A multilevel analysis in dental caries of Italian 12-year-old children

Giuliana Solinas[1] , Giovanni Sotgiu[1], Carmelo Maida[2], Laura Sthromenger[3], Paolo Castiglia[1]

[1] Epidemiology and Biostatistic Unit, Hygiene and Preventive Medicine Institute, University of Sassari, Italy
[2] Dental Institute, University of Sassari, Italy
[3] WHO Collaboration Centre for Epidemiology and Community dentistry of Milan

Corresponding Author:
Giuliana Solinas
Epidemiology and Biostatistic Unit, Hygiene and Preventive Medicine Institute, University of Sassari, Italy
Via Padre Manzella, 4 - 07100 Sassari (Italy)
Tel. +39 079 229959 - Fax +39 079 228540
E-mail: gsolinas@uniss.it

The prevalence of caries is high worldwide and because of its pattern, among 12-year old children it has been defined pandemic [1]. Moreover, caries disease shows high variability among countries, regions within countries, areas within regions and within social and ethnic groups [2]. Several caries determinants have been well identified, as poor oral hygiene and dietary habits, nursing habits (for instance, bottle-feeding, use of pacifier at night), socio-economic factors, life-style and environmental factors and missed implementation of preventive oral health interventions (i.e. fluoride supplementation) [3].

However, the tendency for the disease to cluster has raised new questions about other determinants of the disease concerning, in particular, poverty [4-9] and inequalities [10]. This may explain why dental caries is the most prevalent oral disease in low income countries [11]. In fact, the prevalence and severity of the disease are linked to socioeconomic status across all age groups [12-13].

In the last three decades it has been shown that the prevalence of caries in children living in industrialized countries gradually decreased [14-16], but its proportion remains elevated in disadvantaged communities [17-18]. In fact, epidemiological studies carried out in different Western countries, Sweden [19-20], Denmark [21-22], Great Britain [23], Germany [24] reported a poorer oral health status of children and adolescents belonging to ethnic minorities and coming from foreign countries than that of the general population [25]; distinct risk profiles associated to living conditions, lifestyles, environmental factors, access to care, parent's education, socioeconomic position and oral hygiene have been described [26]. Notwithstanding, only a few published data concerning social differences in dental health have been reported until now In Italy [27-32].

A population comprehensive indicator of dental health status (decayed, missing, and filled teeth, DMFT), particularly useful among children, has been identified in order to assess the caries experience. Its reliability was proved in different circumstances: the lower the index, the better the dental health of the population [33].

In a recent survey conducted in Italy on 12-year-old children [34], DMFT resulted close to the global goal set by the World Health Organization for the year 2010 (DMFT ≤1).

Nevertheless, notwithstanding the unequal geographical distribution of the disease, with higher scores in Southern Italy, it was hypothesized that the social context, identified as the community risk of acquiring caries, could affects caries experience in 12-year old children.

Aim of this study was to examine the role of both individual characteristics and community factors among 12-year old children in Italy and then investigate their contribution to the DMFT variability in different Italian areas.

Materials and methods

Data were obtained from an Italian pathfinder survey on oral health in 12-year old children [34]. The design

of the study was approved by the Research Ethics Committee of the University of Milan in December 2003. Children were enrolled as participants only with their parent's signed consent. The original sample consisted of 5 342 individuals chosen from each Italian section and stratified according to the National Institute of Statistics [35]. A full description of the adopted methods in the survey was described elsewhere [34]. The survey included dental examinations performed according WHO's guidelines [36]. It was measured the number of decayed missing or filled teeth per child with decay experience, expressed by DMFT index [37]. Parents of the sampled children were asked to compile a self-administrated questionnaire on demographic characteristics and oral health behaviours. Data on oral status were collected during dental check-up by trained and calibrated examiners; details on methodology of training and calibration of all examiners has been discussed in [38].

Since items with missing values for individual characteristics were excluded from analysis, the present study included only 3 199 children whose parents have entirely filled out the questionnaire. The overall effect of discharging subjects with missing data was a loss of participants with slight worst oral health conditions, shifting the DMFT mean value from 1.09 [34] to 1.08. Descriptive statistics (means, standard deviations, 25th percentile, median, 75th percentile) were used to show the distribution of DMFT in each Italian section. Association between DMFT and individual characteristics were evaluated using analysis of variance (ANOVA) at the 5% level of significance.

Since the individual risk of caries cannot be evaluated without keeping into account the community context, we considered a multilevel regression model for the case involving two levels of analysis, assuming that individual observations (level 1) are nested within Italian area (level 2).

As regard the individual characteristics obtained by the questionnaire, for the multilevel analysis were considered as predictors variables of the outcome (DMFT index) only those variables which in the bivariate analysis presented a statistical significant association ($p<0.05$) with DMFT. These variables are: gender (boy, coded 0; girl, coded 1) type of drinking water (mineral water, coded as 1; tap water, coded as 2, spring water, coded as 3), intake of sweet food (never, coded as 0; once a week, coded as 1; more than once a week, coded as 2; once a day, coded as 3; more than once a day, coded as 4); sweet drinks before sleeping (nothing, coded as 0; milk, coded as 1; soft drink, coded as 2; milk and sugar, coded as 3); supply of fluoride (no, coded 0; yes, coded 1); frequency of toothbrushing (less than once a day, coded as 0; equal or more than once a day, coded as 1). Since the information on mother's and father's educational level was obtained from the questionnaire, these are considered as predictor variables at individual level. These variables were coded considering the OECD classification [39] (low level, including primary and middle secondary school, coded as 1; medium level, including upper secondary school, coded as 2; high level, including academic education, coded as 3). Beside these variables, we considered the community variables, obtained by ISTAT grouped in 5 Italian sections: average income (euros), area of dwelling per person (m^2), unemployment rate (%). Also, the number of dentists (per 10 000 residents) was used to represent access to dental health care.

Using the label "*DMFT*" instead of label "*y*" of the response variable, the two level model can be simply specified as two inter-related equations,

$$\boldsymbol{DMFT_{ij}} = \beta_{0j} + \boldsymbol{e_{ij}} \quad (1)$$

$$\beta_{0j} = \beta_0 + \mu_j \quad (2)$$

where equation (1) pertains to individuals: the DMFT, response variable for the *i*th child in the unit *j*, is a function of the mean level of dental health in each of the *j* units (β_{0j}) plus a residual error term (e_{ij}) at level 1 between individuals within areas.

Equation 2 pertains to area sections: the response (β_{0j}), the mean level of dental health in unit *j* is a function of the overall mean level of dental health across all units (β_0) plus a residual at level 2 between areas (μ_j).

The two equations can be combined into an overall multilevel model:

$$\boldsymbol{DMFT_{ij}} = \beta_0 + (\mu_j + \boldsymbol{e_{ij}}) \quad (3)$$

The equation (3), the so called null-model, contains no independent variables, and the DMFT of a child depends only on the mean level of all children in all Italian areas (β_0) and on a differential for each area (μ_j) and for each child (e_{ij}). These two differentials are treated as random variables (indicated by the brackets) and their variability is summarized by two variances, σ^2_{μ} (residual variance among Italian areas) and σ^2_e (residual variance among individuals). Consequently, individual

DMFT is summarized in three parameters: the overall mean, the between-area variance and the within-area variance between-individual.

Starting from the null model of Equation (3) which simply allows the variance to be separated into each level, we have extended the model to include independent variables (***X***) for both individuals (model 2) and areas (model 3). In this study, the final model is

$$DMFT_{ij} = \beta_0 + \beta X_{ij} + (\mu_j + e_{ij}) \quad (4)$$

where the parameters β assess the relationships between dental health, individual and community variables across all area sections.

The multilevel models were constructed with the GLLAMM (Generalized Linear Latent and Mixed Model) command [40] running in STATA software (StataCorp LP, College Station, TX).

In order to analyse whether the addition of an independent variable X improves the fit of the model with its precedent, we used the difference in the log likelihood values or the deviance to test it, with a chi-squared distribution and the degrees of freedom equal to the number of additional parameters [41].

Results

On 3 199 children, 1 653 were girls (51.7%) and 1 546 were boys (48.3%). Caries experience was detected in 40.9%, with a girl:boy ratio of 1.2:1. As reported in Figure 1, girls were overrepresented in groups with the highest DMFT; in particular, DMFT>4 was identified in 7.5% girls and 4.2% boys. Overall, DMFT was 1.08 (1.69): girls 1.2 (1.8) *vs* boys 0.9 (1.6), p=0.001, with an heterogeneous distribution by Italian areas (Fig. 2), ranging from 0.85 in the major Islands to the highest values in the Southern sections (1.56). The distribution of the individual and community variables is described in Tables 1 and 2, respectively. Table 3 reports the descriptive statistics of DMFT by individual characteristics.

The association between individual characteristics and DMFT index was significant, except for months of breastfeeding and use of toothbrush (p>0.05).

The results of the multilevel analysis are shown in Tab. 4. The null model intercept gives the mean of DMFT for an individual. The results in model 1 indicate that there is a large variability in DMFT at individual level (σ^2_e = 2.84, p<0.001) and far less at the area level (σ^2_μ 0.04, p<0.001). Therefore, the variation between areas, 1.4% of the total variance, was much smaller than the variability at the individual level (98.6%), nevertheless it was statistically significant (p<0.01).

Only 5.98% [100•(2.84-2.67)/2-84] of the individual level variance in DMFT was explained by individual variables. Gender inequality on DMFT has indicated that girls have a significantly higher mean DMFT value than boys (b=0.20, p=0.001). Furthermore, children who eat sweet food frequently and drink sweet beverages (for instance, milk and sugar) before sleeping had a significantly higher mean DMFT (b = 0.09, p = 0.003; b = 0.06, p = 0.03, respectively). Dental hygiene and preventive interventions, like toothbrushing habits ≥2 times a day and supply of fluoride were significantly associated with a decrease in DMFT (b = -0.21, p =

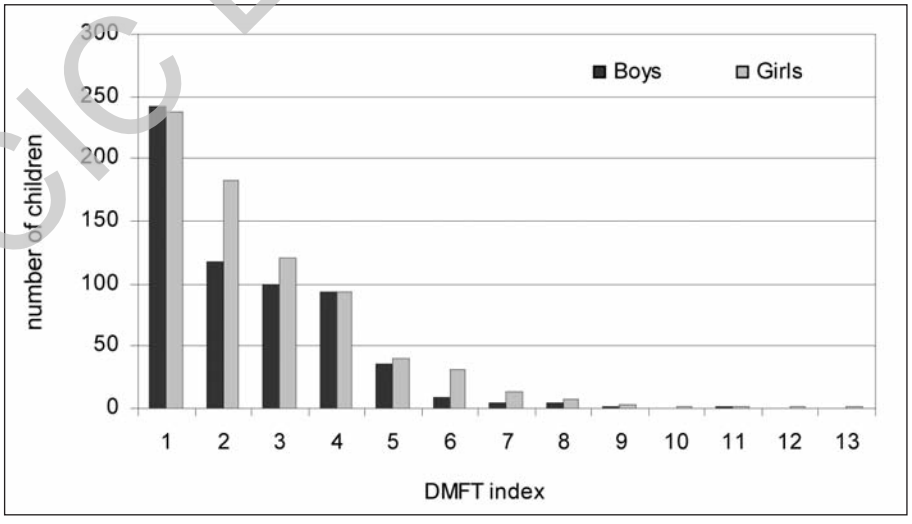

Figure 1. Distribution of DMFT in 12 year-old children with DMFT>0

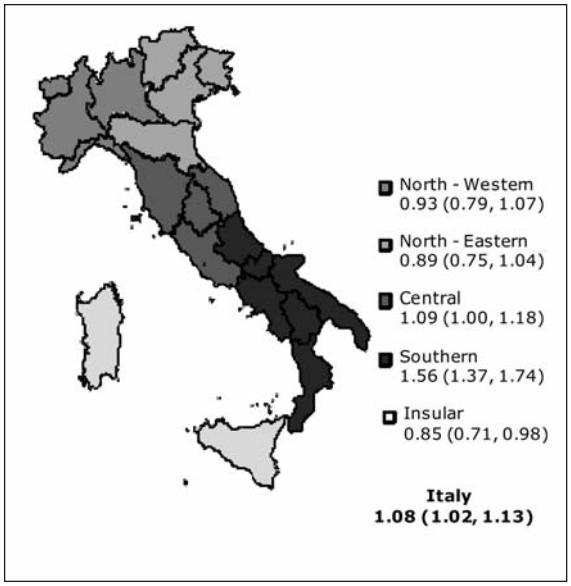

Figure 2. Mean of DMFT in Italian areas (95% CIs in brackets)

0.001; b = -0.15, p = 0.015, respectively). Higher education levels of father and mother contributed to DMFT decrease (b = -0.28, p<0.001; b = -0.37, p<0.001, respectively).

Every community variable was associated to the DMFT except the number of dentists (r=-0.001, p=0.99) that, consequently, was excluded from the model.

In Model 3 the unexplained variation reduction of DMFT between areas was estimated. It was found that 97.3% of DMFT variance by section-areas was explained by community variables. The variances at the individual and area levels were 2.67 and 0.004, respectively. Only the area of dwelling per person significantly contributed to DMFT decrease (b=-0.09, p=0.001).

Conclusions

This study confirms that several individual characteristics play a role in the variability of the DMFT. In fact, their inclusion in the second model leads, not surprisingly, to a reduction in residual variance between individuals (σ^2_e). Moreover, the inclusion of community variables in the model 3 leads to a change in the residual variance between Italian areas (σ^2_μ).

Considering the predictors of caries experience, the improvement of toothbrushing habits contributed to a reduction of DMFT from 3 to 1.0 in several countries strengthended by fluoride effect in toothpastes or other topical applications. This was confirmed by our study

Table 1. MDistribution of individual characteristics of 12-year-old children.

Individual characteristics	n	%
Gender		
Boy	1 546	48.3
Girl	1 653	51.7
Breastfeeding (months)		
<4	1 216	38.0
4-6	904	28.3
>6	1 079	33.7
Type of drinking water		
plain water	527	16.5
mineral water	2 403	75.1
spring water	269	8.4
Intake of sweet foods		
Never	41	1.3
Once/week	303	9.5
>Once/week	854	26.7
Once/day	1 642	41.9
>Once/day	659	20.6
Sweet beverages before sleeping		
Nothing	2 908	90.9
Milk	183	5.7
Soft drink	61	1.9
Milk and sugar	47	1.5
Intake of fluoride		
No	1 233	38.5
Yes	1 966	61.5
Frequency of toothbrushing		
<Once/day	1 203	37.6
≥Once/day	1 996	62.4
Education level of father		
Low	162	5.1
Medium	1 054	33.9
High	1 953	61.0
Education level of mother		
Low	161	5.0
Medium	1 001	31.3
High	2 037	63.7

Table 2. Descriptive characteristics of community variables for five Italian areas.

Community variables	Mean (SD)
Average income (10 000 €)	2.8 (0.3)
Area of dwelling per person (m^2)	36.9 (2.6)
Unemployment rate (%)	7.5 (3.7)
Number of dentists per 10 000 residents	18.5 (1.2)

Table 3. Statistics of DMFT in 12-year-old children

	DMFT			
		Percentile		
Characteristics	Mean (SD)	25th	50th	75th
Gender ***				
Boy	0.9 (1.6)	0	0	1
Girl	1.2 (1.8)	0	0	2
Breastfeeding (months)				
<4	1.1 (1.7)	0	0	2
4-6	1.1 (1.7)	0	0	2
>6	1.0 (1.6)	0	0	2
Type of drinking water *				
mineral water	1.1 (1.7)	0	0	2
plain water	0.9 (1.5)	0	0	1
spring water	1.3 (1.8)	0	0	2
Intake of sweet foods *				
Never	1.2 (1.8)	0	0	2
Once/week	0.9 (1.5)	0	0	1
>Once/week	1.0 (1.6)	0	0	2
Once/day	1.1 (1.7)	0	0	2
>Once/day	1.2 (1.8)	0	0	2
Sweet beverages before sleeping ***				
Nothing	1.0 (1.7)	0	0	2
Milk	1.5 (1.9)	0	1	3
Soft drink	1.1 (1.7)	0	0	2
Milk and sugar	2 (2.4)	0	1	4
Supply of fluoride **				
No	1.2 (1.8)	0	0	2
Yes	0.9 (1.6)	0	0	1
Frequency of toothbrushing***				
<Once/day	1.3 (1.9)	0	0	2
≥Once/day	0.9 (1.6)	0	0	1
Father's education level ***				
low	2.1 (2.2)	0	1	4
medium	1.3 (1.8)	0	0	2
high	0.9 (1.5)	0	0	1
Mother's education level ***				
low	2.2 (2.2)	0	2	4
medium	1.4 (1.8)	0	0	2
high	0.8 (1.5)	0	0	1

** p<0.05, ** p<0.01, ***p<0.001, p-value is from ANOVA*

where the daily use of toothbrushing is inversely associated with caries experience as the fluoride supply. While the intake of sweet food and sweet drinks before sleeping seems to contribute to the increase of DMFT. Moreover, the parents' educational level was highly associated to a low DMFT, in particular that of the father. This characteristic, although classified in the present study as individual one, since it was obtained from the questionnaire, reflects a social context.

Inequality in dental health was associated to gender: a positive regression coefficient for girls indicates the need of equitable interventions among children. This results suggest to better investigate on this characteristic which may imply social features with equitable consequences.

Overall, this study highlights that caries experience of Italian 12-year old children is low if compared to other European countries where, on the other hand, better organized public oral health services for children and adolescents are in place [42]. In particular, as regard community context, the number of dentists resulted non correlated to DMFT, implying a limited role of dental ser-

Table 4. Multilevel estimates for models of DMFT index: regression coefficients and standard errors.

	Model 1		Model 2		Model 3	
	b	SE	b	SE	b	SE
Intercept	1.19***	0.04	2.25***	0.24	9.66**	2.94
Individual variables						
Gender (girl)			0.20	0.06**	0.20	0.06**
Type of drinking water			0.11	0.06	0.10	0.06
Intake of sweet foods			0.09	0.03***	0.09	0.03**
Drink before sleeping			0.06	0.03*	0.06	0.03*
Intake of fluoride			-0.15	0.06*	-0.15	0.06*
Frequency of toothbrushing (daily)			-0.21	0.06**	-0.21	0.06**
Father's educational level			-0.28	0.06***	-0.27	0.06***
Mother's educational level			-0.37	0.06**	-0.37	0.06**
Community variables						
Average income (euros)					-0.0001	0.001
Area of dwelling per person (m^2)					-0.09	0.03**
Unemployment rate					-0.13	0.07
Random effect						
Individual level variance (σ^2_e)	2.84	0.07	2.67	0.07	2.67	0.07
Area level variance (σ^2_μ)	0.04	0.01	0.15	0.06	0.004	0.01

*Significant at the level: *p<0.05; **p<0.01; ***p<0.001*

vices in preventing caries in our Country.

Based upon the results of this study, there is the suggestion that beside individual characteristics also the social, i.e. community context, may influence DMFT in Italy. Further research, using other direct indicators of social background, is then needed to elucidate the mechanisms by which the social context affects dental caries.

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