

RESEARCH ARTICLE

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# Tobacco use and caries risk among adolescents – a longitudinal study in Sweden

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## Abstract

**Background:** Smoking and the use of smokeless tobacco have a detrimental impact on general and oral health. The relationship to dental caries is however still unclear. As caries is a multi-factorial disease with clear life-style, socio-economic and socio-demographic gradients, the tobacco use may be a co-variable in this complex rather than a direct etiological factor. Our aim was to analyze the impact of tobacco use on caries incidence among adolescents, with consideration to socio-economic variables by residency, using epidemiological data from a longitudinal study in the region of Halland, Sweden.

**Methods:** The study population consisted of 10,068 adolescents between 16–19 years of age from whom yearly data on caries and tobacco use (cigarette smoking and use of smokeless tobacco) were obtained during the period 2006–2012. Reported DMFS increment between 16 and 19 years of age ( $\Delta$ DMFS) for an individual was considered as the primary caries outcome. The outcome data were compared for self-reported never vs. ever users of tobacco, with consideration to neighborhood-level socio-economy (4 strata), baseline (i.e., 16 years of age) DMFS and sex. The region consists of 65 parishes with various socio-economic conditions and each study individual was geo-coded with respect to his/her residence parish. Neighborhood (parish-level) socio-economy was assessed by proportion of residing families with low household purchasing power.

**Results:**  $\Delta$ DMFS differed evidently between ever and never users of tobacco (mean values: 1.8 vs. 1.2; proportion with  $\Delta$ DMFS > 0: 54.2% vs. 40.5%;  $p < 0.0001$ ). Significant differences were observed in each neighborhood-level socio-economic stratum. Even after controlling for baseline DMFS and sex,  $\Delta$ DMFS differed highly significantly between the ever and never users of tobacco (overall  $p < 0.0001$ ).

**Conclusion:** Tobacco use was clearly associated with increased caries increment during adolescence. Hence, this factor is relevant to consider in the clinical caries risk assessment of the individual patient as well as for community health plans dealing with oral health.

**Keywords:** Adolescents, Caries, Tobacco use, Socio-economy, Prevention

## Background

It is generally thought that smoking and the use of smokeless tobacco may have a detrimental impact on general and oral health [1-3]. The relationship to dental caries is however still unclear. Several studies world-wide have denominated tobacco use as a risk factor for coronal and root caries and disclosed increased caries rates in tobacco smoking young adults, adults, and elderly [4-9]. However, a recent epidemiologic survey conducted in Sweden failed to demonstrate a relationship between tobacco use and

caries in adults and elderly [10]. A recent systematic review on tobacco use and dental caries was based solely on cross-sectional studies and, as a result, the overall quality of evidence was concluded to be poor [11].

As caries is a multi-factorial disease with clear life-style, socio-economic and socio-demographic gradients, the tobacco use may be a co-variable in this complex rather than a direct etiological factor [12,13]. We have previously presented caries risk in children and adolescents in relation to neighborhood socio-economic factors with aid of a geo-mapping tool in the Region of Halland, Sweden [14,15]. The epidemiological data collected in this region provides an opportunity to examining the impact

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of tobacco use on caries risk among adolescents, with consideration to socio-economic variables by residency. Importantly, as the epidemiological data have been collected annually, we can apply a longitudinal approach.

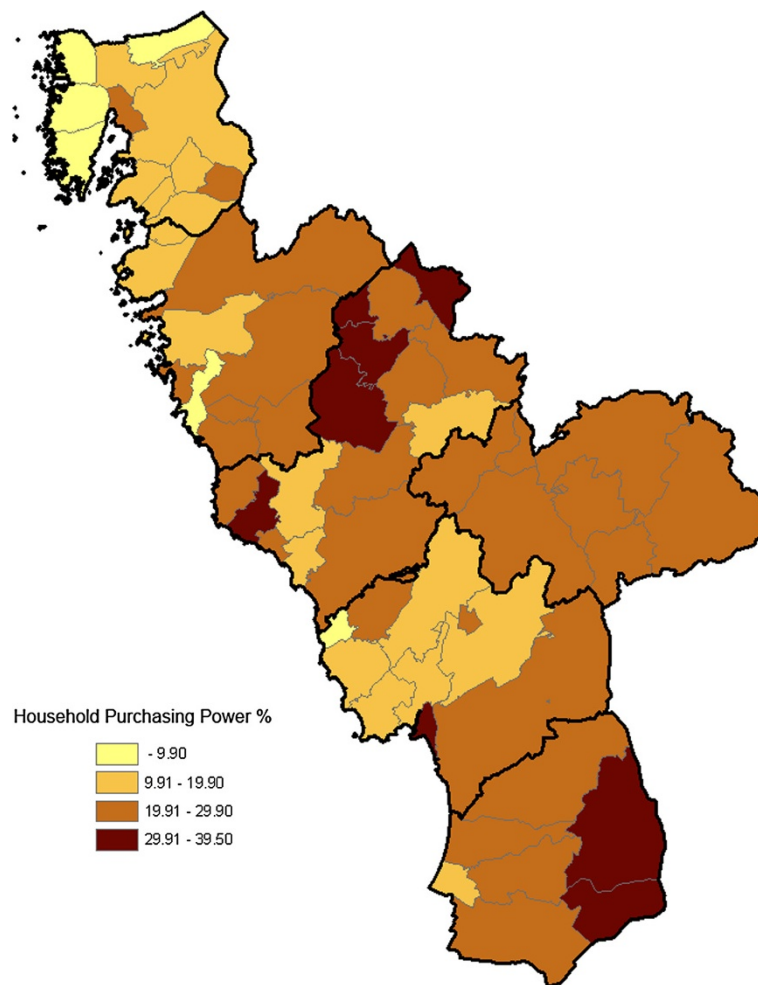
## Methods

### Study population

The vast majority of all children and adolescents (93%) in the region are listed as regular patients at the Public Dental Service that provides free dental care between 1 and 19 years with recall intervals varying from 3 to 24 months depending on the individual need. Data on the experience of manifest (dentin) caries is registered according to the WHO-criteria [16] and annually reported to the community dentistry unit. Caries data were primarily based on clinical examinations and bitewing radiographs were only taken on individual indications.

Annual data on caries and tobacco use were collected during the period 2006–2012. We considered four birth-year-cohorts, 1990, 1991, 1992 and 1993, with observation periods 2006–2009, 2007–2010, 2008–2011 and 2009–2012, respectively. Reported DMFS increment ( $\Delta$ DMFS) between 16 and 19 years of age, i.e. between the first and last year of the relevant observation period for an individual, was considered as the primary caries outcome. In total, the present study included 10,068 individuals with outcome data. The coverage of the total 16–19-year population of the Halland region was around 70%. The remaining adolescents were not recalled for a regular check-up at a relevant year or visited a private dentist at a clinic not among the in-reporting ones or located outside the region.

The study was approved by the Halland Hospital Ethical committee as well as The Swedish Data Inspection Board.



**Figure 1** Geo-map on household purchasing power for the 61 parishes in the county of Halland. The residential areas (parishes) were classified into <10%, 10–19.9%, 20–29.9% and ≥30% of the residing families with low household purchasing power according to Swedish standards (see definition in the methods section). The thicker borderlines delimit the six municipalities of Halland.

**Table 1 DMFS outcome data at baseline and change in DMFS during the follow-up period for each tobacco group and birth cohort, with p-values for the tobacco group comparisons of change in DMFS**

Birth cohort	Tobacco group	DMFS baseline 16 years				Change in DMFS, 16–19 years				p-values§
		N	Mean	SiC*	CF†	N	ΔMean	ΔSiC	ΔDMFS>0%‡	
1990	Ever users	390	3.7	7.7	27.7	390	1.8	4.2	57.2	< 0.001
	Never users	2233	2.9	7.6	35.9	2233	1.3	4.1	43.9	
1991	Ever users	342	3.9	8.3	25.4	342	2.0	4.5	57.3	< 0.001
	Never users	2191	2.6	7.5	39.4	2191	1.3	4.5	40.9	
1992	Ever users	357	3.5	8.0	31.1	357	1.8	4.6	56.0	< 0.001
	Never users	2070	2.7	7.6	38.4	2070	1.2	4.1	41.6	
1993	Ever users	370	3.5	7.8	33.5	370	1.6	4.6	46.5	< 0.001
	Never users	2116	2.5	7.3	41.0	2116	0.9	3.9	35.3	
Total	Ever users	1459	3.6	7.9	29.5	1459	1.8	4.5	54.2	< 0.001
	Never users	8609	2.7	7.5	38.7	8610	1.2	4.2	40.5	

\* Significant caries index based on DMFS.

† Proportion caries-free.

‡ Proportion with new caries during the observation period (16–19 years).

§ P-value from the Wilcoxon-Mann-Whitney test comparing the distributions of DMFS between ever vs. never users. The overall p-value < 0.0001 (stratified Wilcoxon-Mann-Whitney test).

#### Data on tobacco use

Each study individual was asked about his/her tobacco use at the annual clinical examination by the examining dentist or dental hygienist. Individuals who reported use of tobacco in at least at one of the four examination occasions were defined as ever users (n=1,459). Tobacco use included both cigarette smoking and the use of smokeless tobacco (snuff). Among those who reported use of tobacco, approximately 35% reported only use of snuff. No information on the amount or frequency of the tobacco use was available. All other individuals were classified as never users (n=8,609).

#### Neighborhood socio-economy

Each study individual was geo-coded with respect to his/her residence parish. Statistics Sweden provided parish-level data from year 2010 on the socio-economic indicator we considered, viz. the proportion of families with low household purchasing power (according to Swedish standard; ≤19,500 USD household purchasing power) among all residing families with at least one child (≤19 years old; family with the same residence address). Household purchasing power was defined as total family disposable income adjusted for the composition of the family (number of adults and children). The parishes were classified

**Table 2 DMFS outcome data at baseline and change in DMFS during the follow-up period for each tobacco group and residential-area household purchasing power group, with p-values for the tobacco group comparisons of change in DMFS**

% low household purchasing power	Tobacco group	DMFS baseline 16 years				Change in DMFS, 16–19 years				p-values§
		N	Mean	SiC*	CF†	N	ΔMean	ΔSiC	ΔDMFS>0%‡	
< 10	Ever users	152	2.5	7.6	41.4	152	1.3	4.2	43.4	0.02
	Never users	1553	1.7	6.5	49.8	1553	0.9	3.7	34.8	
10-19.9	Ever users	382	3.3	7.3	30.1	382	1.6	4.2	51.8	< 0.001
	Never users	2295	2.4	6.8	38.1	2295	1.0	3.8	38.2	
20-29.9	Ever users	755	3.9	8.0	27.3	755	1.8	4.6	56.7	< 0.001
	Never users	3826	3.0	7.8	35.8	3826	1.5	4.4	43.0	
30+	Ever users	162	4.4	8.9	27.8	162	2.3	5.0	59.3	< 0.001
	Never users	892	3.7	8.8	32.2	892	1.5	4.6	46.0	

\* Significant caries index based on DMFS.

† Proportion caries-free.

‡ Proportion with new caries during the observation period (16–19 years).

§ P-value from the Wilcoxon-Mann-Whitney test comparing the distributions of DMFS between ever vs. never users. The overall p-value < 0.0001 (stratified Wilcoxon-Mann-Whitney test).

**Table 3 DMFS outcome data at baseline and change in DMFS during the follow up period for each tobacco group, residential-area household purchasing power group and baseline DMFS group, with p-values for the tobacco group comparisons of change in DMFS**

SE group	Baseline DMFS group	Tobacco group	DMFS baseline		ΔDMFS		p-value*
			N	Mean	N	Mean	
< 10	0	Ever users	63	0.0	63	0.4	0.33
		Never users	774	0.0	774	0.4	
	1-3	Ever users	49	1.6	49	1.2	0.44
		Never users	492	1.7	492	1.0	
	> 3	Ever users	40	7.6	40	2.8	0.20
		Never users	287	6.5	287	1.8	
10 – 19.9	0	Ever users	115	0.0	115	0.7	0.05
		Never users	875	0.0	875	0.6	
	1-3	Ever users	129	1.9	129	1.6	0.001
		Never users	810	1.8	810	0.9	
	> 3	Ever users	138	7.3	138	2.5	0.002
		Never users	610	6.8	610	1.7	
20 – 29.9	0	Ever users	206	0.0	206	0.7	0.001
		Never users	1370	0.0	1370	0.5	
	1-3	Ever users	241	1.9	241	1.8	0.001
		Never users	1285	1.8	1285	1.1	
	> 3	Ever users	308	8.0	308	2.7	0.45
		Never users	1171	7.8	1171	2.5	
30+	0	Ever users	45	0.0	45	0.8	0.10
		Never users	287	0.0	287	0.6	
	1-3	Ever users	47	2.0	47	2.3	< 0.001
		Never users	293	1.9	293	1.2	
	> 3	Ever users	70	8.9	70	3.3	0.57
		Never users	312	8.8	312	2.6	

\* P-value from the Wilcoxon-Mann-Whitney test comparing the distributions of DMFS between ever vs. never users. The overall p-value < 0.0001 (stratified Wilcoxon-Mann-Whitney test; with additional stratification by sex).

into <10%, 10–19.9%, 20–29.9% and ≥30% based on this indicator (Figure 1).

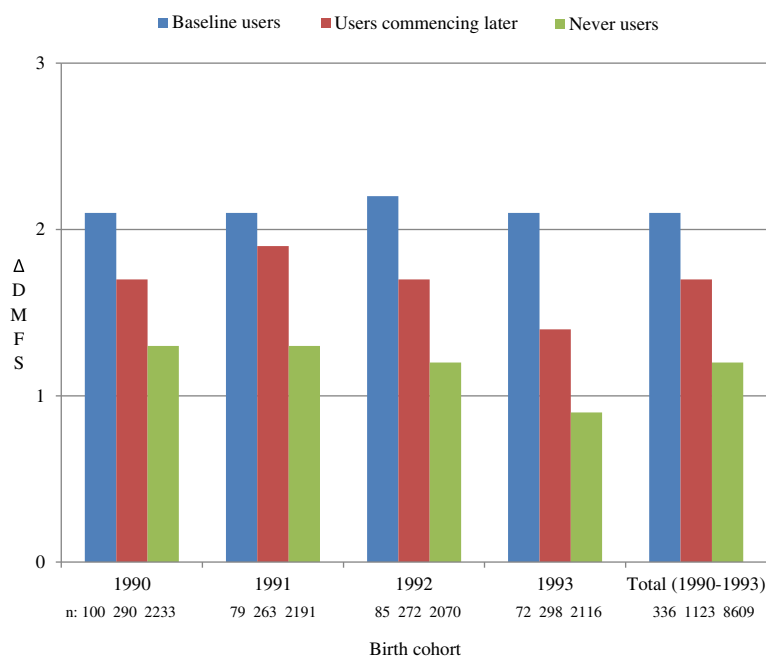
### Statistical methods

The DMFS variable at a specific observation year (i.e., year of age for a given birth-year-cohort) was summarized by mean, significant caries index (SiC) based on DMFS [17] and proportion of caries-free (CF). The outcome variable ΔDMFS was summarized by mean, ΔSiC and proportion with ΔDMFS > 0. Outcome data for never vs. ever users of tobacco were basically compared by the Wilcoxon-Mann-Whitney test, as data were highly skewed, with a high proportion of “zero”. The complete data were generally stratified by birth-year and an overall p-value was obtained by the stratified Wilcoxon-Mann-Whitney test [18]. Moreover, further controlled overall p-values were computed by the stratified Wilcoxon-Mann-Whitney test (never vs. ever users) with additional stratification on

neighborhood-level socio-economy, baseline DMFS (0, 1–3, >3) and sex. The cut-off values for baseline DMFS were based on the epidemiological caries data in the Halland region, reflecting no, low and high caries experience. IBM SPSS 20.0.2 and StatXact 6.2.0 (Cytel Inc., Cambridge, MA, USA) were used for the statistical analyses.

### Results

ΔDMFS differed evidently between ever and never users of tobacco (Table 1; overall p < 0.0001). Significant differences were observed in each neighborhood-level socio-economic stratum (Table 2; overall p < 0.0001). As expected, a socio-economic gradient in caries burden was evident in the study population (Table 2). Nevertheless, baseline DMFS was consistently higher among ever users, as compared with never users in neighborhoods with a similar socio-economic characteristic (Table 2). Even after controlling for baseline DMFS and sex,



**Figure 2** Caries development, depicted by mean values of  $\Delta$ DMFS for each birth cohort as well as the total study group, for three exposure groups: reported tobacco users at baseline, i.e., 16 years of age (“baseline users”), the remaining users reported tobacco use at any subsequent occasion during the follow-up, i.e., 17–19 years of age (“users commencing later”) and “never users”, respectively.

$\Delta$ DMFS differed highly significantly between ever and never users (Table 3; overall  $p < 0.0001$ ). The pattern of more pronounced DMFS increment during adolescence among the ever users of tobacco was consistent across the strata of neighborhood-level socio-economy and baseline DMFS, although the degree of statistical evidence varied (Table 3). The change in DMFS displayed a different pattern in the most vulnerable groups (SE groups 20–29.9 and 30+, baseline DMFS  $> 3$ ), indicating a weaker influence of tobacco use. On the other hand, the statistical evidence of a tobacco effect was also weaker for the individuals in the residential areas with  $< 10\%$  of the families with low purchasing power, within each stratum of baseline DMFS.

## Discussion

To our knowledge, this report is based on the first longitudinal study addressing the impact of tobacco use on caries development among adolescents. The main finding was clear-cut; self-reported use of tobacco was significantly associated with increased incidence of dental caries over a 3 year-period, irrespective of socio-economic and geographic characteristics. Therefore, the immediate clinical implication is that the question “do you use tobacco?” is important and should be relevant to include as a component of the individual caries risk assessment. Such a comprehensive risk assessment is crucial for appropriate treatment decisions concerning prevention, non-operative

and operative caries therapy [19–21] and for determination of individual recall intervals [22]. On population level, information on the use of tobacco should be incorporated in oral health community plans.

The large size of the material, the high population coverage and the robust clinical scoring of caries were strongly enhancing the external validity of this project. The study design had still a number of limitations. The findings were based on a very crude classification of self-reported data on tobacco use, dichotomized as “ever” or “never” and the actual frequency and duration of the tobacco use was not reported. It is also likely that the true frequency of tobacco-use was somewhat under-reported, especially in the younger age-groups, due to reluctance to admit “a bad habit” in front of health professionals and sometimes parents. Furthermore, tobacco-use included both cigarette smoking and the use of smokeless tobacco (snuff) with differences in gender- and geographical pattern. Girls in urban parishes were more likely to smoke while the use of smokeless tobacco was more prevalent among rural boys (data not reported). In spite of exposure misclassification, likely to have induced bias towards the null, we were still able to demonstrate clear impact of reported tobacco use. Nevertheless, timing of exposure is an interesting aspect to investigate further. By dividing the “ever users” group into reported tobacco users at baseline (i.e., 16 years of age) and the remaining users reported tobacco use at any subsequent

occasion during the follow-up (i.e., 17–19 years of age), our crude data indicate a higher mean  $\Delta$ DMFS among the “baseline users” as compared with the “users commencing later” (Figure 2). Hence, the adverse effect on caries development could have been influenced by exposure time.

Another study limitation was that we were unable to control for other life-style and behavior-related factors although the adjustment for baseline DMFS and sex to some extent may have captured such obvious confounders.

The socio-economic statistics applied here were from 2010, but this was only a minor concern as the neighborhood characteristics proved to be stable over the total observation period [14]. Moreover, we considered family purchasing power as the primary indicator of neighborhood socio-economy. This indicator takes solely residing families with at least one child ( $\leq 19$  years of age) into account; the elderly population was disregarded, which can be advocated. Nevertheless, family purchasing power corresponded fairly well with other alternative socio-economic indicators on the parish level, such as educational level and the proportion of immigrants [14].

Interestingly, the caries burden remained relatively unchanged over the four cohorts. On the other hand, the change in DMFS clearly depended on vulnerability (socioeconomic status), as seen in Table 3. A notable observation was that the SiC-index displayed less pronounced differences in caries incidence between tobacco-users and non-users compared with the crude mean values, considering the individuals in the neighborhoods with less favorable socio-economy (Table 2). As the distribution of caries is skewed, the SiC-index was constructed to more accurately mirror the dental health in the proportion of the population with the highest caries burden [17]. Consequently, those individuals were the adolescents with highest caries-activity and most filled surfaces at baseline, which may have limited the number of actual surfaces available for new obvious caries lesions over the study period. Bitewing radiographs were only taken on individual indications and were likely more often exposed in the high caries-group; this procedure may have enhanced the difference between the exposure groups. We also noticed that the statistical evidence of a tobacco effect was weaker for the individuals in the neighborhoods with most favorable socio-economy, within each stratum of baseline DMFS. Possible explanations could be a higher general awareness of factors associated with a healthy life-style or a less heavy use of tobacco products.

## Conclusion

In conclusion, tobacco use was clearly associated with increased caries development during adolescence. Thus, this factor should be relevant to include in the clinical caries risk assessment of the individual patient as well as for community health plans dealing with oral health.

## Competing interests

The authors have no conflicts of interests to declare.

## Authors' contributions

All of the listed authors contributed to the conduct of the study. AH, US and ST analyzed/interpreted the data and drafted the manuscript. KM provided technical and administrative support. All authors approved the final version of this manuscript.

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Received: 22 April 2013 Accepted: 8 July 2013

Published: 15 July 2013

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doi:10.1186/1472-6831-13-31

**Cite this article as:** Holmén et al.: Tobacco use and caries risk among adolescents – a longitudinal study in Sweden. *BMC Oral Health* 2013 **13**:31.

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