience by this age, with those children living in the most deprived communities having the highest prevalence of caries. This type of anticipatory care is advocated to improve child health and welfare outcomes in Scotland¹² and is likely to be most effective if it commences early in a child's life-course as part of a 'from birth' strategy. Complex intervention programmes are needed to support breast feeding, weaning and the use of fluoride dentrifice from the time of first eruption.

The study of 'life-course' with respect to general health outcomes increasingly recognises that both the intra-uterine period and the earliest years have lasting health effects on whole-life outcomes.^{31–33} Interventions are easier to deliver to groups within a defined setting than similar interventions aimed at individuals dispersed within communities. Therefore, previous dental health promotion activity generally did not commence until infants had started to attend at school and, latterly, the nursery setting. Thus, to a great extent, timings of historic oral health interventions in many areas (including NHSGGC) have been based on convenience rather than any evidence of the efficacy of caries prevention strategies within the life-course, and little was understood about

the balance of caries initiation before and after commencing nursery education at three years of age.

The ROC plot for the model including SIMD as a predictor of dental caries shows a clear curvature away from the diagonal (c-index = 0.64). However, the line is nearer the diagonal than the top left corner. A ROC plot graphs sensitivity against 1-specificity for each combination of risk factors in the model. Therefore, an extremely predictive model would go up the left hand axis and along the top line. This means that although deprivation cannot be used to reliably predict caries in an individual three-year-old child, it does demonstrate that even at the age of three years, the effect of deprivation has already begun its course towards being the single greatest factor in predicting the occurrence of a child's caries experience.

This study indicates that the determinants of poor dental health and inequality commence early in life. There are various theories as to how inequalities in oral health arrive, which are usefully summarised by Patrick *et al.*³⁴ and also by Sisson.³⁵ Preventive interventions are therefore required to commence from birth, or even before birth. Comparing these data with future ROC plots will permit assessment of the degree to which the association between deprivation and poor dental health is mitigated over time by local and national community-based health improvement programmes.

There is a distinctive pattern of caries in the children studied whereby the upper anterior teeth have high levels of caries for such a young age group. Also, there are very high levels of caries in the molars. Monitoring of the extent to which individual teeth are affected by dental caries will permit assessment of the population impact of future clinical preventive interventions such as topical fluoride varnishes and fissure sealant programmes. Nearly a third of three-year-old children in SIMD1 are exhibiting caries in teeth which have only been exposed for one to three years. This highlights the need to target pre-nursery children.

CONCLUSION

The occurrence of dental caries at d_3mft level in NHS Greater Glasgow and Clyde is clinically apparent even at the age of

3.5 years in at least 25% of the population. The disease is particularly prevalent in deprived communities. While many pre-school oral health improvement initiatives take place in the nursery setting, it is also essential that appropriate caries-preventive approaches are implemented from birth, with more intensive support for those at increased risk of disease. These types of 'directed population' approaches are currently being developed and evaluated via Scotland's Childsmile demonstration programme.

- Merrett M C W, Goold S, Jones C M *et al.* *National dental inspection programme of Scotland. Report of the 2008 survey of P1 children.* Dundee: Scottish Dental Epidemiological Coordinating Committee, 2009. ISBN: 978-0-9550957-4-0.
- Marthaler T M. Changes in dental caries 1995–2003. *Caries Res* 2004; **38**: 173–191.
- Edelstein B L. The dental caries pandemic and disparities problem. *BMC Oral Health* 2006; **6**(Suppl 1): S2.
- Petersen P E. *The World Oral Health Report 2003. Continuous improvement of oral health in the 21st century – the approach of the WHO Global Oral Health Programme.* Geneva: World Health Organization, 2003.
- Haugejorden O, Birkeland J M. Evidence for reversal of the caries decline among Norwegian children. *Int J Paediatr Dent* 2002; **12**: 306–315.
- Spencer A J. *Narrowing the inequality gap in oral health and dental care in Australia.* pp 4–7. Sydney: Australian Health Policy Institute, 2004. http://www.menzieshealthpolicy.edu.au/other_tops/pdfs_pubs/dental111104.pdf (accessed 18 March 2009).
- Thomson W M, Poulton R, Milne B J, Caspi A, Ayers K M S. Socioeconomic inequalities in oral health in childhood and adulthood in a birth cohort. *Community Dent Oral Epidemiol* 2004; **32**: 345–353.
- Pitts N B, Evans D G, Pine C M. British Association for the Study of Community Dentistry (BASCD) diagnostic criteria for caries prevalence surveys – 1996/97. *Community Dent Health* 1997; **14**: 6–9.
- Landers J R, Koch G G. The measurement of observer agreement for categorical data. *Biometrics* 1977; **33**: 159–174.
- Scottish Executive. *An action plan for improving oral health and modernising NHS dental services in Scotland.* Edinburgh: Scottish Executive, 2005. <http://www.scotland.gov.uk/Publications/2005/03/20871/54813> (accessed 17 March 2010).
- Shaw D, Macpherson L, Conway D. Tackling socially determined dental inequalities: ethical aspects of Childsmile, the national child oral health demonstration programme in Scotland. *Bioethics* 2009; **23**: 131–139.
- Scottish Executive. *Better health, better care: a discussion document.* Edinburgh: Scottish Executive, 2007. <http://www.scotland.gov.uk/Resource/Doc/194854/0052337.pdf> (accessed 17 March 2010).
- Carstairs V, Morris R. Deprivation and mortality; an alternative to social class? *Community Med* 1989; **11**: 210–219.
- Carstairs V. Deprivation indices: their interpretation and use in relation to health. *J Epidemiol Community Health* 1995; **49**(Suppl): S3–S8.
- Sweeney P, McColl D, Nugent Z, Pitts N. *Scottish Health Boards' Dental Epidemiological Programme. Deprivation and dental caries.* Dundee: University of Dundee Dental Health Services Research Unit, 1997. <http://www.dundee.ac.uk/dhsru/publications/shb-dep95/dep0595/sd.htm> (accessed 17 March 2010).
- Sweeney P, Allison D, Davies J, Pitts N. *Scottish Health Boards' Dental Epidemiological Programme. An investigation of the association between deprivation and dental caries experience among 12-year-old children in Scotland.* Dundee: University of Dundee Dental Health Services Research Unit, 1998. <http://www.dundee.ac.uk/dhsru/publications/shb-dep96/scotdep.htm> (accessed 17 March 2010).
- Scottish Executive. *Using the Scottish Index of Multiple Deprivation 2006.* Edinburgh: Scottish Executive, 2006. <http://www.scotland.gov.uk/Resource/Doc/151598/0040732.pdf> (accessed 17 March 2010).
- Carr-Hill R, Chalmers-Dixon P. *The Public Health Observatory handbook of health inequalities measurement.* Lin J (ed). Oxford: South East Public Health Observatory, 2005.
- Noble M, Smith G, Wright G, Dibben C, Lloyd M. *Measures of deprivation in Northern Ireland.* Oxford: University of Oxford Social Disadvantage Research Centre, 2001. [http://www.nisra.gov.uk/deprivation/archive/Measures%20of%20Deprivation%20for%20Northern%20Ireland%20\(28th%20June\).pdf](http://www.nisra.gov.uk/deprivation/archive/Measures%20of%20Deprivation%20for%20Northern%20Ireland%20(28th%20June).pdf) (accessed 18 March 2010).
- ISD Measuring Deprivation Subgroup. *Deprivation and urban rural measurements in ISD. Summary Report, 2004.* Edinburgh: ISD, 2004. http://www.isdscotland.org/isd/files/Measuring_deprivation_in_ISD_v3.pdf (accessed 17 March 2010).
- Hinds K, Gregory J R. *National diet and nutrition survey: children aged 1.5–4.5 years. Volume 2. Report of the dental survey.* London: HMSO, 1995.
- Altman D G, Bland J M. Diagnostic tests 3: receiver operating characteristic plots. *BMJ* 1994; **309**: 188.
- Campus G, Solinas G, Strohmenger L *et al.* National pathfinder survey on children's oral health in Italy: pattern and severity of caries disease in 4-year-olds. *Caries Res* 2009; **43**: 155–162.
- Oliveira L B, Sheiham A, Bonecker M. Exploring the association of dental caries with social factors and nutritional status in Brazilian preschool children. *Eur J Oral Sci* 2008; **116**: 37–43.
- Vargas C M, Ronzio C R. Disparities in early childhood caries. *BMC Oral Health* 2006; **6**(Suppl 1): S3.
- Poser W J, Pendrys D G, Morse D E, Zhang H, Mayne S T. Associations of ethnicity/race and socioeconomic status with early childhood caries patterns. *J Public Health Dent* 2006; **66**: 23–29.
- Hong L, Ahmed A, McCunniff M, Overman P, Mathew M. Obesity and dental caries in children aged 2–6 years in the United States: National Health and Nutrition Examination Survey 1999–2002. *J Public Health Dent* 2008; **68**: 227–233.
- Ferreira S H, Beria J U, Kramer P F, Feldens E G, Feldens C A. Dental caries in 0- to 5-year-old Brazilian children: prevalence, severity, and associated factors. *Int J Paediatr Dent* 2007; **17**: 289–296.
- Kramer M S, Vanilovich I, Matush L, Bogdanovich N, Zhang X. The effect of prolonged and exclusive breast-feeding on dental caries in early school-age children. *Caries Res* 2007; **41**: 484–488.
- Lawrence H P, Binguis D, Douglas J *et al.* Oral health inequalities between young Aboriginal and non-Aboriginal children living in Ontario, Canada. *Community Dent Oral Epidemiol* 2009; **37**: 495–508.
- Barker D J P. Fetal origins of coronary heart disease. *BMJ* 1995; **311**: 171–174.
- Berney L, Blane D, Davey Smith G, Holland P. Lifecourse influences on health in early old age. In Graham H (ed) *Understanding health inequalities.* pp 78–95. Maidenhead: Open University Press, 2004.
- Barker D J P. The developmental origins of insulin resistance. *Hormone Res* 2005; **64**: 2–7.
- Patrick D L, Shuk Yin Lee R, Nucci M, Grembowski D, Jolles C J, Milgrom P. Reducing oral health disparities: a focus on social and cultural determinants. *BMC Oral Health* 2006; **6**(Suppl 1): S4.
- Sisson K L. Theoretical explanations for social inequalities in oral health. *Community Dent Oral Epidemiol* 2007; **35**: 81–88.
- Batchelor P, Sheiham A. The limitations of a 'high-risk' approach for the prevention of dental caries. *Community Dent Oral Epidemiol* 2002; **30**: 302–312.
- Batchelor P A, Sheiham A. The distribution of burden of dental caries in schoolchildren: a critique of the high-risk caries prevention strategy for populations. *BMC Oral Health* 2006; **6**: 3.
- Sagheri D, Hahn P, Hellwig E. The development of a directed population approach to tackle inequalities in dental caries prevalence among secondary school children based on small area profile. *Cent Eur J Public Health* 2008; **16**: 65–70.