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What are the most accurate predictors of caries in children aged 5 years in the UK?

T. Broomhead[1], S.R. Baker[1], K. Jones[2], A. Richardson[3] and Z. Marshman[1]

[1]*School of Clinical Dentistry, University of Sheffield, UK;* [2]*Public Health England, Sheffield, UK;* [3]*Sheffield City Council, Sheffield, UK*

Objective: To find the most accurate indicators of the distribution of dental caries in 5-year-olds in the city of Sheffield, UK, using a conceptual framework based on the social determinants of health. ***Method:*** A list of structural and intermediary indicators was compiled based on the Commission on the Social Determinants of Health's (CSDH) conceptual framework. To quantify these indicators, existing data on dental caries were obtained from the NHS Dental Epidemiology Programme, while data on social position, education, employment, income, material circumstances, social cohesion, psychosocial factors and individual behaviours were obtained from the Public Health Intelligence Team at Sheffield City Council. These data were mapped onto a simplified framework of the social determinants of dental caries. Regression analysis was conducted on this simplified framework to determine the amount of variance each indicator contributed to the distribution of dental caries at neighbourhood level. ***Results:*** The total score for the 2010 Index of Multiple Deprivation contributed a significant amount of variance (60.4%) compared to the combined variance of the other 13 indicators (70.5%). ***Conclusion:*** The total IMD score has the potential to be used as an indicator for the targeting of oral health improvement programmes where survey data are not available. A large prospective study is required in the UK to investigate the full range of factors in the CSDH model to develop a new index which might better predict dental caries experience than IMD.

Key words: *caries, United Kingdom, children, predictors, deprivation, social determinants of health, conceptual framework*

Introduction

Many studies have established the social gradient that exists in dental caries in children in the UK and other developed countries. Social inequalities in the distribution of dental caries have been found using single items such as income in Australia and parental education in Scotland (Hallett and O'Rourke, 2003; Schou and Uitenbroek, 1995), and area-based measures such as the proportion of children receiving free school meals in England (Muirhead and Marcenes, 2004). Such patterns have also been found using measures of deprivation such as the Townsend Index in England and the Carstairs Index and DEPCAT scores in Scotland (Ellwood *et al.*, 2004; Sweeney *et al.*, 1999). More recently, associations between caries and deprivation have been found with the Index of Multiple Deprivation in England and Scotland (McGrady *et al.*, 2012). However, there has, at times, been a lack of consideration of theories of the social determinants of health inequalities and their applicability to oral health inequities (Watt and Sheiham, 2012).

Various theoretical models have been developed to explain the social determinants of health inequalities. These models emphasise the central role of the concept of social position (World Health Organization, 2008). The World Health Organization (WHO) Commission on the Social Determinants of Health (CSDH) developed a framework (Figure 1), based on earlier models, which shows how the 'structural determinants' including social, economic and political contexts give rise to a set of socio-economic positions which in turn shape the 'intermediary determinants' including material and psychosocial circumstances and behavioural and biological factors. The most important indicators of these structural determinants are income, education, occupation, social class, gender and race. For the intermediary determinants, the CSDH included factors such as living conditions in the form of material circumstances, psychosocial stressors and social support in the form of psychosocial factors, and, behavioural and biological factors including nutrition, physical activity and consumption of alcohol and tobacco. Unlike previous models, the CSDH framework also includes the health system as an intermediary determinant because of differing experiences in access to health services (WHO, 2010). The concept of social capital and cohesion is cross-cutting in nature, and has direct links with both structural and intermediary determinants. The CSDH suggests the framework can be used to identify opportunities to intervene to tackle underlying determinants and reduce inequalities.

Several authors have commented on the applicability of the CSDH framework to oral health inequalities (Sheiham *et al.*, 2011; Watt, 2012) but the model has not yet been applied within the field of oral health inequities. More specifically, the relative contribution of structural and intermediary determinants to inequalities in dental caries remains unknown.

Currently in the UK the targeting of programmes aimed at reducing inequalities in dental caries experience is largely based on the results of surveys carried out as part of the NHS Dental Epidemiology Programme. However, given the proposed relationship between the

Correspondence to: Dr Zoe Marshman, Dental Public Health, School of Clinical Dentistry, University of Sheffield, 19 Claremont Crescent, Sheffield, S10 2TA, UK. Email: z.marshman@sheffield.ac.uk

structural and intermediary determinants of health inequities described by the CSDH it may be possible to use indicators, other than dental caries data, for targeting oral health improvement programmes. The aim of this study was therefore to apply the CSDH framework to examine which indicators, from existing datasets, most accurately predict the distribution of dental caries in Sheffield, UK, 5-year-olds.

Methods

Based on the CSDH framework (Figure 1) a list of indicators of the structural and intermediary determinants was compiled. From this list the variables that most closely related to the indicators that were available from local or national sources were identified and obtained. A simplified version of the CSDH framework was developed that contained only those variables that were already available (Figure 2).

Data for this study were obtained from several sources. Dental caries data were collected from 3896 5-year-olds (71.3%) from 117 state schools in Sheffield during 2011/12, as part of the NHS Dental Epidemiology Programme. This provided data on the mean $d_3$mft scores, namely the mean number of teeth with caries at dentinal level, extracted or filled because of caries. The remaining

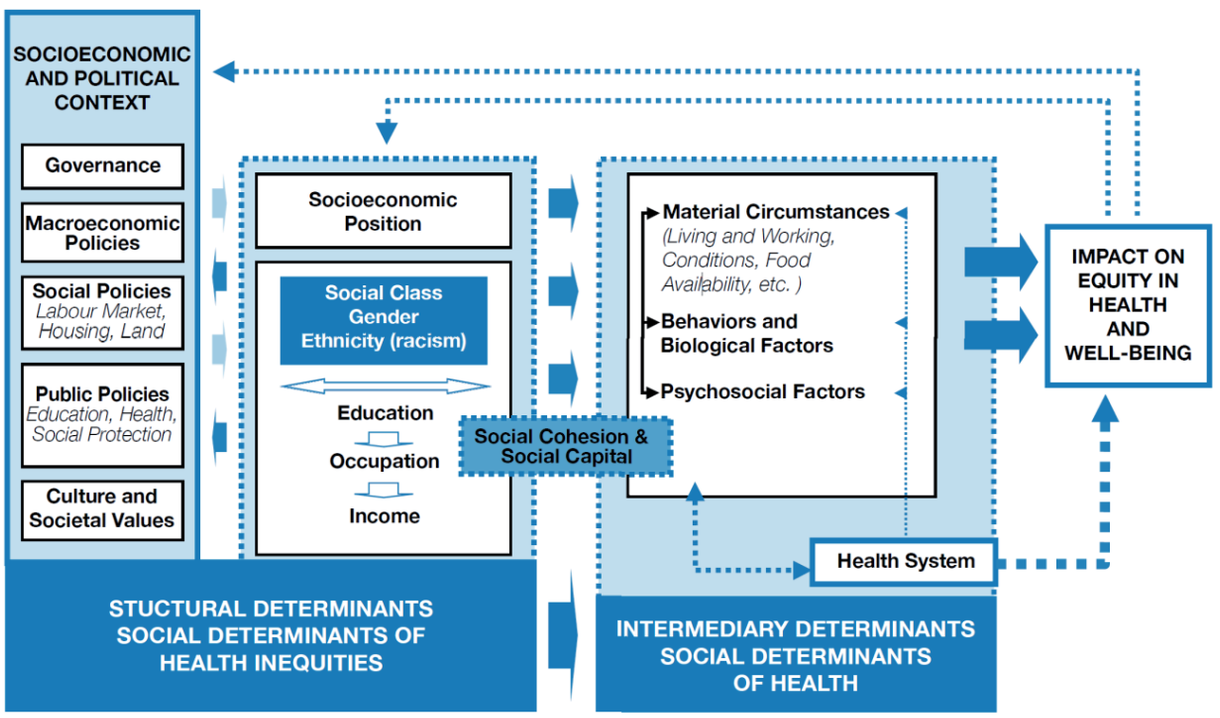

Figure 1. *Conceptual framework for the social determinants of health (WHO, 2010, p48)*

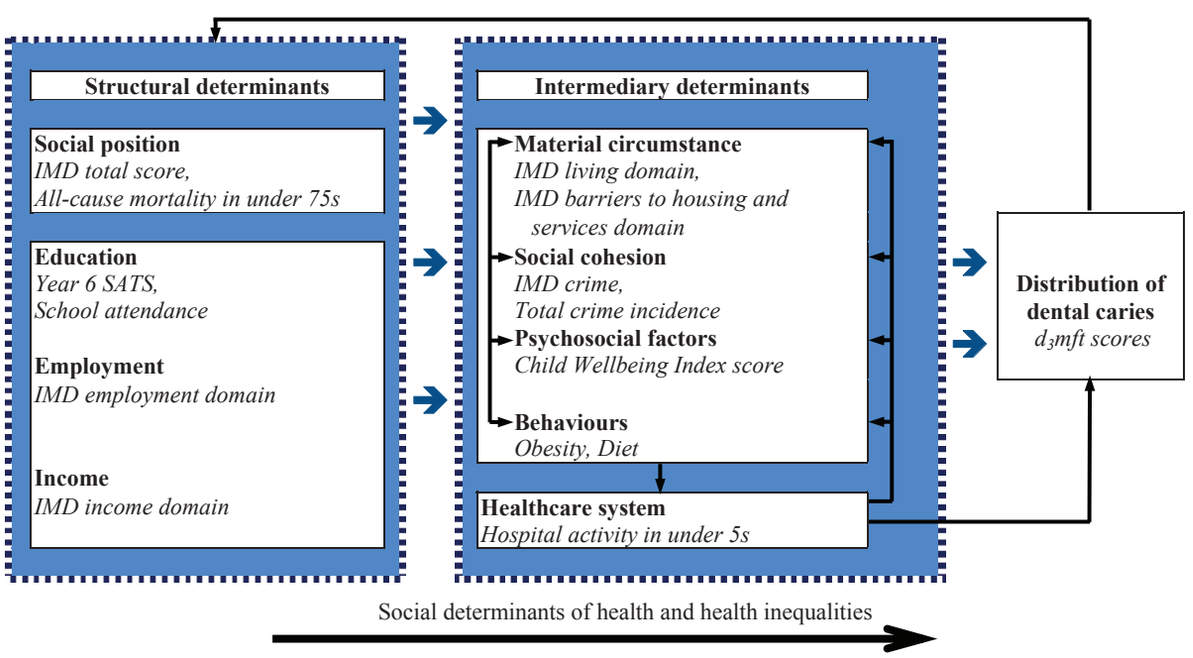

Figure 2. *Simplified conceptual framework for the social determinants of health and health inequalities populated with variables for each indicator and with their selected measures (in italics)*

data were obtained from the Public Health Intelligence Team at Sheffield City Council, including obesity figures for 4-5 year olds, scores for the 2010 Indices of Multiple Deprivation (IMD) and 2009 Child Wellbeing Index, and a number of other population, socio-economic and material indicators. All of the data involved in the study were aggregated from individual level or where these were not available from lower super output area level to the 'neighbourhood' level, the boundaries of which are defined by Sheffield City Council to represent 100 natural communities within Sheffield. Neighbourhood level data are used in Sheffield to monitor small area variations in health and social care indicators.

Fourteen indicators were used to populate the simplified model (Figure 2). The first group related to structural determinants and quantified social position, education, employment and income. For social position, the chosen indicators were the Index of Multiple Deprivation (IMD) 2010 (Department for Communities and Local Government, 2011) and mortality data. The IMD 2010 is an area-based composite measure of deprivation, and is calculated by totalling its seven weighted domains, these being: income; employment; education, skills and training; living environment; health, deprivation and disability; crime; and barriers to housing and services. Due to the variety of indicators used in its creation the index contains both structural and intermediary based domains. A higher score indicates higher levels of deprivation.

All-cause mortality for those aged under 75 years old is regarded as premature mortality. All-cause mortality was expressed using a directly age standardised rate per 100,000 people (2007-2011), i.e. the number of deaths that would occur if a given area had the same age structure as the standard population (the European Standard population was used), and the local age-specific rates of that area applied.

The education indicators selected were results from national Standard Assessment Tests (SATs) taken by 10-11-year-olds, 'Year 6 SATS' and school attendance. The variable 'Year 6 SATS' was expressed as the number of pupils in the year group attaining the expected level for their age in both English and Maths (2010/11), as a percentage of the year's pupils in Sheffield. These data were attributed to neighbourhoods based on pupils' home postcode. The school attendance variable was expressed by overall primary school attendance (2010/11) as a percentage of sessions attended during the first five half terms of the academic year.

The indicator chosen for employment was the employment domain of the IMD expressed using the IMD Employment Domain score for 2010 (Department for Communities and Local Government, 2011). The domain includes data on jobseekers allowance, incapacity benefits, disability allowance and participants in the 'New deal for communities' scheme.

Similarly, income was indicated by the IMD Income Domain score expressed using the IMD Income Domain score for 2010 (Department for Communities and Local Government, 2011). This domain includes data on income support, jobseeker allowance, pension credits, child tax credits and asylum seekers in receipt of subsistence support and/or accommodation support.

The second group of indicators related to the intermediary determinants and quantified material circumstances, social cohesion, psychosocial factors, behaviours and the healthcare system. The indicators chosen for the material circumstances factors of the intermediary determinants were the Living Environment and Barriers to Housing and Services Domains of the IMD. The IMD Living Environment was expressed using the IMD Living Environment Domain score for 2010 (Department for Communities and Local Government, 2011). This domain includes data on housing conditions, heating within housing, air quality and local road traffic accidents.

The IMD Barriers to Housing and Services Domain was expressed using the IMD Barriers to Housing and Services Domain score for 2010 (Department for Communities and Local Government, 2011). This domain includes data on homelessness, household overcrowding, housing affordability, and road distances to general practices, food shops, primary schools and Post Offices.

The indicators chosen for social cohesion were the Crime Domain of the IMD and total crime incidence. The IMD Crime Domain was expressed using the IMD Crime Domain score for 2010 (Department for Communities and Local Government, 2011). This domain includes data on levels of violence, burglary, theft and criminal damage.

Total crime incidence was expressed as a rate per 1,000 people, and included all types of crime occurring. These data were taken from the British Crime Survey (Home Office, 2011), for which 51,000 people were surveyed on questions of personal security, awareness of and attitude towards asset recovery, anti-social behaviour, E-crime, attitudes to alcohol and drug behaviour and trust in official figures.

The Child Wellbeing Index (CWI) was used to indicate psychosocial factors and expressed as an overall score for 2009 (Department for Communities and Local Government, 2010), where a higher score indicates a worse level of child well-being. The seven weighted domains that make up the overall index are: material well-being; health; education; crime; housing; environment; and children in need.

The indicators chosen to indicate behaviours were obesity and modelled consumption of fruit and vegetables by adults. Obesity was expressed as the percentage of children (aged 4/5 years) who were obese (excluding those classed as overweight) in each school year (National Child Measurement Programme, 2008-2011). Adult fruit and vegetable consumption was expressed using the percentage of adults over the age of 18 who consumed more than five portions a day (Department of Health, 2012).

The indicator chosen to indicate the healthcare system was emergency hospital admissions for those less than 5 years old expressed as a direct age standardised rate per 100,000 people.

Once obtained, the datasets were checked for any missing values, of which there were none. These datasets were then consolidated into one file, with the analysis conducted in SPSS v20. The threshold for statistical significance was $p=0.05$. As the mean d_3mft data for the neighbourhoods was non-normally distributed the data were logged to allow the variable to be included in a multiple regression model so that the R^2 change statistic could be obtained. A score of one was added to each of the scores in order to eliminate any zeros from the data

which would have prevented the log transformation. The data were entered into the regression model in blocks that represented the structure of the simplified conceptual framework. The first two blocks represented the structural determinants, with the first of these containing the indicators representing social position. The second block included indicators on education, employment and income. The third and fourth blocks were used to represent the intermediary determinants, with the third block containing indicators on material circumstances, social cohesion, psychosocial factors and behaviours. The fourth block contained the indicator for the healthcare system, however this was added to the third block with the other intermediary determinants in a second modified version of this model. The analysis was conducted in this way so that the effect of each block on the overall model could be observed.

Two regression models were run, with the logged mean $d_3$mft data serving as the dependant variable on both occasions. The first regression model contained only the 'IMD total score', which was tested alone due to its combination of structural and intermediary based domains. The second model was used to test the rest of the indicators. Indicators from the 'structural determinants' block which included 'all-cause mortality in under 75s', 'Year 6 SATs', 'School attendance', 'IMD employment domain', 'IMD income domain' were added first. Following this indicators from the 'Intermediary determinants' block were added, namely: the IMD domains for the living environment, barriers to housing and services and crime domain together with indicators for total crime incidence, CWI score, obesity, diet and emergency hospital admissions in under 5s.

Results

Table 1 shows the descriptive statistics for the mean $d_3$mft scores, and the 14 indicators used to populate the framework for the 100 neighbourhoods in Sheffield. The mean $d_3$mft of the Sheffield neighbourhoods was 1.05. The mean IMD total score indicates Sheffield is more deprived relative to the average of all local authorities in England but is not among the most deprived local authorities. In line with this, Sheffield's mean score for the IMD's employment domain (0.11), income domain (0.16), living environment domain (23.00), barriers to housing and services domain (23.75) and crime domain (0.43) all indicated above average deprivation levels (Department for Communities and Local Government, 2011). The mean percentage of children in Sheffield attaining the expected level for their age in both English and Maths (2010/11) in the year 6 SATs was 72%, higher than the Government's target of 60%. The mean percentage for primary school attendance was 94.5% similar to levels for Yorkshire and the Humber (94.8%), and England (95.0%) (Department for Education, 2012). Sheffield's mean total crime incidence score was 37 compared to 76 for England and Wales, and 78 in South Yorkshire (Home Office, 2011). Sheffield's mean CWI score (204) was below average relative to the rest of England, placing it on the boundary of the lowest quartile (Department for Communities and Local Government, 2010). The proportion of children who are obese aged 4-5 in Sheffield (8.9%) compares favourably to Yorkshire and the Humber (9.1%) and England (9.6%) (National Child Measurement Programme, 2011), however the mean percentage of adults eating five or more items of fruit/vegetables

Table 1. Descriptive statistics for the variables used in the simplified model

Variables	*Mean*	*Std. Deviation*	*Range*
Mean $d_3$mft per neighbourhood	1.05	0.74	2.81
Structural determinants			
Social position			
IMD total score	26.78	16.49	63.44
All-cause mortality in under 75s	297.50	102.90	501.20
Education			
Year 6 SATS	72.84	12.59	54.30
School attendance	94.53	1.49	7.50
Employment			
IMD employment domain	0.11	0.06	0.24
Income			
IMD income domain	0.16	0.11	0.47
Intermediary determinants			
Material circumstances			
IMD living domain	23.00	12.06	49.18
IMD barriers to housing and services domain	23.75	5.14	26.02
Social cohesion			
IMD crime domain	0.43	0.72	3.01
Total crime incidence	37.19	20.88	119.60
Psychosocial factors			
Child Wellbeing Index score	204.47	111.81	408.10
Behaviours			
Obesity in 4/5 year olds	8.91	3.54	19.60
Modelled fruit and vegetable consumption	24.78	4.28	15.40
Healthcare system			
Emergency hospital admissions for under 5s	747.80	147.69	817.40

a day (24.8%) was lower than national figures for both adults (31.0%) and 'older adults' (65 or over – 37.0%) (Department of Health, 2012). No comparable data were available for all-cause mortality in those aged under 75 or for emergency hospital admissions for children aged under five.

The first regression model with 'IMD total score' as the indicator accounted for 60.4% of the variance in dental caries (F (1,98)=152.3, p<0.001, adjusted R^2=0.604). The standardised beta value was 0.780 indicating that, in line with expectations, greater IMD scores were associated with higher $d_3$mft scores.

In the second regression model, 70.5% of the variance in dental caries was accounted for, with 68.0% of the variance accounted for by block 1 (social position, education, employment, and income) and 2.5% by block 2 (material circumstances, social cohesion, psychosocial factors, behaviours, and the healthcare system) respectively (F(13,86)=19.2, p<0.001, adjusted R^2=0.705). The structural indicators 'Year 6 SATS' and 'IMD Income Domain' were statistically significant, while of the intermediary indicators, 'IMD Living Domain', 'IMD Crime Domain' and 'Total crime incidence' were statistically significant (Table 2) .

Discussion

The aim of this study was to apply the CSDH framework to examine which structural or intermediary indicators most accurately predict the distribution of dental caries in children aged 5 years in Sheffield. The main finding from the analysis was that the IMD total score accounted for a large and significant amount of the variance in the model, only slightly less than the combined variance of the other 13 indicators. The IMD total score therefore has the potential to be used as an indicator for the targeting of oral health improvement programmes where survey data are not available. In addition, this study has also highlighted the possibility of using the CSDH framework to develop a new index which would better predict the distribution of dental caries in the population than IMD.

The Index of Multiple Deprivation contains domains of both a structural and intermediary nature. Due to this combination of indicators, the Scottish IMD has previously been used in a study of three-year-olds in Scotland (McMahon *et al.*, 2010). The analysis from our study showed that the indicators used for education and income were statistically significant, which is consistent with the importance placed on these indicators in the caries literature (Hallett and O'Rourke, 2003; Schou and Uitenbroek, 1995). Of the intermediary indicators, only those used for material circumstances and social cohesion were statistically significant and previous studies have demonstrated that lack of household material resources increased the likelihood of caries in childhood (Muirhead and Marcenes, 2004). While links have been established between caries and most of the indicators used in this study, the CSDH framework suggests that structural and intermediary determinants feedback on, and influence each other, and this may explain why a composite measure such as 'IMD total score' accounted for such a large amount of the variance while none of the individual indicators did.

This study is the first to examine predictors of the distribution of dental caries in children using a conceptual model based on the social determinants of health. However, only existing data from neighbourhoods in Sheffield were used. A prospective study investigat-

Table 2. Results of the second regression model

Variables	*Standardised coefficients β*	*Significance p*
Structural determinants		
Social position		
All-cause mortality in under 75s	-0.078	0.480
Education		
Year 6 SATS	-0.187	**0.050**
School attendance	-0.126	0.335
Employment		
IMD employment domain	-0.224	0.340
Income		
IMD income domain	0.604	**0.020**
Intermediary determinants		
Material circumstances		
IMD living domain	0.249	**0.015**
IMD barriers to housing and services domain	-0.067	0.299
Social cohesion		
IMD crime domain	0.250	**0.033**
Total crime incidence	-0.323	**0.013**
Psychosocial factors		
Child Wellbeing Index score	0.210	0.355
Behaviours		
Obesity in 4/5 year olds	0.054	0.501
Modelled fruit and vegetable consumption (5 per day)	0.099	0.417
Healthcare system		
Emergency hospital admissions for under 5s	-0.035	0.770

ing all factors in the CSDH model in a large sample in the UK is required to examine the most accurate predictors of dental caries in more detail potentially to develop a new index which might predict dental caries experience better than the IMD. This study has several additional limitations. First, the analysis was conducted with available indicators at neighbourhood level, with data aggregated from the individual or lower level super output area level. This means that patterns and trends of individuals within these areas will have been lost due to aggregation. A second potential limitation was the use of both the IMD total score and five of the seven IMD domains in the analysis, running the risk of replicating certain data within the analysis. However due to a lack of availability of other indicators this was unavoidable, and the potential detrimental effects were lessened due to the IMD total score being tested in a separate model. Thirdly, the statistical power of the second regression model may have been weakened due to 13 predictor variables being tested against a dependant variable that contained only 100 data points. In addition, the accuracy of mean dmft may have varied due to variations in sample size across those neighbourhoods. Finally, the use of the conceptual model may have excluded some caries-specific risk factors known to influence the distribution of caries such as exposure to fluoride.

Conclusion

The aim of this study was to apply the CSDH framework to discover which indicators most accurately predict the distribution of dental caries in children aged 5 years in Sheffield. Using a simplified model, based on available data, the total IMD score explained 60% of variation in dental caries. A large prospective study is required in the UK to investigate the full range of factors in the CSDH model and to develop a new index which might better predict dental caries experience than IMD. Until such time as that is completed the IMD is a readily available tool which can be used where dental caries data are not available.

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