Socio-demographic correlates of early childhood caries prevalence and severity in a developing country - South Africa

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Objectives: To describe Early Childhood Caries (ECC) severity in South Africa and examine the association between ECC and socio-demographic factors, area-based measures of sugar consumption and water fluoride levels. **Methods:** Children, aged 36-71 months, were examined during the 1999/2002 South African National Children's Oral Health Survey (n=5,822). ECC severity was described using Wyne's ECC classification (adapted) and the Significant Caries Index (SiC). Socio-demographic factors, area-based fluoride levels in water supplies, and the area-based per capita sugar expenditure obtained from the 2000 Household Expenditure Survey were examined using bivariate and multivariate analyses. **Results:** The mean population SiC was 7.6 and 32% presented with the severe forms of ECC. Increased per capita sugar expenditure and decreasing water fluoride levels, were significantly associated with an increased risk for any ECC, but was not significantly associated with the severe forms of ECC. Compared to blacks, being of mixed race and white were respectively associated with an increased and a decreased risk for ECC. Unemployment increased the risk for the severe forms of ECC. **Conclusions:** The study findings support the implementation of an integrated primary oral health care strategy in order to address the underlying socio-economic determinants of ECC in South Africa.

Key words: Early childhood caries, primary oral health care, developing country

Early childhood caries (ECC) is a serious public health concern, especially for socially disadvantaged groups, in both the developed and developing worlds[1]. Yet it remains relatively unexplored and poorly defined in many developing countries, particularly in Sub-Saharan Africa.

The 1999/2002 South African National Children's Oral Health Survey (NCOHS)[2] established a dental caries prevalence of 51% amongst 4-5-year-olds, but the reported DMFT/dmft score of 2.4 provides only a vague reflection of the true severity of ECC in South Africa, and does not describe how ECC affects the socially diverse population of that country. The majority of existing studies on ECC[3-5] are either merely descriptive in terms of prevalence, and/or focus on small geographical areas only. In the light of the lack of proper scientific evidence, it was not surprising that in a recent national health review[6], ECC was not recognised as an important chronic disease among South African children.

In developing countries, such as South Africa, a lack of financial resources often limits the number of variables included in oral epidemiological surveys, which in turn limits the extent to which determinants of diseases like dental caries can be examined. This is evident in the fact that the NCOHS did not collect data on factors which are often associated with caries in the general population such as fluoride- and sugar exposure[7,8]. However, in the presence of existing area-based water fluoride[9,10] and sugar consumption data[11] from other sources, an ecological study certainly becomes an attractive alternative to identify the relative contribution of these factors to ECC. If logical results can be obtained using an ecological approach it may become

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a useful alternative for conventional epidemiological studies to research determinants of diseases like dental caries. Ecological studies may indeed be particularly useful in poorly resourced settings, typically encountered in developing countries, where addressing social inequity also remains of public health importance.

This study therefore sought to provide a more detailed description of ECC severity in South Africa and examines the association between ECC (prevalence and severity) and socio-demographic factors, controlling for water fluoride levels and sugar consumption by means of area-based measures obtained from alternative sources.

Materials and methods

Data source and study design

The primary data used in this study were obtained from children that participated in the NCOHS (1999-2002). The methods for the NCOHS have already been published[12]. Briefly, the NCOHS used a two-staged cluster sampling method, weighted to produce a representative sample of South African children. The sample was stratified by geographical location, and participating schools were randomly selected within the various districts. The locality of the school was indicated as urban, peri-urban, or rural. The peri-urban and rural groups were grouped into one category, namely non-urban, during subsequent analyses. All children aged 36 to 71 months examined during the NCOHS were included in this study. The study was restricted to data from seven of the nine provinces that collected information on the households' breadwinners' employment status, in addition to the oral examination records of the children who were surveyed (n=5,822).

Measures

Debates are ongoing about appropriate ECC case definitions[13,14]. Wyne proposed a relatively simple definition that divides ECC into three categories. The first category is mild to moderate ECC, which involves one or two molars and/or incisors (Type I). The second category is moderate to severe ECC, which involves labio-lingual caries on the maxillary incisors, where the molars are either affected, or not (Type II). The third category is severe ECC, which involves virtually all the teeth, including the mandibular incisors (Type III)[14].

Wyne's classification was adapted to a per tooth basis, since the decayed missing filled teeth index (dmft)[15], as opposed to decayed missing filled surfaces (dmfs) was recorded during the NCOHS. Wyne's labelling of the different ECC types was simplified by renaming Type I, II and III ECC respectively to 'isolated' caries, 'severe' and 'very severe' categories of ECC. The Significant Caries Index (SiC)[16] was also calculated.

The occupation of the breadwinner, confirmed by the school's database, was recorded in ten categories, according to the classification of occupations in the South African population census[17]. For statistical analysis purposes, these occupations were grouped into three broad categories[18]. The first grouping (the high-income occupational group) contained occupations in professional occupations, managers and skilled workers. The intermediate grouping contained the occupations such as semi-skilled/manual workers and labourers. Thirdly, the unemployed whether they were seeking employment or not were grouped together. The children's race/ethnicity was recorded according to the four main racial classifications used in South Africa, namely black Africans, coloureds (those of mixed ancestry), Asians, and whites[17].

Based on the South African fluoride supplement dosage schedule[9], previously reported data regarding the fluoride content in public drinking water supplies[9, 10] were used to categorise the fluoride in drinking water (*Table 4*). The school address served as matching reference and in cases where fluoride values were unavailable, the water fluoride content of the closest neighbouring town was used.

Raw data of the Household Expenditure Survey (HHES), which served as the source of information on household expenditure on sugar was obtained from the South African Data Archives, housed at the National Research Foundation, South Africa. The methods employed in the 2000 HHES of South Africa have been previously detailed elsewhere[11]. The mean monthly expenditure per household member on discretionary sugars, including chocolates, was calculated per locality, (urban and non-urban) per administrative district (n=32 districts) for each of the four racial groups. The area-based measure of sugar expenditure per household member computed in South African currency (Rand) from the HHES (n=26,263 households, and n=104,153 household members) was then merged with the dataset of the NCOHS, using the administrative district, the locality and race as the relational link.

Statistical analysis

All statistical analyses were carried out using STATA Release 8 software (Stata Corp., Texas USA). The 'svyset' option in STATA was used to adjust for the potential intra-cluster correlation that could occur at school and district level due to the complex sample design. Bivariate analysis included the use of chi-square statistics for categorical variables. T-tests and analysis of variance were used to test for group differences for continuous variables. The Bonferroni post-hoc test of independence was used for pair-wise contrast analyses (multiple group comparison).

Multiple logistic regression analyses were used to illustrate the independent association between ECC and the socio-demographic factors, sugar expenditure/consumption and fluoride content in drinking water. ECC served as the outcome measure in three separate multiple logistical regression models. For this purpose, ECC was dichotomised as follows: Firstly (Model 1), those without caries (Code 0) were compared with those suffering from any form of ECC (Code 1); secondly (Model 2), of those with caries, those with 'isolated' caries (Code 0) were compared with those with more severe forms of ECC (Code 1); thirdly (Model 3), those with 'isolated' and 'severe' ECC (Code 0) were compared with those with 'very severe' ECC (Code1). The same covariates were used in all three models. The level of statistical significance was set at 5%.

Results

Of the 3-5-year-old subjects, 45% (95%CI: 40 - 51%) were caries-free, 23% (95%CI: 20 - 24%) had 'isolated' caries, 28% (95%CI: 24 - 34%) had 'severe' ECC (maxillary incisors affected) and 4% (95%CI: 3 - 5%) had 'very severe' ECC (mandibular incisors also affected). The mean (SD) SiC for the studied population was 7.6 (3.29). Of those with caries, at least 58% presented with the involvement of mostly the incisors (smooth surface caries), while only 42% presented with 'isolated' caries (*Table 1*).

The mean dmft and sugar expenditure was significantly higher while the fluoride levels in drinking water were significantly lower in the urban areas compared to that of the non-urban areas (*Table 2*). Urbanisation was associated with an increase in ECC prevalence (*Tables 3* and *4*) but not with an increase in ECC severity after controlling for potential confounding factors (*Table 4*).

Compared to black African children, ECC was significantly more prevalent and severe in coloured children, and less prevalent and severe in white children (*Table 3*), even after controlling for confounding factors (*Table 4*).

A significantly larger percentage of the unemployed resided in the ≥0.3ppm fluoride areas when compared with the high and the middle-income groups (*Table 2*).

Table 1 Bivariate association between ECC and dmft, age and sugar expenditure

ECC	n	dmft Mean (Sd)	Age (months) Mean (Sd)	Sugar expenditure Mean (Sd)
No caries	2644	0.00 (0.00)	60.53 (6.78)	7.74 (2.52)
Isolated	1336	2.93 (1.96)	62.02 (6.42)	7.74 (2.70)
Severe	1605	6.24 (3.37)	60.91 (6.66)	7.75 (2.18)
Very severe	237	9.35 (5.47)	62.77 (6.20)	7.84 (2.46)
ANOVA		P<0.001	P<0.01	Not significant

Table 2 The bivariate association between socio-demographic indicators and dmft, sugar expenditure, and fluoride in drinking water

	n	dmft	Sugar expenditure*	Fluoride in drinking water (% distribution)		
		Mean (Sd)	Mean (Sd)	<0.1 ppm (n=2110)	0.1-0.29 ppm (n=2888)	≥0.3 ppm (n=769)
Locality						
Urban	3239	3.07 (3.88)	8.06 (2.78)	43.28%	50.82%	5.90%
Non-urban	2560	2.39 (3.46)	7.35 (1.94)	27.73%	48.63%	23.63%
		P<0.001	P<0.001		P<0.001	
Race/Ethnicity						
Black	4083	2.46 (3.39)	7.14 (1.17)	30.84%	54.49%	14.67%
Coloured	852	4.94 (4.67)	7.87 (1.53)	71.83%	19.84%	8.33%
Asian	226	2.66 (3.52)	9.28 (5.87)	15.93%	77.88%	6.19%
White	606	1.90 (3.26)	11.30 (4.32)	33.50%	52.48%	14.03%
		P<0.001	P<0.001		P<0.001	
Income						
High	1207	2.37 (3.38)	8.29 (3.10)	36.04%	54.76%	9.20%
Middle	2661	3.10 (3.91)	7.63 (1.75)	39.27%	47.54%	13.19%
Unemployed	1518	2.56 (3.65)	7.77 (3.09)	27.40%	56.06%	16.53%
		P<0.001	P<0.001		P<0.001	

*Currency: South African Rand

Table 3 Bivariate association between ECC and gender, race, urbanisation, income and fluoride in drinking water

		Early Childhood Caries				
		No caries	Isolated	Severe	Very severe	Chi ^{2}
	n	%	%	%	%	P
Locality						
Urban	3171	40.37	22.78	32.31	4.55	<0.05
Non-urban	2528	51.13	21.11	24.92	2.84	
Race/Ethnicity						
Black	4012	47.74	21.58	27.32	3.36	<0.001
Coloured	852	23.18	25.08	45.48	6.26	
Asian	226	47.09	20.22	29.64	3.05	
White	577	61.19	20.36	15.43	3.02	
Income						
High	1179	48.83	22.98	24.95	3.24	<0.01
Middle	2610	41.25	23.80	31.45	3.50	
Unemployed	1511	49.43	18.14	28.86	3.57	
Gender						
Male	2816	45.05	20.68	30.33	3.94	0.07
Female	2868	46.15	23.11	27.19	3.54	
Fluoride (ppm)						
<0.1ppm	2112	25.85	18.84	28.41	26.89	<0.001
0.1-0.29	2891	34.38	17.47	19.79	28.36	
≥0.3ppm	796	40.58	16.46	12.94	30.03	

The high-income group spent significantly (Bonferroni, P<0.001) more on discretionary sugars compared to members of the middle-income group and the unemployed group (*Table 2*). ECC was most prevalent and severe in the middle-income occupational group (*Table 3*). Compared to children in the high-income occupational group, only the children of the unemployed showed an increased risk for the severe forms of ECC when compared to 'isolated' caries (*Table 4* – Model 2).

Increasing age was significantly associated with developing ECC (*Table 4* – Model 1). Younger children were more likely to present with the severe forms of ECC compared with isolated' caries (*Table 4* – Model 2). Conversely, increasing age was significantly correlated with the development of 'very severe' ECC when compared to 'isolated' and 'severe' ECC (*Table 4* – Model 3).

Although males had a significantly higher mean dmft compared to that of females (2.89 vs 2.67; P<0.05), the difference in the prevalence of ECC for males and females did not reach statistical significance (P=0.07) (*Table 3*). However, females were significantly less likely than males to present with the severe forms of ECC, compared to 'isolated' caries (*Table 4* – Model 2).

During the multivariate analyses, higher per capita household sugar expenditure was significantly associated with the development of ECC (*Table 4* – Model 1).

Increased water fluoride levels were associated with a reduction in decay, for all the ECC categories except the 'very severe' ECC category (*Table 3*). Even after controlling for potential confounders, a significant association was still observed between decreasing water fluoride levels and an increasing risk for the prevalence of ECC (*Table 4*, Model 1).

However, low water fluoride levels and increased sugar consumption did not significantly increase the risk for the severe forms of ECC when the severe forms of ECC were compared with isolated caries (*Table 4*, Model 2).

Discussion

The finding that nearly one in three children was affected by dental caries on the anterior primary teeth, and with the population's SiC estimated at 7.6, highlights the need to recognise ECC as a serious public health problem in South Africa.

Race/ethnicity and ECC have previously been illustrated as a risk factor for ECC in the developed countries[19] and in South Africa, in particular[12], where there are known social disparities between racial groups. In South Africa, the socio-economic status of the whites is still considerably higher when compared to that of the Asian, coloured and black populations[20]. Therefore, by implication, members of the white population have better knowledge about self-care and disease, access to fluoridated toothpaste, health promotional

Table 4 Multivariate association between ECC and socio-demographic indicators, fluoride in drinking water and sugar expenditure

	Model 1 No caries compared with ECC	Model 2 'Isolated' caries compared with the severe forms of ECC	Model 3 'Isolated' and 'severe' ECC compared with 'very severe' ECC
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age (months)	1.03 (1.01-1.04)*	0.98 (0.97-1.00)*	1.03 (1.01-1.06)*
Gender			
Male (0)	Reference	Reference	Reference
Female (0)	0.97 (0.85-1.11)	0.76 (0.63-0.91)*	0.78 (0.54-1.12)
Locality			
Urban (0)	Reference	Reference	Reference
Non-urban (1)	0.75 (0.59-0.95)*	0.85 (0.68-1.06)	0.71 (0.47-1.07)
Race/Ethnicity			
Black (0)	Reference	Reference	Reference
Coloured (1)	2.34 (1.78-3.07)*	1.36 (1.01-1.82)*	1.36 (0.85-2.16)
Asian (2)	0.81 (0.54-1.22)	1.11 (0.69-1.80)	0.94 (0.50-1.77)
White (3)	0.35 (0.25-0.50)*	0.56 (0.36-0.88)*	1.32 (0.56-3.13)
Income			
High (0)	Reference	Reference	Reference
Middle (1)	1.25 (1.05-1.50)*	1.13 (0.91-1.42)	0.90 (0.59-1.37)
Unemployed (2)	0.99 (0.79-1.24)	1.51 (1.15-1.98)*	1.27 (0.76-2.12)
Fluoride			
<0.10 ppm (0)	Reference	Reference	Reference
0.10-0.29 ppm (1)	0.80 (0.64-0.99)*	0.91 (0.73-1.14)	1.00 (0.64-1.55)
0.30-0.6 ppm (2)	0.62 (0.44-0.87)*	0.71 (0.48-1.04)	1.01 (0.55-1.87)
>0.6 ppm (3)	0.40 (0.25-0.63)*	0.71 (0.25-2.03)	0.57 (0.14-2.38)
Sugar expenditure	1.07 (1.02-1.12)*	1.04 (1.00-1.10)	1.01 (0.95-1.07)

* Statistically significant at P<0.05

aids and dental services, which were not controlled for during this study. The literature shows that low socio-economic status/ poverty[19, 21], as well as an inability to afford toothpaste[22] can be associated with an increase in ECC prevalence. It was therefore not surprising that the prevalence of ECC was relatively lower in the white population group compared with the black Africans and the coloured population.

Sugar has been implicated as a risk factor for ECC[23]. Recently, this causation effect seems to be attenuating in epidemiological studies in the developed countries, probably due to the widespread use of discretionary sugars[24]. Although sugar consumption in South Africa, expressed as a percentage of the total energy intake, is currently slightly higher (11%) than the benchmark of 10%, sugar consumption remains relatively low in comparison to that in countries such as the United States of America[25]. The results of this study suggest that sugar is still significantly associated with ECC prevalence in South Africa, but not with the severe forms that often involve the anterior teeth and possibly develop at a time when extensive use of extrinsic sugars may not have been fully established.

Fluoridated drinking water has been shown to have a significant caries protective effect in the deciduous dentition[26]. The observed protective effect of water fluoride levels in terms of ECC prevalence shown in this study therefore supports a previous recommendation that water supplies with less than 0.6ppm fluoride should be fluoridated in South Africa[9]. The relatively higher ECC prevalence among coloured South Africans may partially be explained by the fact that in contrast to black Africans, most coloured South Africans live in the coastal Western Cape province, where drinking water fluoride levels are very low. However, subsequent to the repeal of apartheid laws that previously restricted where different population groups could reside in South Africa, the situation may change, as the blacks begin to move to urban areas, and those in the rural communities begin to receive water reticulation, thus changing their water source from the traditionally high fluoride-containing ground water supply (e.g., boreholes)[27] to reticulated public water supplies with lower levels of fluoride. These changes, together with indications of changes in terms of cariogenic food-consumption habits in black African children following a rural-to-urban

shift[28], certainly suggest an increase in the prevalence of ECC in the black African population of South Africa may be expected in future.

Severe ECC (maxillary primary incisors affected early in life) is predominantly associated with incorrect infant feeding practices[29,30], with the free provision of fluoridated toothpaste to underprivileged individuals reported to have a limited protective effect on this type of ECC[22]. Since water fluoride levels and sugar was not significantly associated with the severe forms of ECC in the current study, potentially harmful infant feeding practices may explain why the risk for the severe forms of ECC was highest among the unemployed and relatively higher among non-whites. Previously, in a study in the northern parts of South Africa, the majority of those in the lowest socio-economic class had indeed been reported to practice prolonged breast and/or bottle feeding. Furthermore, in the latter study the severity of ECC was also shown to be the lowest among the whites[31]. The finding that ECC was more severe in the coloured (mixed race) population compared with the black African population, although they are of nearly similar socio-economic status[20] suggests less desirable oral health-related behaviour amongst coloured South Africans, which require further investigation. For example, of the racial groups residing in South Africa, coloured South Africans have the highest smoking prevalence[32], which implies that coloured children are more likely to be exposed to second-hand smoke compared with children from the other racial groups. The fact that second-hand smoke has previously been associated with an increased risk for dental caries[33-36] necessitates further research regarding its potential influence on the caries prevalence in young coloured South African children.

Nevertheless, the inconsistent policy surrounding the active prevention of mother-to-child transmission of HIV through breast feeding[37], round about the study period, may also have caused a transition from breastfeeding to even more detrimental bottle feeding practices among the low socio-economic groups who are most affected by HIV/AIDS in South Africa. This taken together with our study findings, suggest the need for clear policy directives on infant feeding and HIV/AIDS and the provision of anticipatory guidance of expectant mothers visiting antenatal clinics with regards to oral health care. These interventions should form part of an integrated Primary Health Care approach, targeted not only for the prevention of mother-to-child HIV transmission but also with due consideration for the promotion of child oral health.

It was worth noting that female study participants, irrespective of race, fluoride availability or level of sugar consumption, tend to display the less severe forms of ECC. Given that time predicts the occurrence of caries experience, the finding that ECC was relatively more severe in males may be due to later exfoliation of primary teeth in males, resulting in an later eruption of the permanent teeth[38-40], thereby creating an underestimation of ECC in the primary teeth of female participants. Similarly, the current finding that ECC of the primary maxillary incisors is associated with younger age compared with ECC of the primary molar teeth is probably due to the earlier eruption of the primary incisors.

A major limitation of this study is its cross-sectional design, thus any inference in the current study on causality should be interpreted with caution. Furthermore, by linking area-based measures to individuals may result in an ecological fallacy[41]. However, mainly due to the now abolished apartheid laws, South Africans still live in racially divided segments spread throughout the country. Therefore, an ecological study of this nature has the advantage of unravelling social determinants of health, which may inform interventions at population level. There is indeed a growing interest in ecological studies[42]. Furthermore, area-based household sugar expenditure may seem a useful alternative measure of sugar consumption in poorly resourced settings. Given that national household expenditure surveys may be more routinely carried out in Sub-Saharan African countries than oral health surveys, data on the per capita household sugar expenditure collected along with data on levels of employment and measures of income disparities may prove to be a useful surveillance measure for monitoring efforts directed towards the prevention of dental caries in these countries. A further strength of this study is the large population sample used.

Conclusion

ECC should be considered a serious public health problem in South Africa, especially among the socially disadvantaged groups. Although water fluoridation may help to reduce the prevalence of ECC, a greater reduction in the more severe forms of ECC (which is the more predominant form of ECC in the studied population) would only be achieved through an integrated Primary Oral Health Care approach that includes not only oral health promotional interventions, but also interventions that address underlying social determinants. This will include interventions directed at improving the living standards of the population, particularly the most disadvantaged groups.

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