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Age-Period-Cohort Analysis of Toothbrushing Frequency in Finnish Adults: Results From Annual National Cross-Sectional Surveys From 1978 to 2014

Eero Raittio^{a*,1}, Satu Helakorpi^b, Anna Liisa Suominen^{a,c,d}^a Institute of Dentistry, University of Eastern Finland, Kuopio, Finland^b Department of Welfare, Finnish Institute for Health and Welfare (THL), Helsinki, Finland^c Department of Oral and Maxillofacial Diseases, Kuopio University Hospital, Kuopio, Finland^d Public Health Evaluation and Projection Unit, Finnish Institute for Health and Welfare (THL) Helsinki, Finland

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ABSTRACT

Objectives: No previous study has analysed age-, period-, and cohort-related long-term trends in toothbrushing frequency among adults using a nationally representative data set. Our aim was to study age, period, and cohort effects on toothbrushing among 15- to 64-year-olds in Finland from 1978 to 2014.

Methods: Data were gathered by nationally representative random cross-sectional samples of 15- to 64-year-old Finns annually from 1978 to 2014, during which response rates decreased from 84% to 53%. The final pooled sample size was 119,665. An age-period-cohort model was used to separate the effects of age, period, and cohort on trends in men's and women's toothbrushing frequency.

Results: From 1978 to 2014, the proportion of respondents who brushed at least twice a day or once a day increased from 42% to 66% and from 83% to 95%, respectively. The proportion of respondents who brushed at least twice a day increased from 27% to 53% among men and from 60% to 75% among women. Increases in at least once-a-day toothbrushing were smaller in both sexes, and in women the increase was minimal over the study years. The increase in toothbrushing frequency occurred particularly among those older than 40 years of age. In men, toothbrushing frequency increased steadily cohort by cohort (cohort effect) and within a single cohort as men in the cohort got older (longitudinal age trend). Instead, in women the cohort effect and longitudinal age trend in toothbrushing were smaller at both frequency thresholds.

Conclusions: On the population level, favourable changes in toothbrushing habits occurred among adult Finns from 1978 to 2014, especially in men.

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Introduction

Dental diseases represent a major economic burden for societies. For instance, in the European Union, dental disease costs were the third-highest after diabetes and cardiovascular diseases.¹ Regular daily toothbrushing with fluoride toothpaste has long been seen as an important measure at all ages to maintain oral health for a lifetime. Toothbrushing is a

cornerstone of maintaining oral health in addition to a low-sugar or sugar-free diet and not smoking.^{1,2} Recently, the regular daily or twice-a-day toothbrushing frequency has been found to be associated with a lower risk of cardiovascular diseases³ and new onset of diabetes.⁴ Among adults, prevalence of twice-a-day toothbrushing varies from population to population. For instance, in Australia, the proportion of those brushing their teeth at least twice a day was 51% in 2016,⁵ whereas 75% of adults reported the same in the United Kingdom in 2009.⁶ In 2013, in Jönköping, Sweden, even as high as 85% of 3- to 80-year-olds brushed their teeth at least twice a day.⁷ However, there is a limited number of representative national population-based studies on toothbrushing frequency

* Corresponding author. Institute of Dentistry, University of Eastern Finland, Yliopistonranta 1, Kuopio, Finland.

E-mail address: eero.raittio@uef.fi (E. Raittio).

¹ ORCID ID Eero Raittio: 0000-0002-9258-9355

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in adult populations, especially with long follow-up periods. According to those few studies, toothbrushing frequency has increased in many countries.⁶⁻¹⁰ But that is not the same everywhere; in Australia⁵ and Finland,¹⁰ for instance, the proportion of people who brush their teeth at least twice a day has not increased from 2004 to 2016 or 2011 to 2017, and these national health surveys were cross-sectional and had long intervals between the surveys.

A small number of longitudinal studies on toothbrushing frequency among adults have been conducted in Norway and Sweden.^{11,12} They indicate relative stability of toothbrushing frequency over time, and the proportions of those who brushed their teeth twice per day remained high from ages 15 to 30 and 50 to 70.^{11,12} In addition to evidence implying that intergenerational transmission in health-related habits and beliefs shape those of the next generation,¹³ a New Zealand study found that intergenerational oral health beliefs influence toothbrushing habits.¹⁴ However, we are unaware of any detailed analyses on age-, period-, or cohort-related long-term trends in toothbrushing frequency in adults in the existing literature. Therefore, it is not known whether there are generational differences in toothbrushing habits, whether there have been any time-related variations in toothbrushing frequency, or how toothbrushing habits tend to change with age at the population level. However, monitoring toothbrushing habits could provide valuable information for oral health care planning purposes, such as advancing toothbrushing habits and techniques that are essential parts of preventive oral health care visits and overall oral health promotion. For instance, if toothbrushing frequency tends to increase during adulthood as people get older, dental professionals can take this into account when working with children and adults or when planning, implementing, or promoting oral health actions.

In addition, because sex-related differences in toothbrushing are common,^{15,16} this study aims to investigate the long-term trends of toothbrushing frequency among Finns of working age from 1978 to 2014 and assess the influences of age-, period-, and cohort-specific effects by sex under the age-period-cohort (APC) framework.

Methods

Data

Data used in this study were derived from the Health Behaviour and Health Among the Finnish Adult Population surveys conducted by the National Public Health Institute of Finland until 2008 and by the Finnish Institute for Health and Welfare from 2009 onwards. Nationally representative postal surveys of 15- to 64-year-old Finns have been conducted annually from 1978 to 2014. Each year the random samples of 5000 individuals were derived from the Population Register Centre of Finland.¹⁷ Survey questions remained mostly similar during these years, and information on toothbrushing frequency was gathered every study year. The response rate decreased steadily from 84% in 1978 to 53% in 2014. After exclusion of those with no remaining teeth ($n=11,022$) or missing information about toothbrushing frequency or number of missing

teeth ($n=2189$), our final pooled sample size was 119,665. More information about the Health Behaviour and Health Among the Finnish Adult Population surveys are provided elsewhere.¹⁷

All procedures performed in studies involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards and were approved by the national research ethical committees of National Public Health Institute of Finland and Finnish Institute for Health and Welfare. The study was reported in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

Toothbrushing frequency was elicited by the question, "How often do you tend to brush your teeth?", and the options were more than once a day, once a day, less than once a day, or never. We dichotomized the variable as "at least twice a day" and "less than twice a day" and as "at least once a day" and "less than once a day." Information about number of missing teeth (including wisdom teeth) was queried with the question, "How many of your teeth are missing?", and the options were no missing teeth, 1 to 5 missing teeth, 6 to 10 missing teeth, >10 missing teeth but not all, and all teeth missing. In addition, year of birth and sex information was gathered with the same questionnaires.

Statistical analyses

The APC model is a descriptive tool to analyse how age, period, and cohort are related to an outcome. The aim of our APC analysis was to estimate the contributions of age, period, and cohort effects on toothbrushing frequency separately for men and women. The age effects represent whether the toothbrushing frequency differs by age; the period effects represent variations in the toothbrushing frequency over time that influence all age groups simultaneously; and the cohort effects represent toothbrushing frequency changes across those with the same year of birth (ie, birth cohort).¹⁸⁻²⁰

To conduct the APC analysis with the Age-period-cohort Web Tool²¹ (Biostatistics Branch, National Cancer Institute), the toothbrushing frequency (both at least once a day and twice a day thresholds) and total population data were arranged using a 2-year period (ie, 1978-1980, 1981-1982, and so on) and age (ie, 15-16, 16-17, and so on) intervals. We focused on the following estimable functions from the Age-period-cohort Web Tool²¹: net drift (ie, estimated annual percentage change of the expected age-adjusted rates of toothbrushing frequency over time); local drifts (ie, annual percentage change of the expected age-specific rates of toothbrushing frequency over time); longitudinal age curve (ie, expected age-specific rates of toothbrushing frequency in a reference cohort adjusted for period effects); period rate ratios (ie, ratio of age-specific rates of toothbrushing frequency in each period relative to the reference period); and cohort rate ratios (ie, the ratio of age-specific rates of toothbrushing frequency in each cohort relative to a reference cohort).²¹ Results of the APC analysis were exported from the Age-period-cohort Web Tool to RStudio statistical software.²² Figures on period rate ratios, cohort rate ratios, longitudinal

age curve, and local drifts with net drifts for men and women were plotted using the ggplot2 package.²³

We also ran the described analyses with poststratification weights, which were computed using official age-sex distributions of the total Finnish adult population aged 15 to 64 years as the reference population.²⁴ However, the poststratification weighted results were identical to those generated without the weights. We decided to represent the unweighted results only because of the smoother calculation process with the unweighted data.

Results

The proportion of respondents who brushed their teeth at least twice a day increased from 42% to 66% (Table 1), and the proportion who brushed at least once a day increased from 83% to 95% during the study period from 1978 to 2014 (Table 2). More women than men brushed their teeth at least once or twice a day in every study year. From 1978 to 2014, the proportion of those who brushed at least twice a day increased from 27% to 53% among men and from 60% to 75% among

Table 1 – Proportion of respondents who brushed their teeth at least twice a day by sex, age group, and birth cohort from 1978 to 2014.

	At least twice a day												
	Total	Sex		Age group					Birth cohort				
		Men	Women	15-24	25-34	35-44	45-54	55-64	1914-1940	1941-1950	1951-1960	1961-1970	1971-1999
1978-1980	42	27	60	49	46	37	36	37	36	43	49	47	
1981-1982	45	29	64	50	49	43	38	39	39	46	51	48	
1983-1984	47	31	63	50	52	46	43	39	42	47	53	49	
1985-1986	50	32	66	52	54	48	47	43	45	48	54	52	41
1987-1988	49	32	65	50	55	50	45	41	42	48	56	51	48
1989-1990	50	33	65	50	55	52	46	38	40	50	55	54	44
1991-1992	52	36	66	52	57	54	49	43	44	51	56	57	48
1993-1994	52	36	67	48	56	57	51	47	47	51	58	56	47
1995-1996	52	36	67	51	56	56	50	45	44	51	56	55	51
1997-1998	53	38	66	50	55	58	52	48	47	51	56	56	51
1999-2000	54	37	68	52	55	57	54	48	51	50	59	56	53
2001-2002	54	39	67	48	57	57	57	51	51	51	59	56	51
2003-2004	55	40	68	52	57	57	58	50	46	51	59	58	54
2005-2006	57	42	69	54	60	57	59	53		52	59	57	57
2007-2008	59	45	70	56	63	59	61	58		58	59	60	60
2009-2010	64	49	75	60	65	66	67	60		56	66	67	63
2011-2012	64	49	75	63	67	65	64	61		60	63	63	66
2013-2014	66	53	75	61	65	71	66	65		63	66	66	66

Table 2 – Proportion of respondents who brushed their teeth at least once a day by sex, age group, and birth cohort from 1978 to 2014.

	At least once a day												
	Total	Sex		Age group					Birth cohort				
		Men	Women	15-24	25-34	35-44	45-54	55-64	1914-1940	1941-1950	1951-1960	1961-1970	1971-1999
1978-1980	83	71	96	86	86	81	76	78	78	84	87	85	
1981-1982	85	75	96	88	87	84	79	82	80	87	88	88	
1983-1984	87	76	97	88	89	87	83	82	83	87	90	87	
1985-1986	89	80	97	90	90	89	85	86	85	89	90	90	83
1987-1988	89	80	97	90	91	89	85	85	84	88	91	92	87
1989-1990	89	81	97	90	92	90	88	84	86	89	92	92	88
1991-1992	91	83	98	91	93	91	89	88	88	90	92	93	90
1993-1994	91	83	98	89	92	93	89	88	89	90	93	92	88
1995-1996	91	84	98	92	93	93	90	87	87	90	93	93	92
1997-1998	92	85	98	92	94	92	92	90	90	91	92	94	92
1999-2000	92	86	98	92	93	95	91	90	91	90	94	94	92
2001-2002	93	86	98	91	95	93	93	90	90	91	94	94	92
2003-2004	94	89	98	93	94	95	93	93	92	93	93	95	94
2005-2006	94	88	99	93	95	95	94	93		93	94	95	94
2007-2008	94	89	98	93	96	94	95	93		93	94	94	94
2009-2010	95	90	98	93	97	97	95	93		92	94	97	95
2011-2012	95	90	98	94	96	97	95	94		93	94	95	95
2013-2014	95	91	98	95	94	97	95	94		95	94	95	95

women. During the years 1978–1984, proportions of those who brushed at least once or twice a day was higher in younger than in the 2 oldest age groups. An increase in toothbrushing frequency occurred in all age groups but most occurred in the 2 oldest groups. Therefore, in the 2010s, the proportions of those brushing their teeth at least once or twice a day were equal in the oldest and youngest age groups, whereas the proportions were highest in the 35 to 44 age group. The oldest birth cohort (those born in 1914–40) had the lowest proportion of those who brushed their teeth at least once or twice a day. Increases in toothbrushing frequency occurred in all birth cohorts. Since the late 1990s, birth cohort-related differences have been small (Tables 1 and 2).

Total annual percentage change in proportion of those with at least twice-a-day toothbrushing frequency (net drifts) and annual percentage changes in each age (local drifts) are shown in Figure 1A. The net drift was 1.89% (95% CI 1.75%–2.02%) per year for men and 0.60% (95% CI 0.50%–0.70%) per year for women. Among women, local drifts were above zero except those around age 25, among whom annual percentage changes were close to zero. Among women, the highest annual percentage increases (around 1%) occurred among those older than 55 years of age. Among men, at least twice-a-day toothbrushing frequency increased more than 1% annually in all age groups. The highest average annual increase occurred in men aged 45 to 55, and the smallest in men around age 25.

The longitudinal age curves for men and women are shown in Figure 1B. Men in the same birth cohort had a strong increase in at least twice-a-day toothbrushing frequency with age, with the strongest increasing from ages 15 to 30. Among women in the same birth cohort, a relatively weak and steady increase in at least twice-a-day toothbrushing frequency occurred with age.

The estimated period and cohort rate ratios of at least twice-a-day toothbrushing frequency are displayed in Figure 1C and D, respectively. Period rate ratios showed that increase in at least twice-a-day toothbrushing frequency during study from 1978 to 2014 occurred in both sexes but were clearly stronger for men than for women. In both sexes, the increase was most rapid from 2000 to 2014. Cohort rate ratios showed that among men at least twice-a-day toothbrushing frequency increased strongly and steadily from the oldest cohort to youngest birth cohort. Among women, toothbrushing frequency increased strongly from the 1914 cohort to the 1957 cohort (reference); however, since then toothbrushing frequency remained at that level in the more recent birth cohorts.

Figure 2A–D shows similar plots for toothbrushing at least once a day. Average annual percentage increases were 0.70% (95% CI 0.60–0.79) in men and 0.08% (95% CI 0.00–0.16) in women and, thus, smaller than in the at least twice-a-day toothbrushing. However, similar shape but weaker (closer to 1) longitudinal age curve, period, and cohort rate ratios occurred in at least once-a-day toothbrushing in both men and women.

Table 3 shows the results of hypothesis tests. In the case of toothbrushing at least twice a day, local drifts were not equal to the net drift, the net drifts differed from 0, and cohort and period rate ratios for men and women were statistically significantly different from 1. Age and period deviations were

slightly smaller in magnitude than the cohort deviations in both sexes. In the case of toothbrushing at least once a day, only the net drift was statistically significantly different from 0 in women, and the hypothesis tests were not statistically significant. In men, the net drift differed from 0, but the drift was similar in all age groups. In addition, the period and cohort rate ratios differed from 1 which were statistically significantly in men.

Supporting material (Supplementary Files 1–4) including full sets of APC result output from the Age-period-cohort Web Tool can be found online.²¹

Discussion

A significant increase in the proportion of those who brushed their teeth at least twice a day occurred among 15- to 64-year-old Finns between 1978 and 2014. Toothbrushing at least twice a day increased in both sexes but more so in men. The increase was smaller in at least once-a-day toothbrushing, and among women the average annual increase in percentage was close to zero (0.08% per year). Our APC analysis revealed that: (1) cohort-related deviations were slightly stronger than age- or period-related deviations in at least twice-a-day toothbrushing; (2) the increase in toothbrushing frequency occurred particularly among those older than 40 years of age; (3) follow-up of the same birth cohorts showed that the proportion of those who brushed their teeth at least once or twice a day increased with age, especially in men; (4) among men, toothbrushing frequency increased cohort by cohort at both frequency thresholds; and (5) in women, at least twice-a-day toothbrushing frequency increased from the 1914 birth cohort to the 1957 birth cohort and remained at that level in more recent cohorts, whereas cohort-related differences in toothbrushing at least once-a-day were minimal.

To our knowledge, this is first detailed analysis of trends in toothbrushing frequency using the APC framework. This study has several strengths. First, the study had a relatively long study period and was conducted with the same questions to preserve comparability between the study years. Second, we used well-established and standardised APC methods and their representations.²¹ The main weakness of our study was significantly decreased response rate over the study period. Nonresponse analysis of the Health Behaviour and Health Among the Finnish Adult Population surveys 1978–2002 revealed that nonresponse had increased faster among younger than older people, faster in men than women, and also faster among people with less education.²⁵ In addition, the nonrespondents in this kind of survey also have clearly higher mortality rates than people who tend to respond to this kind of survey.²⁶ It is possible that the increased nonresponse over the study period has somewhat increased our estimates of toothbrushing frequency in later study years. However, the proportions of those who brushed their teeth at least twice a day were similar in nationally representative Finnish health surveys with higher response rates.^{9,10}

Findings of this study indicated that on the population level there has been favourable changes in toothbrushing habits from 1978 to 2014, especially in men. The increase in at

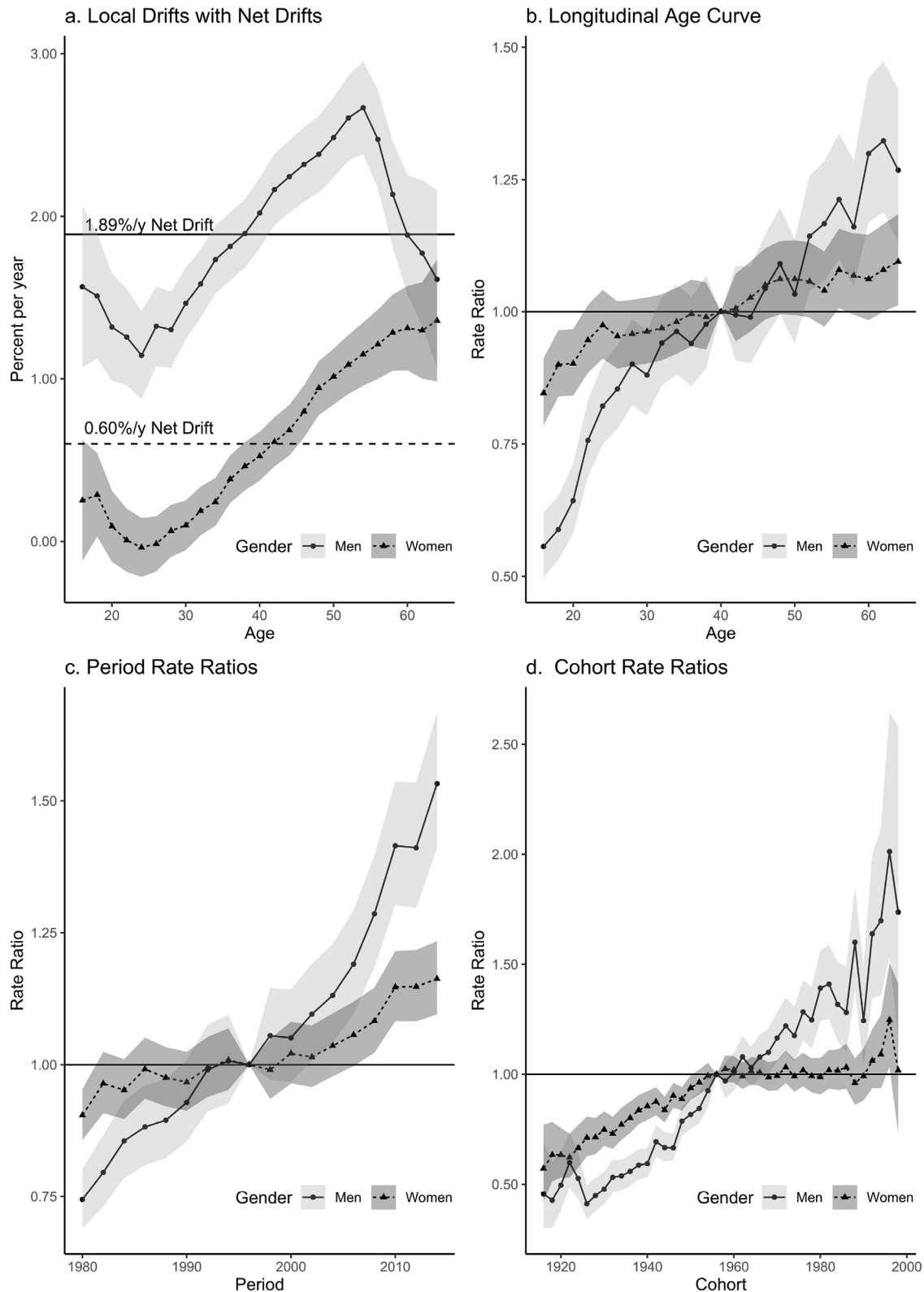


Fig. 1 – Graphical display of age-period-cohort analysis of at least twice-a-day toothbrushing frequency among 15- to 64-year-old Finns from 1978 to 2014. A, Net drift is annual percentage change of the expected age-adjusted rates of toothbrushing frequency over time, and local drifts are annual percentage change of the expected age-specific rates of toothbrushing frequency over time. B, Expected age-specific rates of toothbrushing frequency in a reference cohort adjusted for period effects. C, Ratio of age-specific rates of toothbrushing frequency in each period relative to a reference period. D, Ratio of age-specific rates of toothbrushing frequency in each cohort relative to a reference cohort. The shaded areas represent the 95% confidence intervals.

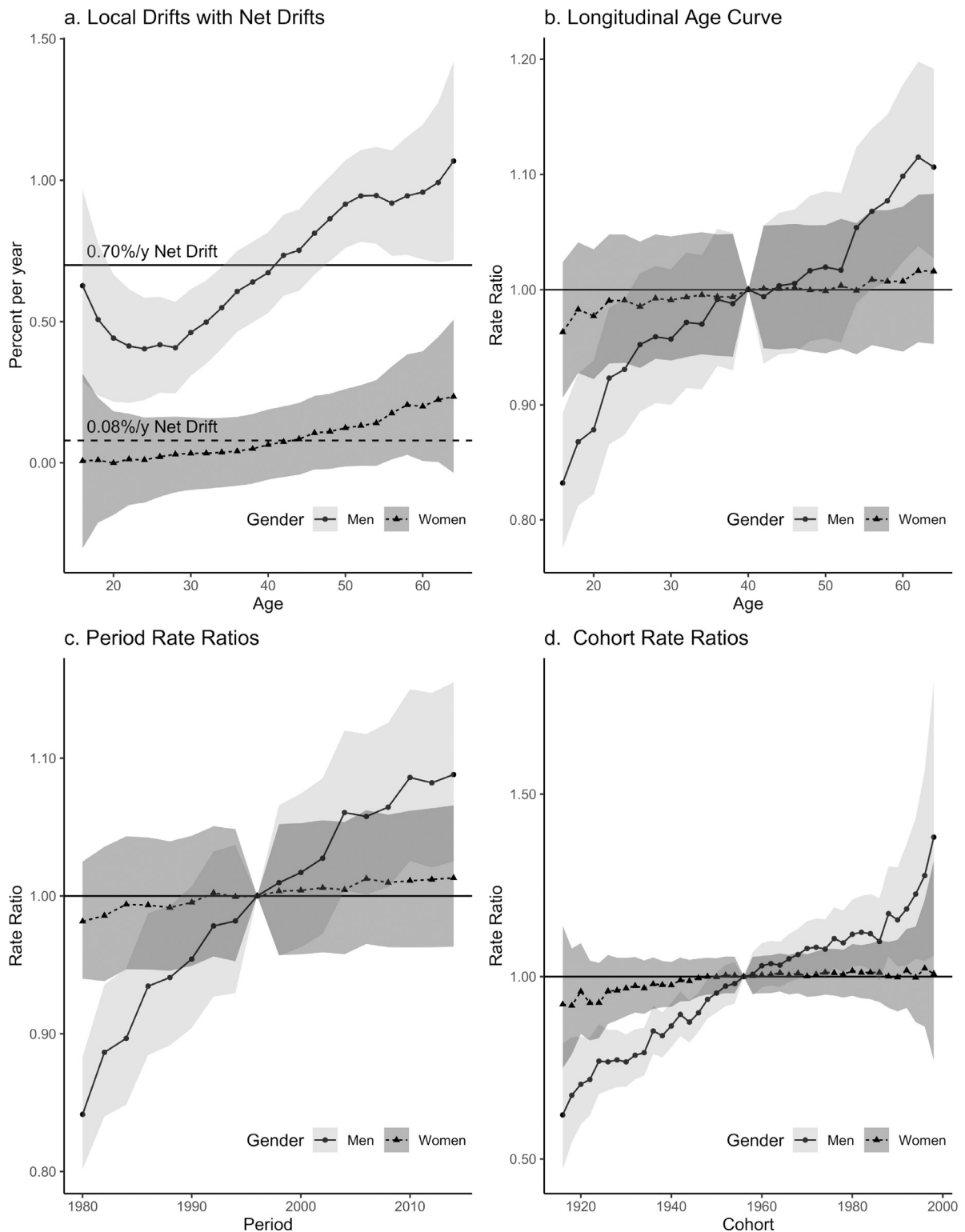


Fig. 2—Graphical display of age-period-cohort analysis of at least once-a-day toothbrushing frequency among 15- to 64-year-old Finns from 1978 to 2014. A, Net drift is annual percentage change of the expected age-adjusted rates of toothbrushing frequency over time, and local drifts are annual percentage change of the expected age-specific rates of toothbrushing frequency over time. B, Expected age-specific rates of toothbrushing frequency in a reference cohort adjusted for period effects. C, Ratio of age-specific rates of toothbrushing frequency in each period relative to a reference period. D, Ratio of age-specific rates of toothbrushing frequency in each cohort relative to a reference cohort. The shaded areas represent the 95% confidence intervals.

Table 3 – Summarisation of statistical hypothesis tests (χ^2 , df, and P) and their implications from age-period-cohort web tool.²¹

Null hypothesis	Implications	At least twice a day						At least once a day					
		Men			Women			Men			Women		
		χ^2	df	P	χ^2	df	P	χ^2	df	P	χ^2	df	P
Net drift = 0	Fitted longitudinal age curve is proportional.	731.3	1	<.001	150.5	1	<.001	218.4	1	<.001	4.3	1	0.04
All age deviations = 0	Fitted longitudinal age curve is log-linear (that is log-additive).	97.8	23	<.001	14.8	23	0.901	16	23	0.85	1.3	23	1.00
All period deviations = 0	Fitted period rate ratios are log-linear (that is log-additive).	25.6	16	0.06	23.0	16	0.115	15.1	16	0.52	0.4	16	1.00
All cohort deviations = 0	Cohort rate ratios are log-linear; all local drifts equal the net drift.	108.4	40	<.001	125.2	40	<.001	31.7	40	0.82	4.5	40	1.00
All period rate ratios = 1	Net drift is 0	797.9	17	<.001	182.3	17	<.001	272.9	17	<.001	5.3	17	1.00
All cohort rate ratios = 1	Net drift is 0 and all local drifts are 0; Longitudinal age curve describes age incidence pattern in every cohort.	853.4	41	<.001	254.8	41	<.001	249.4	41	<.001	8.4	41	1.00
All local drifts = the net drift	Temporal patterns are the same in every age group.	79.8	25	<.001	112.5	25	<.001	28.8	25	0.27	3.9	25	1.00

df, degrees of freedom.

least twice-a-day toothbrushing over the years was much stronger than in the at least once-a-day toothbrushing because the initial level in previous study years was much lower in the at least twice-a-day toothbrushing. APC analysis revealed that, first, there was a positive cohort effect that was slightly stronger than the age or period effects because toothbrushing frequency has increased cohort by cohort, indicating that younger generations have been more likely to adopt at least twice-a-day or once-a-day toothbrushing habits than previous cohorts. This cohort effect is at least partly explained by the intergenerational transmission of health habits.^{13,14} Unfortunately, the positive cohort effect occurred only in men throughout the study years, which had clearly lower toothbrushing frequency than women in the early study years. Secondly, despite smaller than the cohort effects, it seems that there is a positive period effect and that is there are some factors increasing toothbrushing frequency in all individuals during the period. This is likely related to improvements in the general standard of living and to greater awareness and interest in issues related to oral health. Perhaps the marketing of oral self-care products has increased along with support of the dental research community, in addition to, the dental and sugary food and drinks industries.²⁷ Additionally, strong national focus on public health promotion practices and policies emerged in in the 1970s in Finland which seem to have had considerable positive effects on oral health,²⁸ as well as, for instance, on cardiovascular diseases.²⁹ Third, it appears that within a single cohort, toothbrushing frequency increased steadily from age 15 to 64 years, and thus, it seems that at least at the population level a birth cohort can improve its toothbrushing habits throughout adulthood (ie, longitudinal age trend). However, this longitudinal age trend was clearly stronger in men than in women. Traditionally, oral health promotion and services have focused on children and adolescents and have not focused on adults.^{30,31} Fortunately, higher priority has been given to adult oral health care and promotion in recent

decades. For instance, all age-related restrictions on subsidized oral health care were abolished in Finland in the early 2000s.³¹

However, compared to the other Western European countries,^{6,7,32} the proportion of those brushing their teeth twice a day was still rather low among Finnish men in the 2010s. Internationally, Finnish boys' low toothbrushing frequency is seen in their adolescence.¹⁵ This may be linked with the wide sex-related differences in health in Finland. Finnish men smoke more, drink more alcohol, eat less healthfully, have higher cholesterol, higher blood pressure levels, more cardiovascular diseases, more diabetes, less social contacts, and trust other people less than Finnish women do.¹⁶ Thus, promoting twice-a-day toothbrushing habits should be connected to general health promotion of Finnish men, which must also address cultural factors behind their too-common health-harming lifestyles. In particular, as (oral) health behaviours tend to transfer intergenerationally,^{13,14} it is important to support children, adolescents, and their families, including fathers, to ensure that sex-related health differences will be smaller in the future.³³

Conclusions

Our findings indicate that the proportion of those who brushed their teeth at least once or twice a day increased among 15- to 64-year-old Finns from 1978 to 2014. APC analysis revealed age, period, and cohort effects in the trends of toothbrushing in men and women during the study period. The increase in toothbrushing frequency occurred particularly among those older than 40 years of age and was more pronounced in men than in women. The increase in at least once-a-day toothbrushing was smaller, and in women even minimal, over the study years compared with the increase in at least twice-a-day toothbrushing. In men, toothbrushing frequency increased steadily cohort by cohort (cohort effect)

and within a single cohort as men in the cohort got older (longitudinal age trend) at both frequency thresholds. In women, at least twice-a-day toothbrushing increased cohort by cohort only until the 1957 birth cohort, whereas the cohort effect in at least once-a-day toothbrushing was trivial. In addition, the longitudinal age trends were modest in women at both frequency thresholds. In our view, the detected increasing toothbrushing frequency with age, the positive cohort effects on toothbrushing (with likely intergenerational transmission), and the sex-related differences in age-period-cohort trends in toothbrushing habits should be considered in planning and implementing actions that promote oral health.

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Conflicts of interest

None disclosed.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.identj.2020.12.002](https://doi.org/10.1016/j.identj.2020.12.002).

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