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Dental caries prevalence and distribution among preschoolers in Singapore

XL. Gao[1], C.Y.S. Hsu[1], T. Loh[1], D. Koh[2], H.B. Hwarng[3] and Y. Xu[4]

[1]*Department of Preventive Dentistry, Faculty of Dentistry, National University of Singapore.* [2]*Department of Community, Occupational, Family Medicine, Yong Loo Lin School of Medicine, National University of Singapore.* [3]*Department of Decision Sciences, School of Business, National University of Singapore.* [4]*Department of Information Systems, School of Computing, National University of Singapore*

Objective: To describe the prevalence, severity and distribution of dental caries among preschoolers in Singapore. ***Basic research design:*** population-based, cross-sectional study. ***Setting:*** 13 randomly selected People's Action Party Community Foundation (PCF) Education Centers, the main provider of preschool education in Singapore. ***Participants:*** 1,782 children aged 3-6 years. ***Main outcome measures:*** The caries status was evaluated by using WHO examination procedures and diagnostic criteria. ***Results:*** About 40% children (26%, 37%, and 49% for 3-4, 4-5, and 5-6 year-olds, respectively) were affected by caries. The mean (SD) deft and defs were 1.54 (2.75) and 3.30 (7.49), respectively. About 90% of the affected teeth were decayed teeth. A significantly skewed distribution of caries lesions was revealed, indicating that 16% children with high caries activity (deft≥4) were carrying 78% lesions. Rampant caries, defined as caries affecting the smooth surfaces of two or more maxillary incisors, was found in 16.5% of children. About 61% of affected surfaces were smooth surfaces. Malays and boys tended to have more rampant caries. Higher caries severity and treatment need were found among Malays and children in the low socio-economic group. ***Conclusions:*** Caries is a severe oral health problem for Singaporean preschoolers, especially in the Malay community and among children with low economic status.

Key words: Dental caries, preschoolers, prevalence, Singapore

Introduction

The Republic of Singapore is a tropical island country with a multiracial population in Southeast Asia. It is the first country in Asia to institute a comprehensive fluoride programme covering 100 per cent of the population (Loh, 1996). The results of surveys conducted in 1970 and 1994 showed a decline in mean dft from 2.60 to 1.08 for schoolchildren aged 6-11 years, and the mean DMFT had decreased from 2.98 to 1.05 for 6-18 year-olds. The proportion of children free of caries in the permanent dentition increased from 30% to 58.7% (Lo and Bagramian, 1997). These achievements in caries control are mainly attributed to the implementation of water fluoridation and an organized school dental service, which provides free dental care to schoolchildren 6 to 18 years of age (Loh, 1996; Lo and Bagramian, 1997).

However, since the national survey conducted in 1994 among schoolchildren, no caries prevalence data in Singapore have been published. In recent years, the recurrent epidemic of caries reported in some developed countries (Haugejorden and Birkeland, 2002; Pitts *et al*., 2003) warrants the monitoring of current dental caries status and disease trends among Singaporean children, especially after the adjustment of water fluoridation from 0.7ppm to 0.6ppm in 1992 (Lo and Bagramian, 1997).

Previous studies on caries prevalence among children in Singapore focused on schoolchildren. Epidemiological data on the caries status among preschoolers, who are not covered by the school dental service, are scarce. Only some data collected from a few convenience samples of preschoolers have been reported, revealing a 48-54% caries rate, dft of 2.2 among 2-4 year olds and 1.48 among 4-year-old children (Hsu *et al*., 2001; Hong, 2003; Pine *et al*., 2004). Population-based studies are needed to profile the caries status among preschoolers in Singapore, and to provide evidence assisting dental health administrators in the planning of preventive programmes and mobilization of resources to reach this target group.

The objectives of this study are: to describe the caries prevalence and severity, to profile the intra-oral distribution of caries, and to determine the influence of various demographic and socio-economical factors on caries patterns among preschoolers in Singapore.

Methods

The protocol for this study was approved by the National University of Singapore Institutional Review Board (NUS-IRB 04-155) and informed consent was obtained from the parent/guardian of each subject.

In Singapore, the overwhelming majority (about 80%) of preschoolers aged 3-7 years attend People's Action Party Community Foundation (PCF) Education Centers, which are the main public kindergartens in the island (Singapore Ministry of Education, 2005). This study targeted children aged 3-6 years (nursery and kindergarten-1). The sampling unit was a PCF kindergarten. A stratified cluster random sampling, proportionate to the size of the subpopulations among the five administration

Correspondence to: Associate Professor, Chin-Ying Stephen Hsu, Department of Preventive Dentistry, Faculty of Dentistry, National University of Singapore, 5 Lower Kent Ridge Road, Republic of Singapore 119074. E-mail: pndhsus@nus.edu.sg

districts, was adopted. By considering the population size (157,825 children aged 3-6 years in Singapore) (Singapore Department of Statistics, 2001), estimated caries prevalence rate (50%) and a targeted margin of error (2.5%), the sample size was calculated to be 1,522. Therefore, a study sample of 1,600 subjects (400, 300, 290, 280, and 330 for Central, Southeast, Southwest, Northeast, and Northwest districts, respectively) was targeted. Kindergartens in each district were randomly selected from the list of the PCF kindergartens. Only one kindergarten was not able to participate due to the pre-arrangement for other health surveys during the planned fieldwork period. A substitute was selected by proceeding to the next random number in the list of kindergartens in the same district. A total of 13 PCF kindergartens (four in the Central, two in the Southeast, three in the Southwest, two in the Northeast, and two in the Northwest district) participated in this survey. All children attending nursery and kindergarten-1 classes in the participating kindergartens were approached. Fifty-nine (3.2%) children were absent on the day of survey, and five (0.3%) children refused to be checked. In all, 1782 children, representing 1.1% of the children of those age groups in Singapore, were examined.

All subjects were examined by the same examiner from July to October 2005 using WHO examination procedures and diagnostic criteria (WHO, 1997). Before the survey, intra-examiner calibration was conducted and the team was briefed on the examination procedures. The subjects were examined on a portable dental chair using a fiber-optic light. Tooth status was evaluated using visual inspection and then confirmed by tactile inspection with disposable plane mouth mirrors and probes. The probe was used very prudently to avoid damaging sound enamel surfaces. Although the teeth were neither cleaned nor dried before the assessment, the debris obscuring the visual inspection was removed. No radiographs were taken. A tooth was scored as missing only if the subject was at an age when normal exfoliation would not be a sufficient explanation for the absence of the tooth.

For monitoring the intra-examiner reliability, duplicate examinations were carried out on a randomly selected 10% of subjects. The examiner was kept blind of those who were selected for duplicate examinations.

The information on the demographic background and socio-economic status of the children was collected through questionnaires completed by the parents/guardians.

The SPSS (V13) software was used for data analysis. The intra-examiner reliability was evaluated by the Cohen's Kappa statistics. Chi-square tests were used for comparison of proportions. Tukey post-hoc tests or t-tests, as appropriate, were used to compare means when the normal distribution and homogeneity of variance were supported by the skewness test and Levene test. Non-parametric Kruskal-Wallis tests or Mann-Whitney tests, as appropriate, were used when the normal distribution or homogeneity of variance was not supported. Differences in proportions and means between demographic and socioeconomic subgroups have been indicated through the ranks in Table 2 and 3.

Table 1. Characteristics of subjects by district, race, gender, and type of housing

		(1) Sample Population		(2) Resident Population in Singapore *	Difference Between (1) and (2)
		n	%	%	P **
District	Central	451	25	25	0.468
	Southeast	317	18	19	
	Southwest	356	20	18	
	Northeast	301	17	17	
	Northwest	357	20	21	
Race	Chinese	1208	67.8	76.8	<0.001
	Malay	341	19.1	13.9	
	Indian	165	9.3	7.9	
	Others	68	3.8	1.4	
Gender	Male	889	49.9	49.9	0.992
	Female	893	50.1	50.1	
Housing	HDB# apartment with 1-3 rooms	344	21.1	21.2	0.816
	HDB# apartment with 4-5 rooms	1056	64.9	64.9	
	Private apartments/houses	227	14.0	13.9	
Total		1782	100	100	

* HDB stands for Housing & Development Board, which is the main authority managing the development of public housing in Singapore.

Table 2. Caries status by race, gender, age and type of housing

	n	% Affected (deft>0)	% with Untreated Teeth (d- >0)	% High Caries Activity (deft≥4)	% Rampant Caries [a]	Mean (SD)		Components of Affected Teeth		
						deft	defs	d-	e-	f-
Total										
Crude	1782	40.3	38.8	15.9	17.1	1.57 (2.79)	3.38 (7.63)	1.41 (2.61)	0.04 (0.35)	0.12 (0.66)
Re-weighed [b]	1782	40.0	38.5	15.6	16.5	1.54 (2.75)	3.30 (7.49)	1.38 (2.56)	0.04 (0.35)	0.13 (0.66)
Race										
Chinese	1208	39.5	37.8 [II]	15.2	15.5 [II]	1.50 (2.72)	3.17 [I/II] (7.30)	1.33 [II] (2.52)	0.04 [II] (0.34)	0.14 [I] (0.70)
Malay	341	43.4	43.4 [I]	19.3	24.4 [I]	1.81 (2.99)	4.13 [I] (8.27)	1.72 [I] (2.84)	0.05 [II] (0.34)	0.05 [II] (0.41)
Indian	165	37.1	35.1 [I/II]	12.6	10.6 [II]	1.30 (2.48)	2.79 [II] (7.43)	1.15 [II] (2.38)	0 [III] (0)	0.15 [I] (0.73)
Others	68	48.3	45.0 [I/II]	17.6	25.0 [I]	2.23 (3.63)	5.00 [I] (10.44)	1.93 [I/II] (3.32)	0.20 [I] (0.75)	0.10 [I/II] (0.48)
Caucasian	1	100.0	100.0	100.0	100.0	5.00	9.00	5.00	0.0	0.0
Nepalese	29	58.6	55.2	20.7	24.1	2.48 (3.29)	4.97 (7.63)	2.07 (3.02)	0.21 (0.94)	0.21 (0.68)
Indonesian	16	43.8	37.5	14.1	24.4	1.99 (3.36)	4.99 (8.63)	1.81 (3.01)	0.13 (0.71)	0.05 (0.41)
Other Asian ethnics	22	36.4	36.4	12.3	23.2	1.93 (3.02)	4.87 (7.69)	1.70 (2.58)	0.21 (0.68)	0.02 (0.33)
Gender										
Male	889	42.2	40.3	16.5	18.9 [I]	1.65 (2.84)	3.56 (7.55)	1.44 (2.59)	0.05 (0.37)	0.16 [I] (0.80)
Female	893	38.5	37.4	15.3	15.2 [II]	1.48 (2.75)	3.20 (7.71)	1.38 (2.62)	0.03 (0.33)	0.07 [II] (0.47)
Age										
3-4 yrs	194	25.5 [III]	24.5 [III]	6.4 [III]	8.0 [III]	0.70 [III] (1.78)	1.30 [III] (4.32)	0.61 [III] (1.65)	0.03 (0.36)	0.06 [II] (0.42)
4-5 yrs	888	36.9 [II]	35.9 [II]	13.3 [II]	16.2 [II]	1.40 [II] (2.68)	3.02 [II] (7.43)	1.30 [II] (2.57)	0.03 (0.21)	0.08 [II] (0.49)
5-6 yrs	697	48.9 [I]	46.6 [I]	21.9 [I]	20.8 [I]	2.03 [I] (3.07)	4.43 [I] (8.44)	1.78 [I] (2.81)	0.07 (0.47)	0.19 [I] (0.86)
Housing										
HDB [c] apartment with 1-3 rooms	344	41.8	40.9	18.8 [I]	18.8	1.86 (3.18)	4.24 (9.01)	1.78 [I] (3.11)	0.03 (0.34)	0.05 [II] (0.30)
HDB [c] apartment with 4-5 rooms	1056	39.4	38.4	14.4 [II]	16.3	1.45 (2.65)	3.11 (7.11)	1.31 [I/II] (2.45)	0.05 (0.39)	0.09 [II] (0.56)
Private apartments/houses	227	38.6	34.4	16.7 [I/II]	16.7	1.51 (2.64)	3.05 (6.48)	1.16 [II] (2.19)	0.03 (0.21)	0.32 [I] (1.21)

[a] Rampant caries was defined as caries affecting the smooth surfaces of two or more maxillary incisors.
[b] Main statistics re-weighted by "race".
[c] HDB stands for Housing & Development Board, which is the main authority managing the development of public housing in Singapore.
[I-III] Ranking: there were significant differences ($p<0.05$) in the proportions/means between subgroups with different ranks.

Table 3. Mean (SD) affected teeth and surfaces of different types

	Mean (SD) affected teeth				Mean (SD) affected surfaces		
	Anterior	**Posterior**	**Upper**	**Lower**	**Pit and fissure surfaces**	**Approximal surfaces of posterior teeth**	**All other surfaces**
Total	0.66 (1.42)	0.91 (1.73)	0.96 (1.78)	0.61 (1.24)	1.32 (3.04)	0.52 (1.63)	1.54 (3.83)
Gender							
Male	0.68 (1.42)	0.98 (1.78) [I]	0.99 (1.79)	0.66 (1.29) [I]	1.42 (3.06) [I]	0.55 (1.62)	1.58 (3.77)
Female	0.64 (1.42)	0.83 (1.67) [II]	0.92 (1.77)	0.55 (1.19) [II]	1.21 (3.03) [II]	0.48 (1.63)	1.50 (3.89)
Race							
Chinese	0.60 (1.37) [II]	0.90 (1.72)	0.90 (1.73) [II]	0.60 (1.22)	1.29 (3.00)	0.49 (1.58)	1.38 (3.62) [II]
Malay	0.87 (1.57) [I]	0.94 (1.74)	1.18 (1.92) [I]	0.63 (1.32)	1.43 (3.09)	0.55 (1.66)	2.14 (4.39) [I]
Indian	0.58 (1.32) [II]	0.72 (1.48)	0.78 (1.64) [II]	0.52 (1.08)	1.07 (2.71)	0.46 (1.44)	1.26 (3.33) [II]
Others	0.92 (1.74) [I]	1.32 (2.32)	1.37 (2.16) [I]	0.88 (1.66)	1.93 (4.15)	0.97 (2.54)	2.10 (4.46) [I]
Age							
3-4 yrs	0.30 (0.99) [III]	0.40 (1.07) [III]	0.40 (1.08) [III]	0.29 (0.86) [III]	0.53 (1.66) [III]	0.12 (0.72) [III]	0.65 (2.43) [III]
4-5 yrs	0.64 (1.44) [II]	0.76 (1.56) [II]	0.86 (1.73) [II]	0.53 (1.19) [II]	1.09 (2.68) [II]	0.39 (1.38) [II]	1.53 (4.05) [II]
5-6 yrs	0.80 (1.48) [I]	1.23 (2.01) [I]	1.24 (1.94) [I]	0.79 (1.37) [I]	1.83 (3.65) [I]	0.79 (2.02) [I]	1.81 (3.83) [I]

[I-III] Ranking: there were significant differences ($p<0.05$) in the means between subgroups with different ranks.

Results

The mean age of the subjects was 4.8 +/- 0.5 years, with an age range of 3.6-5.7 years. The study sample was reasonably representative of the national population, though with some differences in the racial components (Table 1). According to the percentages of the four ethnic groups in the whole Singapore population, re-weighting for "race" was performed for the main population statistics, such as % affected rate, mean deft and defs, despite the small difference observed between reweighed and crude estimates (Table 2).

The intra-examiner reliability for caries examination was high, with a Kappa concordance coefficient of 0.958. The caries prevalence and severity by main demographic and socio-economical factors are described in Table 2.

In all 40.0% children were affected by caries. The % affected rate were 25.5%, 36.9% and 48.9% for 3-4, 4-5 and 5-6 year-olds, respectively. The mean (SD) deft and defs for all subjects were 1.54 (2.75) and 3.30 (7.49). For 5-6 year-olds, the mean (SD) deft and defs were 2.03 (3.07) and 4.43 (8.44). The proportion of children with high caries activity (deft≥4) and rampant caries (defined as caries affecting the smooth surfaces of two or more maxillary incisors) (Al-Malik *et al*., 2002) were 15.6% and 16.5%, respectively.

The majority (89.6%) of affected (decayed, extracted and filled) teeth were decayed teeth. About 38.5% children were found with untreated teeth. For the whole population, on average, 1.38 teeth needed to be treated for each child. Among those children affected by caries, an average of 3.49 teeth per child required treatment.

A significantly skewed distribution of caries lesions among the children was revealed, with skewness values (SE) of 4.11 (0.06) and 2.52 (0.06) for defs and deft, respectively. About 78% of lesions were found in 16% of children with high caries activity (deft≥4). About one quarter (23%) children with deft>2 were carrying 88% of the lesions. The Significant Caries Index (SiC), *i. e.* the mean (SD) deft for one third of the population with the highest deft values (Bratthall, 2000), was 4.49 (3.23).

A significantly higher mean defs was found in Malays (4.13) than in Indians (2.79) ($p=0.050$). The proportion of children with rampant caries was significantly higher in Malays (24.4%) than in Chinese (15.5%) and Indians (10.6%) ($p<0.001$).

The percentage of children with untreated teeth for Malay children (43.4%) was significantly higher than that for Chinese children (37.8%) ($p=0.041$). The mean number of decayed teeth was significantly higher for Malays (1.72) than for Chinese (1.33) and Indians (1.15) ($p=0.017$ and $p=0.024$, respectively). There was a significantly lower mean number of filled teeth for Malays (0.05) than for Chinese (0.14) and Indians (0.15) ($p=0.013$ and $p=0.046$, respectively).

More boys had rampant caries compared with girls ($p=0.050$). The mean number of filled teeth for boys (0.16) was significantly higher than that for girls (0.07) ($p=0.007$). The significant gradient increase in the caries prevalence and severity with each 1-year increase in age was seen in all the caries indexes (all $p<0.001$). About 12% and 0.7 increases in "% affected rate" and "mean deft" were observed with every 1-year increase in age.

The percentage of children with high caries activity was higher among those living in Housing and Development Board (HDB) apartments with 1-3 rooms than those living in HDB apartments with 4-5 rooms ($p=0.037$). The mean number of decayed teeth in children living in private apartments or houses (1.16) was lower than in children living in HDB apartments with 1-3 houses (1.78) ($p=0.048$), while the mean number of filled teeth was significantly higher in children living in private apartments or houses (0.32), compared with children living in HDB apartments (0.08) ($p<0.001$). Among children living in private apartments or houses, 76.8% of affected teeth were decayed teeth. Among children living in HDB apartments 91.8% of affected teeth were decayed teeth.

The intra-oral caries distribution in different types of teeth and surfaces is summarized in Table 3. About 42% affected teeth were incisors and canines, while the remaining 58% were molars. About 61% of affected teeth were upper teeth. About 39%, 15% and 46% of affected surfaces were "pit and fissure surfaces", "approximal surfaces of posterior teeth", and "all other surfaces", respectively. About 9.5% subjects had caries only in anteriror teeth, while 14.3% subjects had caries confined to posterior teeth. In 16.5% of subjects both tooth types were affected.

The mean numbers of affected posterior teeth and lower teeth were significantly higher in boys than in girls ($p=0.027$ and $p=0.030$). The mean numbers of affected anterior teeth and upper teeth were significantly higher among Malays than among Chinese ($p<0.001$ and $p=0.009$) and Indians ($p=0.050$ and $p=0.022$, respectively).

Discussion

In Singapore, a few caries surveys have been conducted among schoolchildren, a captive group that can be easily accessed through the school dental services. However, the caries prevalence and distribution among preschoolers has been largely neglected possibly due to the methodologically and logistically demanding nature of oral health surveys among preschoolers, and the belief held by the public and, to some extent, some of the dental health workers, that primary teeth are less important than permanent teeth. Although primary teeth are shed caries on primary teeth can pose serious threats to the well-being of the young children. Besides causing severe symptoms (*e.g.* pain and abscesses), caries on primary teeth can give rise to an unaesthetic appearance and affects masticatory functions, which can result in malnutrition and gastrointestinal disorders (Clarke *et al*., 2006; Usha *et al*., 2007). Moreover, the development and eruption of the succeeding permanent teeth can be affected, leading to malocclusion in the permanent dentition (Tinanoff and O'Sullivan, 1997). Caries on primary teeth can severely affect the self-esteems and life qualities of the children (Filstrup *et al*., 2003; Li *et al*., 2008), and the treatment is costly with frequent relapses (Tinanoff and O'Sullivan, 1997). The global goal of oral health, "50% caries-free for 5-6 year olds by the year 2000", has indicated the importance of the primary dentition and set the stage for international comparisons of oral health (FDI World Dental Federation, 1982; WHO, 1995).

Despite the success in caries control among schoolchildren in Singapore (Loh, 1996; Lo and Bagramian, 1997), caries control among preschoolers is relatively poor and might be attributed to the plateau effect of water fluoridation and insufficient organized dental services and oral health promotion for this population. In this study, 39% of affected surfaces were "pit and fissure surfaces", with 15% and 46% of affected surfaces being "approximal surfaces of posterior teeth" and "all other surfaces", respectively. When comparisons were made with the national data for children in USA on the intra-oral distribution of caries, a high percentage of affected anterior teeth and smooth surfaces were found among preschoolers in Singapore, whereas, caries on posterior teeth, especially on pit and fissure surfaces, was the dominating component for children in USA (Li *et al*., 1993). Water fluoridation has been proven to have a major impact on smooth surface caries (O'Mullane, 1995; Roberts, 1995), but this preventive measure is not efficient in preventing smooth surface caries on the primary teeth in this group of children. Supplementary preventive therapies, other than the nationwide water fluoridation, would be needed to prevent and control the disease, especially for high-risk individuals.

The school dental service in Singapore has been recognized as an example of success in caries control (Loh, 1996; Lo and Bagramian, 1997). Based on the findings of this study, it would be advisable to extend the school dental service to preschoolers, in particular the high-risk groups. The percentage of the decayed component in this population (90%) is remarkably higher when compared with the data of most of the developed countries, such as USA (58%) and Australia (38%) (both $p<0.001$) (Slade *et al*., 1996; Beltran-Aguilar *et al*., 2005). This high rate of untreated teeth might be due to the parents' anticipation for and dependence on the school dental service to be delivered to their children at an older age. Extending school dental services to preschoolers could benefit the children by reducing the number of untreated dental caries and the prevalence of malocclusion, as a potential result of the early loss of primary teeth (Alkilzy *et al*., 2007; Usha *et al*., 2007).

A higher caries rate and treatment need were identified in some demographic and socio-economic subgroups, such as Malays and children living in public housing units, especially HDB apartments with 1-3 rooms. The caries problem is less prominent for some other subgroups, such as Indians. The racial, socio-economical difference in caries severity may be attributed to the differences in (1) detrimental behaviours (e.g. prolonged breastfeeding, bed-time bottle uses, frequent sweet intake); (2) parents/ guardians' dental awareness/ knowledge and guidance on the child's oral hygiene measures; (3) cultural characteristics; and (4) barriers to dental care services. Our further analysis on the behavioral pathways explaining oral health disparity will be detailed in another publication and may provide important reference for targeted and cost-effective oral health education and intervention for this population.

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