Community Dent Oral Epidemiol 2006; 34: 205–12

COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY

Can the development of new dental caries in Danish schoolchildren be predicted from surveillance data in the School Dental Service?

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Jeppesen BA, Foldspang A. Can the development of new dental caries in Danish schoolchildren be predicted from surveillance data in the School Dental Service? Community Dent Oral Epidemiol 2006; 34: 205–12. © Blackwell Munksgaard, 2006

Abstract – *Background:* Dental screening programmes for Danish children generally target all children, irrespective of their individual caries risk. The standard screening interval is approximately 12 months. A valid systematic screening tool based on routine information sources is however indispensable, if more selective screening strategies should be developed to target the children at highest risk. *Objective:* To estimate the precision with which Danish schoolchildren at high risk for developing dental caries within 1 year can be identified based on information from routine registers. *Methods:* Based on data from the Danish National Board of Health's Recording System for the Danish Child Dental Services and from the Central Office of Civil Registration, 3705 schoolchildren aged 7–12 years were followed through 1994–1996. Dental health information as of 1994 and changes 1994–1995 were applied in multiple logistic regressions together with social data as of 1995 to estimate the individual 1-year (1995–1996) risk of developing caries. *Results:* In 1995, 37.4% of the children had a DMFS index above 0, and during the following year 21.8% of all children developed new caries. The individual child's 1-year caries risk could be estimated relatively accurately at baseline as indicated by the area (76%) under the receiver operating characteristic curve. About 40% of children with an estimated risk of 20% and above developed new caries, whereas 90% of the rest of the children did not do so. *Conclusion:* Based on information from Danish routine registers children at low caries risk may be identified relatively precisely. This may form the basis for the continuous development and targeting of high-risk strategies, in which the screening for caries among children of estimated low risk may be postponed at least 1 year.

Key words: dental health; predictive validity; schoolchildren; screening

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Submitted 1 October 2004; accepted 21 July 2005

Dental screening programmes for Danish children generally target all children with identical types of service, irrespective of the children's individual caries risk. The choice of a mass preventive approach without taking into account individual caries risk (1, 2) however seems to contrast the fact that only a minority of Danish schoolchildren, 10–15%, have a high-caries experience (3). Moreover, in 2000, 69% of the 5-year-old children and 35% of the 15-year-old teenagers were found never to have experienced any cavitated caries (4). Like in other countries, the Danish caries incidence varies by a series of risk factors, e.g. social background, socioeconomic status and residence (5–9).

In the majority of Danish Public Dental Services (3), the recall interval for schoolchildren is 12 months or less. Until now, this choice of interval has not been based on systematic epidemiological evidence, which will be indispensable for the establishment of a rational basis for a shift from a mass strategy to more selective strategies targeting those most at risk at relevant intervals.

High-risk strategies with differentiated intervals may be hoped to diminish the amount of exposure of low-risk children to dental examinations and intervention and thus also to contribute to cost containment and reallocation of resources to more cost-effective interventions (2, 10). Accordingly, many municipal dental services have individualized their recall intervals according to the actual caries prevalence, so that they vary between 2 and 6 months for children with high-caries prevalence and between 9 and 13 months for children with low prevalence (3). In everyday dental practice, risk estimation is based on the clinical evaluation of the present condition of the individual child by the individual dentist. Social and behavioural observations may exert some less systematic influence (11, 12).

Risk group identification should however not be constrained to the individual dentist's evaluation but rather to systematic forecasts into the future based on scientific documentation. It is not a simple matter to identify relevant target groups, i.e. the high-risk children (2, 13, 14), and their continuous identification demands a stable register with clinical dental and other information. A screening tool of high predictive validity integrated in a systematic, continuous surveillance system will thus be a prerequisite for the development and implementation of a systematic high-risk strategy.

The Danish National Board of Health's Recording System for the Danish Child Dental Services (SCOR) was established as a nation-wide surveillance system in the early 1970s (15) and has since then on a yearly basis provided national, regional and local health service planners with systematic data on the dental health of schoolchildren in whole Denmark, in counties and in municipalities (16, 17). Combined with data from another systematic population information system, e.g. the population register of the Danish Central Office of Civil Registration (CPR), it expectedly may form a relevant basis for the prediction of individual caries incidence, at low marginal cost.

The aim of the present study thus was to estimate the precision (predictive validity) with which schoolchildren at high risk for developing new caries within approximately 12 months may be identified based on information from Danish routine dental and sociodemographic registers, before they develop the new caries, i.e. at the start of the 12 months.

Materials and methods

Study population

In Denmark, every citizen has a unique personal identification number in the CPR. Based on date of birth, 5005 children born during 1982–1987 were identified in the CPR, representing a systematic sample of 31.2% of the total childhood population same age residing in the Municipality of Aarhus as of 1 January 1995. Among these, 3705 (74%) children had complete SCOR information for the years 1994–1996 and were followed for study in the SCOR through 1994–1996.

Data

Data from the CPR included age, gender, family structure, citizenship and status of immigration SCOR information included registration of initial (white-spot lesion with opaque, dull, rough enamel surface; no cavity formation), primary (opaque, rough, mat enamel surface; cavity formation) and secondary (primary caries on a previously restored surface) caries (18) for each tooth surface and for both temporary and permanent teeth, and, furthermore, the defs (decayed, extracted, and filled surfaces for temporary teeth) and DMFS (decayed, missing, and filled surfaces for permanent teeth) indexes (Table 1). In the clinical context, information in the SCOR register is reported, and DMFS/defs are scored, at the beginning of and during the examination of the individual child, before eventual treatment.

Caries incidence was calculated by subtracting the DMFS index or the defs index of 1 year from that of the following year, e.g. DMFS index 1994 from DMFS index 1995. For initial caries, primary and secondary caries, and filled and missing surfaces due to caries, the incidence was calculated according to a number of criteria (19). For example, a 1-year initial caries development (incidence) was registered at a surface, if the surface was caries-free at a given year, and the code for initial caries, primary caries, secondary caries, filling due to

Table 1. Overview of independent variables

Theme	Time specification	Scale type	Source[a]
Demography			
Gender	January 1995	Dichotomy	CPR
Year of birth	January 1995	Ratio	CPR
Social background			
No. of children in household	January 1995	Ratio	CPR
No. of adults in household	January 1995	Ratio	CPR
Danish/non-Danish citizenship	January 1995	Dichotomy	CPR
Previously non-Danish/always Danish citizenship	January 1995	Dichotomy	CPR
Dental health			
No. of surfaces with initial caries			
Occlusal surfaces	1995, 1994–1995[b]	Ratio	SCOR
Approximate and smooth surfaces	1995, 1994–1995[b]	Ratio	SCOR
All surfaces	1995, 1994–1995[b]	Ratio	SCOR
No. of surfaces with primary and secondary caries			
Occlusal surfaces	1995, 1994–1995[b]	Ratio	SCOR
Approximate and smooth surfaces	1995, 1994–1995[b]	Ratio	SCOR
All surfaces	1995, 1994–1995[b]	Ratio	SCOR
No. of filled surfaces			
Occlusal surfaces	1995, 1994–1995[b]	Ratio	SCOR
Approximate and smooth surfaces	1995, 1994–1995[b]	Ratio	SCOR
All surfaces	1995, 1994–1995[b]	Ratio	SCOR
No. of surfaces missing due to caries			
Occlusal surfaces	1995, 1994–1995[b]	Ratio	SCOR
Approximate and smooth surfaces	1995, 1994–1995[b]	Ratio	SCOR
All surfaces	1995, 1994–1995[b]	Ratio	SCOR
No. of decayed, missing and filled surfaces			
Temporary dentition (defs)	1995, 1994–1995[b]	Ratio	SCOR
Permanent dentition (DMFS)	1995, 1994–1995[b]	Ratio	SCOR
Severity zone			
Temporary dentition	1995, 1994–1995[b]	Ordinal[c]	SCOR
Permanent dentition	1995, 1994–1995[b]	Ordinal[c]	SCOR

[a]CPR: The register of the Danish Central Office of Civil Registration. SCOR: The Recording System for the Danish Child Dental Services located at the National Board of Health. Severity Zone: Zone 1: Caries free teeth; Zone 2: Fissure caries on occlusal or smooth surfaces; Zone 3: Approximal caries; Zone 4: Caries on smooth surfaces (18).
[b]Incidence.
[c]Dichotomization for analysis: see Table 2.

caries, endodontic treatment, missing due to caries, or chronic caries (arrested caries lesion, where the enamel surface is hard, smooth and often discoloured) (18) was registered the following year.

Statistical analysis

Applying sociodemographic information from 1995 and dental health information concerning 1994–1995 as baseline data, the aim of the statistical analysis was to (i) identify mutually corrected predictors of new caries occurring during 1995–1996 and (ii), based on this, to estimate the probability of the individual child to develop new caries during that period. The analysis included bivariate Pearson's chi-square and odds ratio (OR) estimation and multiple logistic regression. After derivation of additional variables by dichotomization also of continuous variables in order to optimize the final model fit, the number of candidate predictors was about 180. The predictor population was reduced in the regression by use of forward selection of variables. The chi-square-distributed −2 ln(likelihood ratio) was applied as test for inclusion of variables and $P < 0.05$ selected as general level of significance. Model fit was estimated by the Hosmer–Lemeshow test. The individual 1-year caries probability $E(P)$ was estimated as:

$$E(P) = \frac{R}{1 + R}$$

where R denotes the multiple risk achieved by multiplication of logistic regression model coefficients. Considering the estimated caries probability $E(P)$ as a continuously distributed caries-predictive test, standard predictive criterion validity parameters (agreement, sensitivity, specificity, positive and negative predictive values) were estimated for each of a series of cut-points. A receiver operating characteristic (ROC) curve was used to illustrate the association between stratum-specific sensitivities and specificities (20).

Permissions

The study was approved by the Danish National Board of Health and the Public Dental Health of Aarhus.

Results

Demographic and social characteristic

Among the 3705 enrolled children 48.7% were girls and 51.2% boys. The average age was 9 years (range, 7–12 years), and most (79.8%) lived with more than one adult; 21.1% were only children in the households; 92.6% were Danish citizens and 7.4% had other citizenship.

Dental health

Average DMFS scores as of 1994, 1995 and 1996 were 0.9, 1.2 and 1.5, respectively (defs scores, 3.7, 3.2 and 2.5). DMFS or defs scores above zero were registered for 66.5%, 68.4% and 67.4% in 1994, 1995 and 1996, respectively. In 19.6% of the children the DMFS score increased during 1994–1995 and in 21.8% during 1995–1996. In 1994, 1995 and 1996 the prevalence of children with at least one surface with initial caries was 52.2%, 49.1% and 51.1%, respectively.

Prediction of caries incidence

By multiple logistic regression, a 1-year (1995–1996) DMFS increase was found to be positively associated with 1994–1995 defs increase and with having one surface or more with initial caries in 1995, whereas it was negatively associated with a 1994–1995 increase in DMFS (Table 2). Children born in 1982 had higher risk (OR = 1.75, $P < 0.001$) than younger children, i.e. children born in 1986 and 1987. Moreover, 1995–1996 DMFS increase was negatively associated with a combination of more than one child in the household and the child having a defs increase in 1994–1995.

Precision of prediction of caries incidence

One-year incident caries probabilities were estimated (Fig. 1) based on the regression model of

Table 2. DMFS increase 1995–1996 by dental health 1994–1995, family constitution and year of birth among 3705 schoolchildren (Aarhus, Denmark, 2002)

		DMFS increase 1995–1996		
Dental health	Children, *n* (%)	%	OR[a]	OR[b]
Dental health change 1994–1995				
DMFS increase 1994–1995 (DMFS points)	–	–	–	0.87**[c]
Defs increase 1994–1995 and >1 child in household	664 (17.9)	18.2	0.8*	0.63***
Dental health 1995				
Defs >0	1840 (49.7)	24.8	1.4***	1.46***
DMFS >0	1387 (37.4)	37.0	4.0***	2.30***
>0 surfaces with initial caries	1820 (49.1)	30.7	2.90***	1.44**
>1 surfaces with initial caries	1474 (39.8)	31.0	2.40***	1.26*
>0 occlusal surfaces with initial caries	1276 (34.4)	33.5	2.67***	1.34*
>1 occlusal surfaces with initial caries	616 (16.6)	38.5	2.75***	1.45**
Primary/secondary caries: surfaces, no.	–	–	–	3.50**[c]
Primary/secondary caries: surfaces, %	–	–	–	0.30**[c]
Filled approximal or smooth surfaces, no.	–	–	–	0.50[d]**
Filled approximal or smooth surfaces, %	–	–	–	1.19**[c]
Filled approximal or smooth surfaces, >2	930 (25.1)	33.0	2.2***	1.97***
Severity zone (permanent dentition): >2	384 (10.4)	46.1	3.6***	1.60***
Year of birth				
1987	646 (17.4)	12.4	0.45***	0.62***
1986	637 (17.2)	14.6	0.56***	0.64***
1982	542 (14.6)	35.2	2.24***	1.75***

[a]Bivariate ORs. Only ORs, which were significant ($P \leq 0.05$) in the final multivariate model, are shown.
[b]Significant ORs from multiple logistic regression; model fit, $P = 0.05$. Initial predictor set: parameters of dental health 1995 and dental health change 1994–1995; age; gender; immigration; family constitution. Regression.
[c]Per DMFS point, per surface or per percent.
[d]Per three filled surfaces.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

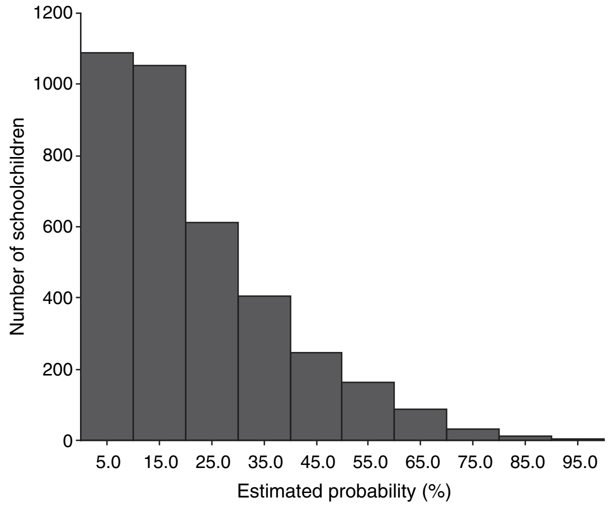

Fig. 1. Frequency distribution of the estimated probability* of DMFS increase 1995–1996 among 3705 schoolchildren (Aarhus, Denmark, 2002). *Based on multiple logistic regression. Model: see Table 2, last column.

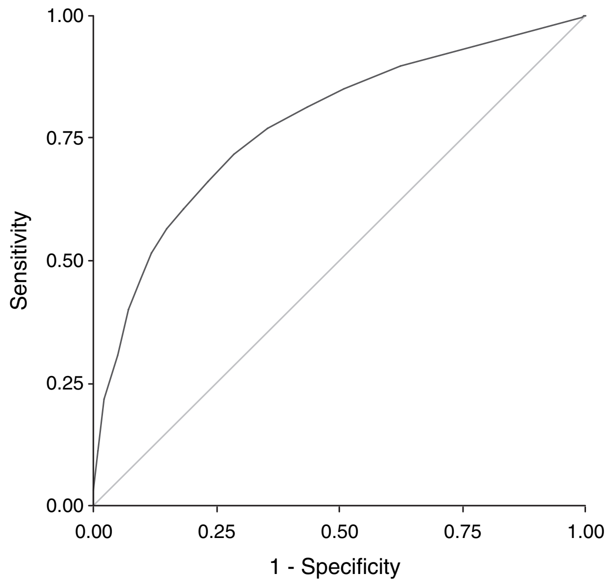

Fig. 2. Receiver operating characteristics (ROC) curve indicating predictive test characteristics* of the estimated probability† of DMFS-increase 1995–1996 among 3705 schoolchildren (Aarhus, Denmark, 2002). *Area under the curve: 76% (95% CI, 75–78%). †Based on multiple logistic regression. Model: see Table 2, last column.

Table 2, last column. The accuracy of the prediction of a DMFS increase was illustrated by an area of more than three-fourth under the ROC curve (Fig. 2).

At cut-point 20%, 57.8% of the children had a negative test (Table 3). The predictive value of a negative test was 90.3%, so that the lack of caries development was correctly estimated in 1933 out of 2140 children (Table 3), whereas the rest (207; 9.7%) of these children actually did develop caries. Furthermore, at cut-point 20%, 1565 children (42.2%) were test positive and thus identified as members of the high-risk group, in which as many as 602 (38.5%) developed caries, corresponding to three-fourth of all cases of new caries (Table 3).

Alternatively, above cut-point 10%, 29.4% would be test negative with 94.6% being correctly estimated as caries-free during the following approximately 12 months, whereas in the high-risk group (70.6% of all children) 28.7% developed caries, constituting 92.7% of all new cases.

Discussion

We found that caries incidence could be predicted relatively precisely based on demographic, social and dental health information from a routine dental screening system in combination with data from the sociodemographic population register. As prediction was based on existing data sources in Denmark, it seems to have left room for a future development aiming at the construction of a clinical decision-sustaining tool for use in everyday preventive dentistry and for dental screening programme calibration.

One could have hoped for further precision based on a J-shaped or U-shaped estimated probability distribution with few intermediate observations, allowing for clear separation of children at high risk from those at low risk. Such a clear picture however turned out not to be within reach (Fig. 1), and the present estimated probability distribution thus illustrates the ambiguity often inherent in the choice of cut-point when dealing with continuous criterion validity tests: focussing on higher sensitivities leads to gradual lowering of specificities and corresponding increasing sizes of identified risk groups.

Accepting to screen those 70% at highest risk every year – and the rest of the childhood population of corresponding age every other year – will however reduce resource consumption considerably and at the same time allow for identification of about 94 of 100 cases of incident caries (Table 3). The inevitable corresponding cost in terms of false negatives will then amount to about five of hundred cases of actual caries, which will remain undetected in the programme as such. This involves a risk of more profound caries lesions in these children. Differentiation of recall intervals thus may create a demand for continued yearly

Table 3. Predictive criterion validity parameters at selected cut-points of the estimated probability[a] of DMFS-increase 1995–1996 among 3705 schoolchildren (Aarhus, Denmark, 2002)

Estimated probability of DMFS increase: cut-point[b]	Test positive	Test negative	Agreement	Sensitivity	Specificity	PPV	PNV
5	90.9	9.1	30.5	99.0	11.3	23.8	97.6
10	70.6	29.4	48.0	92.7	35.5	28.7	94.6
15	53.6	46.4	60.9	83.2	54.6	33.9	92.1
20	42.2	57.8	68.4	74.4	66.7	38.5	90.3
25	32.4	67.6	72.9	62.2	75.9	41.9	87.8
30	26.5	73.5	74.6	52.7	80.8	43.3	85.9
35	20.6	79.4	76.2	42.6	85.6	45.3	84.2
40	15.5	84.4	77.3	33.6	89.5	47.2	82.8
45	11.7	88.3	78.2	26.8	92.6	50.2	81.9
50	7.5	92.5	79.8	21.4	96.5	63.4	81.2

PPV, predictive value of a positive test; PNV, predictive value of a negative test.
[a]Based on multiple logistic regression. Model: see Table 1.
[b]Observations above (higher probability) a cut-point are considered test positive; observations below (lower probability) a cut-point are test negative.

screening among the parents of the children estimated at low risk. Information and advice to both children and parents will be of crucial importance.

If a more concentrated high-risk group is aimed at, e.g. to constitute less than 50% of the population, the number of false negatives will increase. Table 3 illustrates these relations by selected cut-points of increasing estimated probability, indicating the changing balance between considerations of different nature, which have to be mutually weighted when deciding for a programme profile. Increasing precision in order to reduce the ethical dilemmas seems to demand further information, e.g. on oral hygienic behaviour, which is however not available at present from the routine registers applied.

Carrying on screening the whole population every year will approach a goal of 100% sensitivity, whereas, by definition, the specificity will be zero (all are considered at risk), and there will be no room for re-allocation of resources to services, which may be more effective in terms of, e.g. caries prevention. In other Scandinavian countries recall intervals vary between 13 and 17 months (3, 10, 21). Auxiliaries are widely used as routine examiners apparently without negative consequence for the children's dental health (22, 23), and this may form an additional strategic source for cost containment.

Although the main aim was as precisely as possible to identify children who would experience new caries, the intermediate procedure includes the choice of a multivariate regression model with inferable coefficients. Not surprising, the overall picture is that those children, who already have experienced caries, also are at highest risk, as indicated by the association with increasing prevalent defs and DMFS values. Contrasting this, lower caries incidence 1995–1996 was found, when DMFS had increased the year before. A possible explanation could be that preceding caries experience may have introduced changes in health behaviour, e.g. paying more attention to oral hygiene and to healthy diet habits, so that the caries experience in itself resulted in a more preventive behaviour. This may have been sustained by advice given by the dentist performing the routine oral examination.

In the present study, a few sociodemographic variables contributed significantly to the final regression model (Table 2). Previously published studies have found significant associations with, e.g. parents educational and economical status (9), and more detailed socioeconomic information may contribute to the accuracy of prediction. Such information is available from Danish population registers, which are however not as readily accessible at low cost as those applied in the present context. The found association of DMFS increase by year of birth is probably due to the fact that the number of dental surfaces increases with age and, accordingly, such association has been found also in previously published studies (7, 24).

Based on economic (cost containment) and clinical (limitation of exposure to the risk of unnecessary curative intervention) considerations there seems to be good reason to develop high-risk screening strategies with differentiated screening intervals. Once data have been collected and retrieved and the statistical analysis performed, individual risk estimation is fairly simple based on coefficients from multiple regressions. The route to application as a technology for everyday clinical and managerial purposes is thus rather straightaway. It should however be noted that empirical estimates will be more or less time-, place- and population-specific but less so than the individual dentist's clinical estimation of the child's individual caries risk. Consequently, data collection and risk estimation should be repeated at regular intervals in the target population. Moreover, systematic individual risk estimation to sustain the clinical risk estimation should be considered a rather potent technology, which will demand health technology assessment.

Finally, it should be noted that the child dental health system in Denmark with its integrated screening system is comparatively highly developed. There thus rests a research need to focus on the precision of prediction which can be obtained when based on less developed information systems.

Conclusion

Data from Danish routine demographic, social and dental health registers may be combined to form the basis for the development of a prescreening tool aiming at the fairly accurate identification of children at high and low caries risk. Consequently, recall intervals for children at low risk rather safely may be extended from 1 to 2 years, resulting in an extensive reduction of the number of yearly examinations without considerable concurrent negative impact on the detection of caries in schoolchild populations.

Acknowledgements

Dr Bente Nyvad, Associate Professor, The Royal Dental College, University of Aarhus, Denmark, is acknowledged for scientific and clinical counselling.

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