Community Dental Health (2010) **27,** 102–108
Received 16 October 2007; Accepted 9 November 2008

doi:10.1922/CDH_2383Narbutaite07

Caries experience and oral health behaviour among 11 – 13-year-olds: an ecological study of data from 27 European countries, Israel, Canada and USA

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Objective: This study is a part of the cross-national survey on health behaviour in school-aged children (HBSC) – World Health Organization Collaborative Study. The aim was to compare the HBSC data on frequency of toothbrushing, consumption of sweets, soft drinks, fruits and vegetables among 11–13-year-old children in different countries and to estimate the relation of these factors with caries experience at the country level. ***Methods***: Oral health behaviour patterns were assessed from the HBSC survey conducted in the 2001-2002 school year in 27 countries in Europe, Israel, Canada, and the USA. ***Participants***: Representative samples of 11- and 13-year-old schoolchildren were drawn from participating countries and aggregated by the direct age standardisation method. DMFT of 12-year-olds was collected from the international data banks and recent publications. Statistical analysis was performed using multiple linear regression. ***Results***: The most significant factor related with the cross-regional variation of DMFT was the proportion of children who reported regular toothbrushing; it explained 26.3% of the DMFT variation. Low rates of regular toothbrushing and high rates of sweets consumption were related with higher DMFT while high rates of drinking of soft drinks were related with lower DMFT. Consumption of fruits and vegetables had no significant impact. Altogether, factors of this model explained 51.2% of the total DMFT variation across countries. ***Conclusion***: The findings of the study demonstrate that different oral health behaviour profiles among young people across European countries, Israel, Canada, and the USA significantly contribute to the variation in caries experience.

Key words: Children, dental caries, diet, DMFT, toothbrushing.

Introduction

Dental caries is still a major oral health problem in most industrialised countries, affecting 60-90% of schoolchildren and the vast majority of adults (Petersen, 2005).

Poor oral hygiene, frequent and abundant consumption of sugars have been known for many years to play a key role as a behavioural risk factor for oral diseases, such as dental caries and periodontal disease (Touger–Decker and van Loveren, 2003). Toothbrushing less than twice daily and snacking between meals have been identified as key behaviours explaining the presence of dental caries in children (Harris *et al*., 2004). There is evidence to show that good oral hygiene can offset the effects of sugar on dental health (König and Navia, 1995).

The consumption of sweets and soft drinks, containing a lot of free sugar, compete with the intake of more nutritious foods by children. Moreover, it has been found that sugar-sweetened food, rich in energy but low in nutrients, is a most important risk factor in the development of obesity (Gillis and Bar–Or, 2003). Soft drinks may cause dental erosion (Jensdottir *et al*., 2006). Children are more likely than adults to have such unhealthy diets, and thus are at greater risk of dental caries, erosion and obesity (American Dietetic Association, 2003).

An abundant and regular intake of fruits and vegetables initiated during early childhood decreases the risk of developing degenerative chronic diseases, such as cardiovascular diseases and cancer (WHO, 2003). They are important sources of vitamins and minerals, essential to maintain healthy oral mucous membrane and bones (American Dietetic Association, 2003). Raw vegetables, such as carrots and cabbage, as well as wholegrain foods require more mastication, thereby stimulating increased saliva flow. Citrus fruits are known to stimulate saliva production (DePaola *et al*., 1999).

Oral hygiene and dietary advice are very important in the development of effective oral health education programmes and in clinical practice targeted at young people. Those oral health behaviours developed in early childhood may directly or indirectly have an impact on their health in the short or long term and on lifestyle as well. Therefore, these habits should be studied more extensively in the context of broader behavioural patterns, so as to provide a better empirical basis for prevention (Koivusilta *et al*., 2003; Petersen 2005).

The Health Behaviour in School-aged Children (HBSC) is a unique cross-national study conducted in collaboration with the WHO Regional Office for Europe. Its aim is to gain new insight into and to increase understanding of young people's health, well-being, health behaviour and social context (Currie *et al*., 2004).

In this article, we aimed to compare the HBSC data on frequency of toothbrushing, consumption of sweets,

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soft drinks, fruits and vegetables among 11-13-year-old children in European and North American countries and Israel, and to estimate the relationship between these factors with caries experience at the country level.

Methods

This study is a part of the cross-national HBSC study (Currie *et al*., 2004). The HBSC school-based surveys used standardized sampling methods, data collection procedures, and measurements previously described.

The present data were obtained from 27 countries of Europe, Israel, Canada, and the USA participating in the HBSC 2001-2002 year survey among 11 and 13-year-olds. Because Belgium was represented by two regions (Flemish and French speaking) and UK by three regions (England, Scotland and Wales) analysis includes in total 33 regions. The list of countries or regions and number of participating schoolchildren is presented in Table 1.

Instruments and measures

The survey instrument was an anonymous standardized questionnaire, which included structured questions followed by response alternatives. Questions about oral health behaviour were analysed. The rate of missing answers to every question was less than 0.6%.

Table 1. Numbers of respondents, toothbrushing and eating behaviour patterns (%) by country or region, 11-13-year-olds, HBSC survey in the 2001-2002 school year.

Country or region	*n*[1]	*Toothbrushing*[2]	*Fruits*[3]	*Vegetables*[4]	*Sweets*[5]	*Soft drinks*[6]
Austria	3089	71.05	43.05	18.20	21.80	17.80
Belgium Flem[a]	4259	47.25	28.55	52.25	27.95	36.25
Belgium Fren[b]	2942	50.10	40.55	44.20	41.10	36.30
Canada	3154	70.25	41.05	42.45	21.95	20.50
Croatia	2931	51.55	38.80	28.45	35.20	32.15
Czech Republic	3352	65.45	45.10	29.20	25.10	27.55
Denmark	3218	77.60	34.65	30.30	11.65	9.30
England	4269	73.10	27.70	28.20	31.05	37.40
Estonia	2709	55.85	22.05	17.60	30.40	10.65
Finland	3607	39.95	22.20	21.95	8.85	7.30
France[c]	5571	61.45	36.75	46.05	28.20	28.65
Germany[d]	3894	77.75	44.70	32.95	26.40	29.20
Greece	2483	49.20	42.95	23.25	14.30	17.90
Hungary	2747	58.90	34.60	16.30	35.00	31.80
Ireland	1956	58.80	34.10	38.25	46.05	33.50
Israel	3794	65.80	52.40	49.35	40.55	51.80
Italy	3137	61.25	37.25	20.40	37.00	24.65
Latvia	2343	47.25	24.65	30.25	27.45	14.55
Lithuania	3740	38.55	23.90	32.50	20.60	10.30
Macedonia	2631	59.00	43.80	33.20	39.40	32.45
Netherlands	2995	78.15	30.30	41.20	45.05	41.05
Norway	3393	78.70	31.40	23.85	14.20	17.25
Poland	4183	61.85	48.20	37.95	37.50	26.40
Portugal	2128	56.05	51.40	28.80	22.75	35.50
Russia[e]	5458	60.25	29.75	36.90	26.65	22.75
Scotland	3246	67.00	36.35	34.70	46.20	46.10
Slovenia	2863	58.85	41.25	26.35	26.35	38.00
Spain	4067	52.05	38.35	11.75	23.35	29.05
Sweden	2678	79.45	29.05	30.05	12.70	12.25
Switzerland	3027	84.80	37.05	34.85	26.30	30.90
Ukraine	2489	47.70	27.60	47.90	36.00	17.75
USA	3400	71.75	30.85	30.80	33.55	41.70
Wales	2722	66.65	23.80	19.90	25.75	35.60
Total/average	108475	61.92	35.58	31.52	28.68	27.40

[1] Number of respondents.
[2] Percentage toothbrushing more than once a day.
[3] Percentage eating fruits every day.
[4] Percentage eating vegetables every day.
[5] Percentage eating sweets every day.
[6] Percentage drinking soft drinks every day.
[a] Flemish-speaking part.
[b] French-speaking part.
[c] Nancy and Toulouse regions only.
[d] Nordrhein-Westfalen region only.
[e] St. Petersburg and district of the Russian Federation only.

Toothbrushing was assessed by the question: How often do you brush your teeth? Answer options were: more than once a day, once a day, at least once a week but not daily, less than once a week, never. As twice daily toothbrushing is advised, response options were dichotomised into: "regular brushing" (more than once a day), and "irregular brushing" (once a day or less often – the remaining answers).

Dietary habits were recorded from the questions about the frequency of eating fruits, vegetables, sweets (candies or chocolate) and consuming soft drinks. Answer options for each item were: never, less than once a week, once a week, 2-4 days a week, 5-6 days a week, once a day, more than once a day. Response options were dichotomised into: "daily use" (once a day or more often), and "less than daily use" (the remaining answers).

Questionnaires were administrated in schools between October 2001 and June 2002. The survey was conducted in school classes with a teacher or investigator overseeing the process. All personnel involved in the fieldwork were fully trained and followed agreed guidelines. Anonymity of the answers was ensured in each country.

National data files were prepared and exported to the HBSC international databank at the University of Bergen (Norway). The data were checked and cleaned according to strict criteria. The final population of the cleaned data comprised more than 108.000 participants. The study population was well balanced by gender and age in all countries.

Oral health status of 12-year-old children

DMFT was used to measure caries experience and, in general, the oral health status of 12-year-olds. Mean DMFT values in participating countries and regions were collected from the international data banks and recent publications. The main international epidemiology reference for oral health was the WHO Global Oral Data Bank. Currently, the bank contains 1850 data sets on dental caries for 178 countries (Nithila *et al*., 1998; WHO, 2007a; 2007b).

Data for Malta and Greenland were not included as DMFT data were not available

Statistical analysis

Statistical analysis, involving two steps, was performed using the SPSS (version 13.0) statistical package.

The first step sought to estimate tootbrushing and dietary habits for each country. The national HBSC files were used for this purpose. The proportions of regular toothbrushers and daily users of fruits, vegetables, sweets and soft drinks were calculated by age group. The age-adjusted proportions for the 11-13-year-old populations were constructed as the average of age-specific rates in order to avoid unbalanced age distributions in several countries. The estimated proportions represented country-level indicators of oral health behaviour.

The second step included inter-country comparisons and analyses of country-level data. A working data set, which included 33 records corresponding to each country or region, was prepared. The country-level indicators of oral health and DMFT values constituted a record. All countries or regions in the data set were represented equally without weighting for numbers of observations or population size. The associations between country-level indicators were demonstrated using multiple linear regression. In this analysis the quantitative dependent variable was DMFT. The explanatory or independent variables were proportions of regular toothbrushers, and daily consumption of fruits, vegetables, sweets and soft drinks.Statistical significance was assumed when $p<0.05$.

Results

The percentages of regular toothbrushers as well as percentages of 11-13-year-olds who daily ate fruits, vegetables, sweets and drinking soft drinks for each country are presented in Table 1.

The percentage claiming to brush their teeth more than once a day was highest in Switzerland (85%), followed by Norway, Sweden (79%), Denmark, Germany and Netherlands (78%). Fewer than 50% of the 11-13-year-olds claimed to be regular toothbrushers in Lithuania (39%), Finland (40%), Macedonia (44%), Latvia (47%), Belgium (47-50%), Ukraine (48%) and Greece (49%).

The percentage who consumed fruit once or more than once a day was highest in Israel (52%), Portugal (51%), Poland (48%), Czech Republic and Germany (45%), and was lowest in Finland, Estonia (22%), Lithuania, Wales (24%) and Latvia (26%).

Percentage of vegetable eating once or more than once a day was the highest in Belgium (52-44%), Israel (49%), Ukraine (48%) and France (46%), and the lowest in Spain (12%), Austria, Estonia (18%) and Wales (20%).

Low percentage of daily sweets consumption was reported by adolescents in Finland (9%), Denmark (12%), Sweden (13%), Norway and Greece (14%). The highest percentage of 11-13-year-olds reported about eating of the sweets once a day or more in Scotland (46%), Ireland (46%), Netherlands (45%), Belgium Flemish-speaking part (41%) and Israel (41%).

The highest percentages of 11-13-year-olds who reported drinking soft drinks at least once a day were in Israel (52%), Scotland (46%), USA (42%) and Netherlands (41%). Use of soft drinks was very uncommon in Finland (7%), Denmark (9%), Lithuania (10%), Sweden (12%) and Latvia (15%).

Oral health

The oral health status of 12-year-olds in participating countries and regions is presented in Table 2 as a mean DMFT collected from the international data banks and recent publications. The geographical differences in DMFT are substantial, with levels ranging from less than 1.0 in Denmark (0.9), Netherlands (0.8), Sweden (0.9), Switzerland (0.9), England (0.9) and Wales (0.9) to over 3.5 in Lithuania (3.6), Poland (3.8) and Ukraine (4.4). The median for the selected countries and regions was 1.6. The DMFT of most Eastern and Central European countries was above the median.

Association between oral health and oral health behaviour patterns

In countries that were characterised by a higher proportion of regular toothbrushers, DMFT was more likely to be low (Spearman's rank correlation $r = -0.542$; $p = 0.001$)

Table 2. Mean DMFT among 12-year-olds in participating countries and regions.

Country or region	*DMFT*	*Year*	*Reference*
Austria	1.0	2002	WHO, 2007c
Belgium (Flemish speaking part)	1.1	2001	WHO, 2007c
Belgium (French speaking part)	1.6	2002	Widström, 2004
Canada (Quebec)	2.1	1996-1997	WHO, 2007d
Croatia	3.5	1999	WHO, 2007c
Czech Republic	2.5	2002	WHO, 2007c
Denmark	0.9	2001	WHO, 2007c
England	0.9	2000-2001	WHO, 2007c
Estonia	2.7	1998	WHO, 2007c
Finland	1.2	2000	WHO, 2007c
France	1.9	1998	WHO, 2007c
Germany	1.2	2000	WHO, 2007c
Greece (Attica)	2.2	2000	WHO, 2007c
Hungary	3.3	2001	WHO, 2007c
Ireland (non-fluoridated)	1.3	2002	WHO, 2007c
Israel	1.66	2002	WHO, 2007c
Italy (North Italy)	1.5	2001-2002	WHO, 2007c
Latvia	3.5	2002	WHO, 2007c
Lithuania	3.6	2001	WHO, 2007c
Macedonia	3.0	1999	WHO, 2007c
Netherlands	0,8	2002	WHO, 2007c
Norway	1.5	2000	WHO, 2007c
Poland	3.8	2000	WHO, 2007c
Portugal	1.5	1999	WHO, 2007c
Russia	2.9	1996-1998	WHO, 2007c
Scotland	1.8	1996-1997	WHO, 2007c
Slovenia	1.8	1998	WHO, 2007c
Spain	1.12	2000	WHO, 2007c
Sweden	0.9	2001	WHO, 2007c
Switzerland (Canton of Zurich)	0.9	2000	WHO, 2007c
Ukraine	4.4	1990-1995	WHO, 2007c
USA (12-15 years)	1.19	1999-2004	WHO, 2007d
Wales	0.9	2000-2001	WHO, 2007c

(Figure 1). Therefore bivariate correlation between DMFT and dietary variables was not statistically significant.

Multiple linear regression was conducted to predict the mean DMFT using a set of the country level variables. These independent variables included the proportions of schoolchildren who reported regular toothbrushing and daily consumption of fruits, vegetables, sweets and soft drinks. Statistically significant associations with DMFT were found (Table 3). The most significant factor associated with the cross-regional variation of DMFT values was the proportion of regular toothbrushers. The negative association (Figure 1) demonstrated that lower DMFT was associated with a higher proportions of regular toothbrushers. This covariate explained 26.3% of the total DMFT variation across countries. A high proportion of sweets consumers might be also associated with higher DMFT. The proportion of daily consumers of soft drinks was also statistically significantly associated with DMFT in regression model but the association was negative. Eating of fruits and vegetables had no significant impact on DMFT. Altogether, factors involved in this model explained 51.2% of the total inter-country DMFT variation.

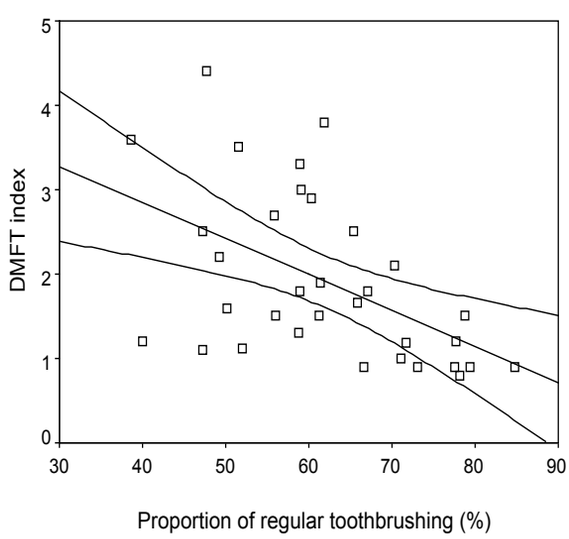

Figure. 1. *Scatterplot illustrating the relationship between the proportion of regular toothbrushers and the DMFT (country level data).*

Table 3. Multiple linear regression analysis of the DMFT by country level independent covariates.

	Unstandardized Coefficients		*Standardized Coefficients*	*t*	*Sig.*	*Partial R Square*
	B	*Std. Error*	*Beta*			
Constant	2,588	0.978		2.647	0.013	
Proportion toothbrushing more than once a day	-0.034	0.012	-0.409	-2.886	0.008	0.263
Proportion drinking soft drinks every day	-0.061	0.018	-0.689	-3.282	0.003	0.142
Proportion eating sweets every day	0.061	0.020	0.613	3.099	0.004	0.045
Proportion eating fruits every day	0.031	0.018	0.264	1.759	0.090	0.058
Proportion eating vegetables every day	0.007	0.014	0.072	0.493	0.626	0.004
					Total:	0.512

Discussion

As with any international study, the comparisons in our study should be interpreted with caution. Moreover, the data sets used for this study originated from two different sources.

The first data source was the cross-national HBSC survey conducted in 2001/02. The set of items used in the survey aimed to reflect general oral hygiene and dietary patterns in a cross-national oral health perspective. This study permits a reliable comparison of oral health behaviour in a large number of countries using standardized methods for sampling and data collection. The age standardized estimates, which represented aggregated samples of two selected age groups (11- and 13-year-olds), were applied for the cross national data comparison.

The comparison of results from the present study with previous studies, indicating consistent patterns in all the studies, suggests that the data had high reliability. Strong similarities in the interrelationships between variables in different countries also support the validity of these international comparisons.

The results about toothbrushing in our study are in accordance with the findings of the previous HBSC surveys in 1993-1994 and in 1997-1998 (Honkala *et al*., 1990; Kuusela *et al*., 1997). In all country surveys the highest proportion of children who brushed their teeth regularly were in Northern European countries: Sweden, Norway and Denmark. Since the last HBSC survey, Switzerland moved from the third place to the top of the country scale due to a small decrease in the prevalence of regular brushing in Sweden and Denmark. In contrast, the lowest proportions of regular toothbrushers over many years were in Lithuania and Finland, countries with the quite different socio-economic backgrounds and oral health care systems. Fewer than half of the children brushed their teeth regularly in Flemish-speaking Belgium and Greece, as reported in previous surveys.

There are few data to explain the differences in oral hygiene habits across the countries based on different national economies or the health care systems, although, studies have shown the importance of socio-economic background for determining children's toothbrushing behaviour (Addy *et al*., 1990; Koivusilta *et al*., 2003; Maes *et al*., 2006).

Children's eating patterns were studied as well. According to the American Dietetic Association (ADA, 2003), diet and nutrition are an integral component of oral health. Our findings indicate that there are also substantial differences in dietary habits between countries. Food availability and culture, in addition to personal and social factors, are known to be important (Schneider, 2000; WHO, 2003).

Regardless of the wide variation in food consumption patterns, the ranking of countries in this study corresponded well with those found in previous surveys. The highest proportions of daily consumption of sweets remained in Scotland and Ireland, and the highest proportions of daily consumption of soft drinks was still in the USA, Scotland, and Israel.

Consistent regional patterns of toothbrushing and eating in all HBSC studies lead to the conclusion that these habits may have an effect on the oral health of young people. The HBSC did not record any oral health indices for individuals. To avoid this study limitation, in the present study the mean DMFT of 12-year-olds was used as a global oral health indicator for the country or region.

The second data source, the WHO Global Oral Data Bank and recent publications, provided consistent information about DMFT among 12-year-olds. The reliability of the reported data is difficult to evaluate, because of variation in the times of data collection and limitations in regional sample representativeness.

There was a large difference in DMFT between countries: the lowest in the Netherlands (0.8) to the highest in Ukraine (4.4). Although caries experience data from recent studies in all European countries showed a general declining trend, in some Central and Eastern European countries, caries experience in children was still high (Marthaler, 1996; Milciuviene, 2001; Pitts *et al*., 2002; Szoke and Petersen, 2000). Some studies (Eaton *et al*., 1998; Widström and Eaton, 2004) have attempted to explain regional variations in DMFT among 12-year-olds by the extent and nature of governmental involvement in planning and coordination of oral healthcare services and oral health care workforce payment mechanisms. It was hypothesized, that the caries reduction among 12-year-olds between 1970 and the 1990 in Western European countries was a consequence of the general reduction of workloads, particularly for younger age groups, while in Eastern European countries, extensive privatisation of the public oral health services and the slow development of insurance systems covering treatment costs had an impact as well.

Caries can be considered as a behavioural disease. It is well known that regular toothbrushing and proper diet are important factors in dental caries prevention (Addy *et al*., 1990; König and Navia, 1995) and an association between caries and sugar consumption is well established (König and Navia, 1995; Touger–Decker and van Loveren, 2003). Soft drinks have been found to be risk factors for the development of dental erosion (Jensdottir *et al*., 2006). Thus, the food items in this survey can be looked on as indicators of oral health-related lifestyles. This approach was confirmed by a recent HBSC data analysis (Zaborskis *et al*., 2004), which showed statistically significant interrelationships between toothbrushing and food items at the individual level.

The findings of our study provide information about the relationship between oral health behaviour patterns and caries experience among children in the studied countries. An ecological research approach (international comparisons) was applied. Although the associations between variables in international comparisons do not necessarily represent the associations that exist at individual level, the data of our study could help to explain the variance in caries experience between countries.

The use of multiple regression analysis in international comparison of DMFT among 12-year-olds demonstrated that the regularity of toothbrushing was inversely associated with DMFT and was a very significant factor in explaining variation in caries experience between countries. High consumption of sweets was correlated with increased caries prevalence in countries and had also a significant impact on the DMFT variability. These two logical associations are consistent with numerous findings from experimental and epidemiological studies at the individual level (Addy *et al*., 1990; Harris *et al*., 2004; Touger–Decker and van Loveren, 2003). The relationship between sugar availability and dental caries development has been shown in an ecological study by Woodward and Walker (1994).

The relationship between drinking of soft drinks and DMFT in international comparisons deserves a special comment. The results of our study showed that the proportion of persons drinking soft drinks every day has a statistically significant relationship with DMFT in the multiple linear regression model but the association was negative. The results of some individual level studies showed positive association between the consumption of soft drinks and caries experience (Heller *et al*., 2001; Levine *et al*., 2007). At first glance these findings do not match with results of our study. One explanation might be that nowadays, in the countries of Central and Eastern Europe, where caries prevalence is higher, the consumption of soft drinks is still increasing. Consumption of soft drinks in a population should be considered as a country development indicator. Sugar-sweetened soft drinks may constitute a major part of total sugar intake. The consumption of sugar-free soft drinks is becoming more popular. Unfortunately, in the present study we were not able to ascertain the proportions sugar-free and sugar-sweetened soft drinks consumed by the study participants. Future individual level studies should provide better information. Similar weaknesses in ecological studies linking sugars intake to the risk of dental caries for developed countries have been noted (Woodward and Walker, 1994).

Conclusion

Cross-national comparison of data provides indications that the different oral health behaviour profiles that exist among young people between European countries, Israel, Canada and the USA significantly contribute to the variance in caries experience. Therefore in ecological studies, the risk to caries experience of children based on their oral health behaviour patterns should be assessed with caution.

Acknowledgements

The Health Behaviour in School-Aged Children Survey is a WHO/EURO collaborative study. The international coordinator is Candace Currie (University of Edinburgh, Edinburgh, Scotland); the data bank manager is Oddrun Samdal (University of Bergen, Norway). A complete list of participating researchers can be found on the HBSC website (Currie *et al*., 2004).

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