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ORIGINAL ARTICLE

Regional variations in caries experience, predictors, and follow-up among children and adolescents in Western Norway

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ABSTRACT

Objective: To identify regional differences in, and determinants of dental caries among children in western Norway

Material and methods: We studied dental caries in 705 children aged 12 years and 18 years living in the southern region ($n = 403$) and other parts of Hordaland County ($n = 302$) in Norway. Information on oral hygiene, fluoride intake, and sugar consumption was collected using questionnaires. We also collected information from the Public Dental Service (PDS) on the history of decayed, missing, or filled teeth; professional fluoride application; recall and regular check-up intervals and treatment visits. Residence (southern region versus the rest of Hordaland, the reference) was the independent variable. We analysed regional differences in (i) caries prevalence and severity, (ii) potential contributors to caries, and (iii) procedures and routines in PDS.

Results: Caries prevalence and severity were higher in the southern region (67% and 24%, respectively). Self-reported brushing habits, fluoride use, and sugar consumption patterns were similar between regions. We observed more frequent application of professional fluoride (incidence rate ratio [IRR] = 3.05, 95% CI: 1.99–4.66], fewer check-ups [IRR = 0.88, 95% CI: 0.81–0.95], and fewer treatment visits [IRR = 0.77, 95% CI: 0.60–0.98] among participants in the southern region, compared to the rest of Hordaland. The recall intervals in the southern region were 10% longer among 12-year-olds and 10% shorter among 18-year-olds, compared to their respective counterparts in Hordaland.

Conclusions: The observed regional gradients in caries experience mirrored regional differences in dental routines and procedures. Caries-related risk behaviours did not explain the observed differences in caries experience.

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Introduction

Dental caries is a prevalent, multifactorial condition that affects the quality of life of children and adults worldwide [1]. It is the primary cause of tooth loss and pain in the oral cavity. In most industrialised countries, rates of dental caries have declined since the mid-1970s [2]. Since the mid-1990s, dental caries among 12-year-olds have dropped by about 90%. [3] The decline was even more impressive among those aged 15–19 years [2]. The use of fluoride (mainly in toothpaste) [4–6], preventive public health policies, regular use of dental services, and improved living conditions and oral hygiene [7] have all contributed to reducing rates of dental caries.

In Norway, the rates of dentine-level caries have been reported annually at the county level for individuals aged 5, 12, and 18 years old since 1985. The Public Dental Service (PDS) in Norway offers free regular check-ups for all children younger than 19 years. Observations from dental health personnel and aggregated data from Statistics Norway suggest a higher prevalence of dental caries in municipalities in the southern part of Hordaland County, compared to the overall county average. However, because the aggregated data do not discriminate between decayed, missing, and filled teeth (DMFT) due to caries and DMFT due to other reasons, the data may overestimate DMFT due to caries.

To examine this issue more closely, we invited all 12-year-olds and 18-year-olds living in the southern part of Hordaland County (hereafter, the South region) and their counterparts living in five other county municipalities (hereafter, Hordaland) to participate in a comprehensive study of caries status and related health behaviours.

The primary objective of the study was to explore regional differences in dental caries prevalence and severity

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Supplemental data for this article can be accessed here.

at the individual level. The secondary objective was to analyse whether regional distributions in behavioural risk factors and in routines in PDSs (including treatment visits, recall intervals, and fluoride applications) mirror the regional differences in dental caries patterns.

Material and methods

Study population and data collection

We included participants aged 12 and 18 years old from five municipalities in the South region and from five other municipalities in Hordaland. Children in the South region were followed in six clinics and those in Hordaland in five clinics. The number of children in audit at each clinic was similar.

Individuals aged 12 (hereafter, younger participants) or 18 (hereafter, older participants) years old in selected municipalities received an invitation to participate in the study. Older participants agreed to participate by replying to an SMS message containing a link to the survey. For younger participants, written consent was obtained from their parents.

Information was collected using a web-based questionnaire (SurveyXact, Rambøll). The questionnaire collected the following data: (i) socio-demographic characteristics (sex, country of origin, municipality, and mother's employment), (ii) oral hygiene practices and fluoride intake, and (iii) consumption of sugar-containing items. We also analysed the PDS's digital records to assess fluoride application in the last 10 years, recall intervals, number of visits and regular check-ups in the last five years. We ensured that DMFT data reflected only caries-related filled surfaces. The Norwegian Centre for Research Data approved the study (project number 50107).

Study design, exposure variable and covariates

We used a cross-sectional design to study differences between the South region and Hordaland (reference category).

Study outcomes

Caries experience – prevalence and severity

We assessed differences in dental caries experience using PDS's digital records of full clinical oral examinations and bitewing x-rays. Decayed surfaces included all caries lesions in dentine. Dental caries prevalence was measured as the presence (DMFT $\geq$ 1) or absence (DMFT $=$ 0) of caries. Individuals with DMFT $\geq$ 1 were categorised using the Significant Caries Index (SiC Index). The SiC index is the mean DMFT for one-third of the population with the highest caries score.

Self-reported oral hygiene and fluoride use

We also analysed regional differences in self-reported toothbrushing frequency and fluoride use.

Consumption of sugar-containing items

To assess sugar intake, study participants were asked to report the types of drinks consumed during and between meals. Reported items were categorised as 'no added sugar' (water, milk, coffee, or tea) and 'added sugar' (juice, soda, and others). We then compared the odds of consuming 'added sugar' beverages during or between meals across regions of residence. Study participants also reported their consumption frequency ('never,' '1–2 times/month,' 'once/week,' '3–4 times/week,' and 'every day') of eight popular items: (1) chocolate milk, (2) fruit yoghurt, (3) chocolate spread, (4) jam, (5) biscuits and cakes, (6) sweets, (7) juice, and (8) soda. We constructed a correlation matrix for consumption frequencies of these items (Figure S1 in the online supplemental material) and observed a relatively low correlation between them. We further analysed regional differences in consumption patterns of these items using three different approaches. First, we created a total frequency score by summing the frequency scores (0 points for 'never' and 5 points for 'every day') of individual items as follows. Then, we created a score for frequently consumed items ($\geq$3 times/week). Finally, we created a variable that will values '1' for participants consuming frequently any sugar-containing item and '0' otherwise.

Public dental service data

The outcomes for analyses included (i) history of fluoride application at the clinic in the last 10 years, and (ii) number of regular check-ups, (iii) recall intervals, and (iv) number of treatment visits during the last five years.

Statistical analysis

Continuous variables are presented as means and standard deviations (SD) or median and range. Categorical variables are presented as frequencies and percentages. Regional differences, adjusted for sex and age group, were explored using logistic regression (simple or ordered), negative binomial regression, and zero-truncated negative binomial regression, depending on the distribution and characteristics of the outcome variables. Two-sided tests with a 0.05 significance level were used. Analyses were performed using STATA software, version 14. The interaction between the region of residence and age group was assessed by introducing an interaction term in the models. Age group-specific analyses are presented in the supplemental material.

Results

Study population characteristics

Table 1 shows the baseline characteristics of the 705 individuals who completed the questionnaires and gave us consent to access their dental records. The proportion of males was 41.4% (46.6% among younger and 34.9% among older participants). Younger participants accounted for 55.7% of the study population. Most (93.7%) were born in Norway (93.9% of younger and 93.4% of older participants). Overall, 54.2%

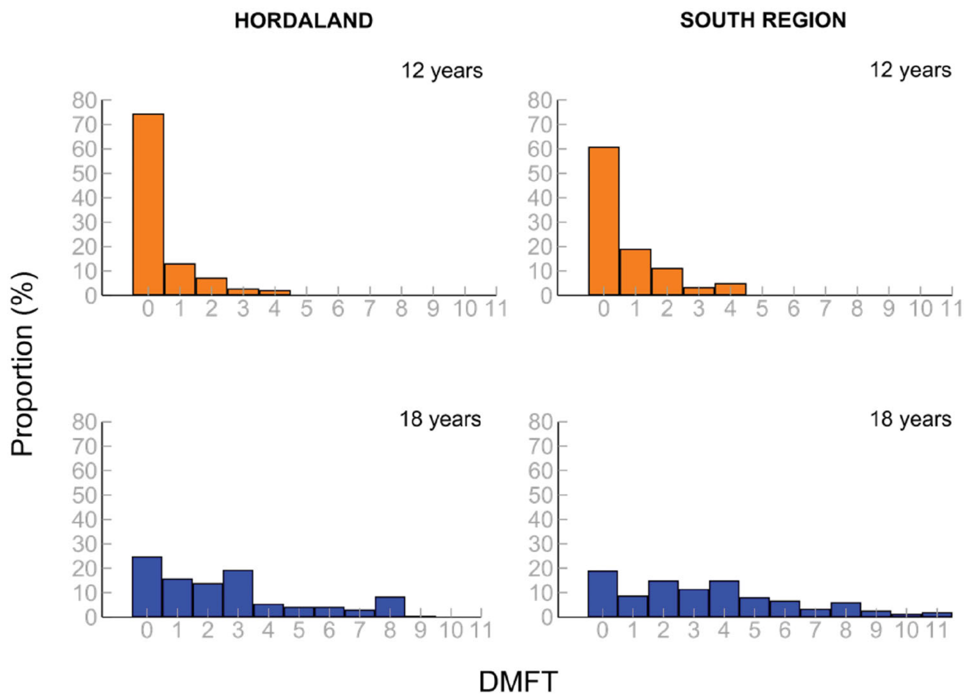

Figure 1. Distribution of decayed, missing, filled teeth (DMFT) score across regions of residence.

Table 1. Baseline characteristics of study participants.

	Total ($n = 705$)	South region ($n = 403$)	Hordaland ($n = 302$)	P value
Sex, (male) n (%)	292 (41.4)	170 (42.2)	122 (40.4)	.634
Age group				
12-year-olds	393 (55.7)	256 (63.5)	137 (45.4)	<.001
18-year-olds	312 (44.3)	147 (36.5)	165 (54.6)	
Country of birth				
Norway	655 (93.7)	373 (93.9)	282 (93.4)	.756
Abroad	44 (6.3)	24 (6.1)	20 (6.6)	
Mother's occupation*				
Unemployed/disabled	48 (6.8)	29 (7.5)	19 (6.6)	.962
Higher education and/or leading position	382 (54.2)	219 (56.4)	163 (56.6)	
Clerk	204 (28.9)	117 (30.2)	87 (30.2)	
Manual worker	42 (6.1)	23 (5.9)	19 (6.6)	

*Based on the International Standard Classification of Occupations-08.

had mothers who completed higher education or had a leading position (56.2% of younger and 51.6% of older participants). We observed no statistically significant differences in participants' characteristics across regions except that younger individuals accounted for 63.5% of the study participants in the South region, compared to 45.4% of participants in Hordaland ($p < .001$). Aggregated data from Statistics Norway revealed similar proportions of immigrants in the South region and in Hordaland (data not shown). It is therefore unlikely that cultural differences can affect the outcome in the current investigation.

Patterns of caries occurrence

Figure 1, Table S1, and Table 2 summarise the pattern of dental caries by region and age group. The proportions of caries-free participants in Hordaland and in the South region were 74.5% and 60.9% among younger participants and 24.9% and 19.1% among older participants, respectively. The median DMFT scores were 0 (range 0–4) among younger participants in both regions, 2 (range 0–9) among older participants in Hordaland, and 3 (range 0–11) among older participants in the South region. The severity of caries (as measured *via* the Significant Caries Index) was lower in Hordaland than in the South region in both younger (1.77 vs. 1.86) and older (4.87 vs. 6.03) participants (Table 2).

Table 2. Caries experience by age group and region of residence.

	12-year-olds		18-year-olds	
	Hordaland ($n = 137$)	South region ($n = 256$)	Hordaland ($n = 165$)	South region ($n = 147$)
DMFT, median (range)	0 (0–4)	0 (0–4)	2 (0–9)	3 (0–11)
DMFT categories				
0 (caries-free)	102 (74.5)	156 (60.9)	41 (24.9)	28 (19.1)
≥1	35 (25.5)	100 (39.1)	124 (75.1)	119 (80.8)
SiC	1.77	1.86	4.87	6.03

DMFT: decayed, missing, filled teeth; SiC: significant caries index.

As shown in Table 3, compared to Hordaland, the odds of having dental caries (DMFT > 0) in the South region were 67% higher (OR $= 1.67$; 95% CI: 1.17–2.37). Among individuals with dental caries (DMFT ≥ 1), severity was 24% higher

Table 3. Regional differences (adjusted for age group and sex) in decayed, missing, or filled teeth (DMFT) score.

	All participants ($n = 701$)	Participants with DMFT ≥1 ($n = 375$)
	Odds ratio* (95% CI)	Incidence rate ratio† (95% CI)
Region of residence		
Hordaland	1reference	1reference
South region	1.67 (1.17–2.37)	1.24 (1.04–1.48)
Age group		
12-year-olds	1reference	1reference
18-year-olds	7.40 (5.18–10.57)	3.16 (2.52–3.96)
Sex		
Male	1reference	1reference
Female	1.25 (0.89–1.75)	1.09 (0.91–1.30)

*Estimated from logistic regression where DMFT is treated as a 2-category variable (0 vs. ≥1).
†Estimated from zero-truncated negative binomial regression (DMFT treated as a discrete variable).

(IRR = 1.24; 95% CI: 1.04–1.48) in the South region. Age group analyses revealed that regional gradients in caries prevalence occurred only among younger participants, whereas regional gradients in caries severity occurred only among older participants (Table S2).

Oral hygiene and self-administered fluoride

We did not observe statistically significant regional differences with regard to tooth-brushing frequency or self-reported fluoride intake (Table 4). Age group-specific analyses revealed similar patterns among younger and older study participants ($P_{\text{interaction}} = .44$) (Table S3).

Sugar-containing food and beverages

We observed no statistically significant regional differences with regard to the consumption of sugary drinks (Table 5). Again, the direction and magnitude of associations were similar across age groups ($P_{\text{interaction}} = .32$) (Table S4). Figure S2 depicts the distribution of the frequency score of eight sugar-containing items by region of residence. Overall, the median frequency score was 24 (range 10–34) in Hordaland and 22 (range 11–40) in the South region. The adjusted analyses did not reveal statistically significant regional differences in the frequency score (IRR = 0.99, 95% CI: 0.97–1.02) of consumption of sugar-containing items (Table 6). Figure S3 depicts the number of sugar-containing items consumed frequently (≥3 times/week) across regions of residence. The adjusted analyses also did not reveal statistically significant regional differences in the number of sugar-containing items consumed frequently (IRR = 1.03, 95% CI: 0.94–1.13). Last, we compared the proportion of participants who consumed at least one sugar-containing item and again found no statistically significant regional differences (OR = 1.24, 95% CI: 0.74–2.08). Table 6 summarises the results. None of the age group-specific analyses were statistically significant (Table S5).

Information obtained from public dental service records (Table 7)

We observed statistically significant regional differences in recall intervals. Younger participants in the South region waited longer between clinic visits (IRR = 1.10, 95% CI: 1.04–1.17), compared to those in Hordaland, despite higher caries prevalence in the South region. Among older participants in the South region, recall intervals were shorter (IRR = 0.90, 95% CI: 0.84–0.96) than those in Hordaland ($P_{interaction} < .001$).

Residents of the South region received fluoride applications at the clinic more often (IRR = 3.05, 95% CI: 1.99–4.66), compared to residents of Hordaland. These regional differences were more pronounced among younger (IRR = 3.75) than older (IRR = 2.56) participants ($P_{interaction} = .035$).

Residents of the South region had fewer check-ups during the last five years, compared to Hordaland residents (IRR = 0.88, 95% CI: 0.81–0.95), and the overall pattern was similar across age groups ($P_{interaction} = .190$). Last, the number of treatment visits was lower among residents of the South region, compared to Hordaland (IRR = 0.77, 95% CI: 0.60–0.98).

Discussion

Our study confirmed the presence of higher caries prevalence and severity among residents of the South region, compared to the rest of Hordaland County in Norway. Interestingly, we found no regional differences in the distribution of well-known, lifestyle-related risk factors for dental caries, including toothbrushing routines, fluoride use, and consumption patterns of sugar-containing items. Based on normative assessments, we did observe (i) higher odds of receiving professional fluoride applications, (ii) fewer check-ups, and (iii) fewer treatment visits among residents of the South region, compared to those of Hordaland. Interestingly, the recall intervals in the South region were longer among younger study participants and shorter among older participants, compared to recall intervals among their counterparts in Hordaland.

The observed higher fluoride application rates in the South region may indicate that dental personnel in the region are aware of elevated baseline caries risk and thus increased its use for preventive purposes. However, this reasoning does not align with the longer recall intervals we observed among younger residents in the South region, compared to their counterparts in Hordaland. Further studies are needed to understand whether recall intervals reflect a pre-established routine related not only to the burden of caries but to other external, administrative, or resource-related factors. Whatever the reason, it seems that daily routines do not match the observed burden of caries. However, higher fluoride application rates may have attenuated real differences in caries risk when caries-preventive measures are not applied [8].

The observed lower number of treatment visits among older participants in the context of higher caries severity in the South region, compared to Hordaland, requires further attention. For example, residents in the South region may have less access to dental personnel, difficulty accessing dental care, or poor uptake of dental care services [9]. Our findings also align with those of other international studies

Table 4. Regional differences (adjusted for age group and sex) in teeth brushing and fluoride intake.

	All participants		12-year-olds		18-year-olds		
	Hordaland ($n=302$)	South region ($n=403$)	Hordaland ($n=137$)	South region ($n=256$)	Hordaland ($n=165$)	South region ($n=147$)	Adjusted analyses
Brushing teeth, %							0.96
< Twice/day	30.2	29.3	25.7	25.8	33.9	35.3	(0.77–1.21)†
Twice/day	69.8	70.7	74.3	74.3	66.1	64.6	
Fluoride use, %							0.78
No/never	11.3	12.9	2.2	7.4	18.8	22.5	(0.52–1.19)‡
<1 year	19.2	18.6	15.3	16.0	22.4	23.1	
1–3 years	32.4	34.0	40.2	36.4	26.1	29.9	
≥4 years	37.1	34.5	42.3	40.2	32.7	24.5	

†Odds ratio (95% CI) estimated from logistic regression.
‡Odds ratio (95% CI) estimated from ordered logistic regression.

Table 5. Regional differences (adjusted for age group and sex) in the consumption of drinks with added sugar during and between meals.

	All participants		12-year-olds		18-year-olds		
Use of drinks with added sugar	Hordaland ($n=302$)	South region ($n=403$)	Hordaland ($n=137$)	South region ($n=256$)	Hordaland ($n=165$)	South region ($n=147$)	Odds ratio (95% CI)
During meals, %							
No	77.4	83.4	83.1	86.0	72.7	78.9	0.75
Yes	22.6	16.6	16.9	14.0	27.3	21.1	(0.47–1.19)
Between meals, %							
No	82.7	85.1	86.7	87.8	79.4	80.3	0.93
Yes	17.3	14.9	13.3	12.2	20.6	19.7	(0.67–1.28)

Table 6. Regional differences (adjusted by age group and sex) in consumption patterns of relevant sugar-containing items.

	All participants		12-year-olds		18-year-olds		
	Hordaland ($n=302$)	South region ($n=403$)	Hordaland ($n=137$)	South region ($n=256$)	Hordaland ($n=165$)	South region ($n=147$)	Adjusted analyses
Frequency score, median (range)	24	22	21	21	26	26	0.99
	(10–34)	(11–40)	(10–30)	(11–40)	(13–34)	(14–35)	(0.98–1.02)†
Number of items consumed ≥ 3 times/week, median (range)	3	2	1	1	4	4	1.03
	(0–8)	(0–8)	(0–6)	(0–8)	(0–8)	(0–7)	(0.94–1.13)†
Frequent use of ≥ 1 item, %							
No	14.3	16.9	30.4	26.1	0.6	0.7	1.24
Yes	85.7	83.1	69.3	73.8	99.4	99.3	(0.74–2.08)‡

†Incidence rate ratio and 95% confidence interval estimated from negative binomial regression.
‡Odds ratio and 95% confidence interval estimated from logistic regression.

Table 7. Adjusted regional differences in follow-up and treatment procedures at dental clinics.

	All participants*		12-year-olds**		18-year-olds**		$P_{interaction}$†
	Hordaland ($n=302$)	South region ($n=403$)	Hordaland ($n=137$)	South region ($n=256$)	Hordaland ($n=165$)	South region ($n=147$)	
Recall interval (in months), median (range)	18	18	18	20	18	15	
	(6–36)	(3–25)	(6–36)	(6–25)	(6–24)	(3–24)	
Incidence rate ratio (95% CI)‡	–		1.10 (1.04–1.17)		0.90 (0.84–0.96)		<.001
Fluoride applications, median (range)	0	2	0	2	0	2	
	(0–10)	(0–10)	(0–9)	(0–10)	(0–10)	(0–9)	
Incidence rate ratio (95% CI)‡	3.05 (1.99–4.66)		3.75 (2.90–4.85)		2.56 (2.00–3.29)		.035
Regular check-ups, median (range)	4	3	4	3	4	3	
	(1–8)	(1–8)	(1–8)	(2–8)	(1–7)	(1–7)	
Incidence rate ratio (95% CI)‡	0.88 (0.81–0.95)		0.83 (0.75–0.93)		0.93 (0.83–1.04)		.190
Treatment visits, median (range)	–	–	–	–	2	2	
					(0–39)	(0–16)	
Incidence rate ratio (95% CI)‡	–		–		0.77 (0.60–0.98)		N/A

N/A: not applicable.
*Adjusted for age group and sex.
**Adjusted for sex.
†Interaction between age group and region of residence.
‡Estimated from negative binomial regression.

reporting similar associations between oral health status and frequency of dental visits [10,11]. If patients are exposed to preventive information when visiting the dentist, then every visit may serve as a reminder of the importance of oral hygiene, which can affect oral-health-related attitudes. Though the self-reported data in our study did not indicate differences in oral hygiene, it is possible that a "reminder effect" not captured in our questionnaire could have led to temporal (rather than habitual) improved hygiene. It is also unknown whether children in Hordaland received more pit and fissure sealant services than children in the South region, though we observed a lower frequency of regular check-ups among residents of the South region. The evidence on the oral health benefits of frequent check-ups also needs further investigation, as concerns have been raised regarding the preventive utility and risk of overtreatment associated with frequent attendance patterns [12].

Study strengths and limitations

Our study combined self-reported information on various risk factors related to oral health and objective measures obtained from Public Dental Service records, including caries prevalence and severity and frequencies of regular check-ups, treatment visits, and professional fluoride applications.

Our study has some limitations. For example, the cross-sectional design could not establish a causal relationship between exposure and outcomes. Further, because caries is a cumulative process, the caries status of the 18-year-old study participants at the age of 12, might differ from that of the actual 12-year-old participants in this study. Following the same cohort over time would provide better information than that obtained by transversally investigating two different cohorts at the same time.

Self-reported data carry the risk of social-desirability bias with study participants reporting 'good' behaviour rather than an unbiased response regarding their oral hygiene habits. In theory, recall bias is another threat for self-reported data, though evidence suggests that this bias may be more relevant for subjective assessments than for concrete attitudes about tooth brushing and the amount or frequency of sugar consumption [13]. Although Public Dental Service practices in Norway are equipped with the same types of diagnostic tools, the observed differences in caries experience may be due to lack of calibration of personnel [14], though such proportion was low in Norway [15]. Other elements associated with participants' socio-economic positions, concepts, and beliefs, as well as organisational and functional details of the Public Dental Service, unaccounted for in our analyses, may have influenced the observed regional gradients in caries experience and severity.

Conclusions

We observed regional gradients in caries prevalence and severity among children living in western Norway. The self-reported oral health behaviour, consumption frequency and patterns of sugar-containing items, and demographic factors among study participants did not explain the observed regional gradients in their caries statuses. However, we observed regional differences in dental follow-up routines and treatment procedure frequencies that paralleled the observed regional gradients observed. Our findings suggest that the Public Dental Service should consider current and regional characteristics when establishing dental health policies such as recall intervals and daily routines for oral care. Strengthening the dental service and targeting individual caries risk factors and history at regular check-ups [16] may help improve overall paediatric dental health in Norway.

Disclosure statement

The corresponding author is an associate editor for *Acta Odontologica Scandinavica*.

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