

ORIGINAL ARTICLE



Association between alcohol use and periodontal pockets in Finnish adult population

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ABSTRACT

Objective: To investigate whether alcohol use is associated with deepened periodontal pockets and whether this association is dependent on age, gender or socioeconomic position (SEP).

Material and methods: This cross-sectional study, based on the Health 2000 Survey, consisted of dentate, non-smoking Finnish adults aged 30–65 years ($n = 3059$). The outcome was the number of teeth with deepened (≥ 4 mm) periodontal pockets. The exposure was self-reported alcohol use assessed as amount, frequency, and use over the risk limit. Zero-inflated negative binomial regression models were used to estimate relative risks (RRs) and 95% confidence intervals (95% CI).

Results: In this study, alcohol use did not consistently associate with the number of teeth with deepened periodontal pockets. An association with the number of teeth with deepened periodontal pockets was found among men, older participants, and those participants belonging to basic or intermediate educational groups. An association with poor periodontal health was observed among men or older participants who belonged to the basic or intermediate educational group, whereas such associations were not observed among those participants belonging to the higher educational group.

Conclusions: The association between alcohol use and periodontal health appears to be confounded by individual characteristics such as age, gender, and especially one's SEP.

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Introduction

Harmful alcohol use increases the risk for many diseases, but whether alcohol use is a risk for infectious periodontal disease is still unclear [1]. Earlier studies have suggested that alcohol use is unrelated to periodontal condition [2–4] or it has an adverse effect on periodontium [5–9] or it has a linear dose-response association with the risk of periodontitis [10] or even an inverse association with periodontitis [11].

Potential adverse effects can be attributed to a number of known harmful effects of alcohol. These include, for instance, the suppression of immunoregulatory cytokines and altered T and B-cell functioning [12,13]. Apart from alcohol's biological effects, studies have emphasized the fact that alcohol use is associated with several behavioral and lifestyle factors. For example, it has been observed that the effects of alcohol use are dependent on the individual's socioeconomic status [14] and gender [15]. It has also been reported that older people are more vulnerable to the effects of alcohol than are younger people [16].

Because harmful use of alcohol is a well-known risk for many diseases, we hypothesized that higher amounts or frequent intake of alcohol is a risk for periodontal diseases. In this study, we aimed to investigate whether alcohol use, measured by means of amount, frequency, and use over the risk limit, was associated with the number of teeth with deepened (≥ 4 mm) periodontal pockets among a representative non-smoking population. To provide new evidence on the role of age, gender, and socioeconomic position (SEP) on the association between alcohol use and the occurrence of teeth with deepened periodontal pockets, we performed stratified analyses among younger and older participants, among men and women, and among participants with different educational backgrounds.

Material and methods

Study design and study population

This study was based on the Health 2000 Survey, a nationally representative survey conducted in 2000–2001 by the

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 Supplemental data for this article can be accessed [here](#).

National Institute for Health and Welfare (THL) (formerly the National Public Health Institute [KTL] of Finland). The Survey had a two-stage stratified cluster sampling frame of 8028 Finnish adults aged ≥ 30 years and the data were collected through interviews, self-administered questionnaires, and clinical health examinations including oral health examinations and laboratory measurements. Written informed consent was obtained from all the participants. The Survey was approved by the Ethical Committee for Research in Epidemiology and Public Health at the Hospital District of Helsinki and Uusimaa. More information about the Health 2000 Survey is available in the report by Heistaro [17].

The participants in the present cross-sectional study consisted of 30–65-years-old, dentate (at least one natural tooth) subjects, who did not smoke and whose periodontal health was measured ($n = 3059$). Due to the high degree of co-occurrence of alcohol use with smoking, current smokers (daily and occasional) were excluded from the study. Supplementary analyses were performed in a population with identical restrictions but included both non-smokers (those who had never smoked, those who had smoked less than 100 times in their whole life but did not smoke during the study, and those who had quit smoking at least one month ago) and current smokers ($n = 4319$). This manuscript is in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for human observational studies.

Outcome variable

Five licensed dentists, who were trained and calibrated, performed the oral clinical examinations. The periodontal examinations were performed in a portable dental treatment unit with a portable chair using a fibre optic light, a fibre optic headlamp, a mouth mirror, and a WHO periodontal probe (Plandent Oyj, no. 19577) with a ball end and markings at 3.5 and 5.5 mm. A force of 20 g was used in the measurements (calibrated using a letter scale). The periodontal pocket depths were measured on four surfaces of each tooth (distobuccal, mid-buccal, mid-palatal/lingual and mesio-palatal/lingual) except third molars and tooth remnants. The deepest pocket depth measurement on each tooth was recorded as no pocket, a pocket with a depth of 4–5 mm or a pocket with a depth of ≥ 6 mm. For periodontal pocket measurements, the kappa values for inter-examiner and intra-examiner reliability were 0.41 and 0.83, respectively [18]. The pocket depth categories of 4–5 mm and ≥ 6 mm were merged for the statistical analyses. The number of teeth with deepened (≥ 4 mm) periodontal pockets was then used as the outcome variable (a count variable ranging from 0 to 28).

Explanatory variables

Information on alcohol use was collected through a questionnaire, in which participants were asked about their drinking behaviour, such as the amount, frequency, use over the risk limit, and type of alcohol use. The explanatory variables

used in this study were 1) amount of alcohol use in grams per week (g/week) (continuous and categorical), 2) frequency of alcohol use and 3) alcohol use over the risk limit.

Alcohol use in g/week was categorized into four groups of equal percentiles: non-users, 0.1–23.8 g/week, 23.9–79.4 g/week and 79.5–1303.5 g/week. The frequency of alcohol use during the past 12 months was categorized into three groups: none, seldom (varying between a couple of times a month to once a year) and often (at least once a week). Alcohol use over the risk limit was based on the maximum amount of alcohol consumed during any one drinking session in the past 12 months. Risk limit for men was defined as over seven portions and for women over four portions according to the guidelines of the National Public Health Institute of Finland at the time of the survey (a portion equals one bottle [1/3 l] of beer, a glass [12 cl] of mild wine, a glass [8 cl] of strong wine or a glass [4 cl] of spirits or other strong alcohol). This gender-specific variable for alcohol use over the risk limit was a dichotomized variable: no *versus* yes. Further information can be obtained from the Health 2000 questionnaire (https://thl.fi/documents/189940/4108213/T2002_eng.pdf/83a57f85-0acb-4b25-af7d-29d7bf4b2282).

Covariates

Information about age and gender of the participants was obtained from population registers. Age was used as a continuous variable in regression analyses, and in stratified analyses, it was categorized into two groups: 30–49 years and 50–65 years. Education was used to indicate the SEP of the participants. Responses about participants' educational level were categorized in three groups: basic, intermediate and higher. The basic level comprised subjects who had an education below the high school level, the intermediate level comprised those who had graduated from high school or from vocational school and the higher level of education comprised those who had graduated from a polytechnic or university. For the purpose of stratified analyses by age and gender within different socioeconomic groups, the categories of basic and intermediate educational levels were combined due to the lower number of subjects in the basic education category.

The subjects reported their toothbrushing frequency during an interview and it was categorized into three groups: twice a day or more, once a day, or less frequently. The interview also yielded information about the subjects' dental attendance patterns, and the question asked was 'Do you usually go to a dentist?' and the response options were 1) for regular check-ups, 2) only when you have a toothache or some other trouble and 3) never. For the statistical analyses, responses two and three were combined resulting in a dichotomous variable with response options: regular check-ups *versus* irregular check-ups.

Each participant's oral hygiene level was assessed by the presence of plaque, clinically measured using a modified version of the method described by Silness and L  e [19]. It was measured from three index teeth: the buccal surface of the

Table 1. Basic characteristics of the study population ($n = 3059$).

	All ($n = 3059$)	Men ($n = 1331$)	Women ($n = 1728$)	<i>p</i> Value
Age, mean (SD)	46.9 (9.7)	46.8 (9.6)	46.9 (9.7)	.362
Level of education (%)				.000
Basic	25.3	25.6	25.0	
Intermediate	35.6	41.7	30.4	
Higher	39.2	32.7	44.6	
Presence of plaque (%) ($n = 3041$)				.000
None	41.0	32.6	48.0	
In gingival margins	49.3	53.6	45.7	
Also elsewhere	9.7	13.8	6.3	
Toothbrushing frequency (%) ($n = 2958$)				.000
$\geq$ Twice a day	65.0	48.6	78.9	
Once a day	30.0	41.7	20.0	
Less frequently	5.0	9.7	1.1	
Dental attendance pattern (%) ($n = 2959$)				.000
Regular	65.2	59.9	69.6	
Irregular	34.8	40.1	30.4	
Total number of teeth, mean (SD)	24.4 (6.7)	24.6 (6.7)	24.2 (6.6)	.008
Number of teeth with periodontal pockets ≥ 4 mm, mean (SD)	3.4 (4.7)	4.1 (5.3)	2.7 (4.2)	.000
Alcohol use g/week, mean (SD)	67.4 (113.3)	107.5 (145.4)	33.6 (58.2)	.000
Alcohol use g/week (%)				.000
Non-users	25.5	17.4	32.3	
0.1–23.8	24.4	16.4	31.2	
23.9–79.4	24.5	24.3	24.6	
79.5–1303.5	25.6	42.0	11.9	
Alcohol use frequency (%)				.000
Never	11.2	9.2	12.8	
Seldom	47.4	37.6	55.7	
Often	41.4	53.2	31.5	
Alcohol use over the risk limit ^a (%)				.000
No	70.0	59.5	78.8	
Yes	30.0	40.5	21.3	
Occurrence of diabetes (%)				.131
Yes	5.6	6.2	5.1	
No	94.4	93.8	94.9	
Body mass index, mean (SD) ($n = 3058$)	26.7 (4.6)	27.2 (4.1)	26.4 (5.0)	.000
Use of lipid-lowering drugs (%) ($n = 3059$)				.000
No	69.2	65.7	72.2	
Yes	15.3	17.1	13.7	
Missing information	15.5	17.2	14.1	
Use of non-steroidal anti-inflammatory drugs (%) ($n = 3059$)				.000
No	55.8	56.4	55.3	
Yes	37.0	31.9	41.3	
Missing information	7.2	11.7	3.5	

SD: standard deviation

^aMen >7 portions and women >4 portions.

most posterior teeth on the right maxilla, the lingual surface of the most posterior teeth on the left mandible, and the buccal surface of the left mandibular canine. The oral hygiene level was categorized into three groups based on the presence of plaque; (1) no plaque, (2) plaque in gingival margins only and (3) plaque also elsewhere. The participants' oral hygiene level was indicated by the highest plaque scoring of any of the index teeth.

Information about participants' smoking habits was recorded through a health interview, in which participants were asked 'Do you currently smoke (cigarettes, cigars or pipe)?' and the response options were daily, occasionally and not at all. Those who reported 'not at all' were called as non-smokers and included those who had never smoked, smoked less than 100 times in their whole life but did not smoke during the study, and those who had quit smoking at least one month ago.

Diabetes was determined on the basis of a clinical health examination, laboratory tests and health interview. Subjects were deemed as diabetics if diagnosed with

diabetes earlier by a physician or if their fasting glucose level was 7.0 mmol/l or more, and/or in a situation where the fasting glucose was normal but the result of the glucose tolerance test was 11.1 mmol/l or more. Because numerous studies have reported periodontal diseases to be associated with obesity [20] and the use of drugs, such as lipid-lowering drugs [21,22] and nonsteroidal anti-inflammatory drugs (NSAIDs) [23], we used them as covariates in the regression models. The use of lipid-lowering drugs (yes/no) and the use of NSAIDs (yes/no) were assessed by an interview. Body mass index (BMI) was calculated mainly based on information about height and weight obtained during the clinical health examination, but in the case of missing data, information from the questionnaire was used [17].

Table 1 shows the basic characteristics of the study population and Table 2 shows the basic characteristics of the study population according to the number of teeth with deepened (≥ 4 mm) periodontal pockets. Supplementary tables, Tables S1 and S2, present the basic characteristics of

Table 2. Basic characteristics of the study population according to the number of teeth with deepened (≥ 4 mm) periodontal pockets ($n = 3059$).

	No teeth with periodontal pockets ≥ 4 mm ($n = 1254$)	At least one tooth with periodontal pocket ≥ 4 mm ($n = 1805$)	<i>p</i> Value
Age, mean (SD)	45.2 (9.8)	48.0 (9.4)	.000
Gender (%)			.000
Male	37.5	51.2	
Female	62.5	48.8	
Level of education (%)			.014
Basic	24.1	26.1	
Intermediate	33.7	36.8	
Higher	42.2	37.1	
Presence of plaque (%)	($n = 1240$)	($n = 1801$)	.000
None	54.0	32.2	
In gingival margins	40.5	55.3	
Also elsewhere	5.6	12.5	
Toothbrushing frequency (%)	($n = 1207$)	($n = 1751$)	.002
$\geq$ Twice a day	67.5	63.4	
Once a day	29.2	30.5	
Less frequently	3.4	6.1	
Dental attendance pattern (%)	($n = 1208$)	($n = 1751$)	.972
Regular	65.2	65.2	
Irregular	34.8	34.8	
Total number of teeth, mean (SD)	23.8 (7.5)	24.8 (6.0)	.599
Number of teeth with periodontal pockets ≥ 4 mm, mean (SD)	0	5.6 (5.0)	.000
Alcohol use g/week, mean (SD)	54.9 (89.1)	75.9 (126.4)	.000
Alcohol use g/week (%)			.003
Non-users	27.9	23.9	
0.1–23.8	25.2	23.9	
23.9 – 79.4	24.6	24.4	
79.5 – 1303.5	22.3	27.9	
Alcohol use frequency (%)			.040
Never	11.6	10.9	
Seldom	49.8	45.8	
Often	38.6	43.3	
Alcohol use over the risk limit ^a (%)			.014
No	72.5	68.3	
Yes	27.5	31.7	
Occurrence of diabetes (%)			.241
Yes	5.0	6.0	
No	95.0	94.0	
Body mass index, mean (SD)	26.3 (4.6)	27.1 (4.6)	.000
Use of lipid-lowering drugs (%)			.048
No	71.7	67.6	
Yes	14.3	15.9	
Missing information	14.0	16.5	
Use of non-steroidal anti-inflammatory drugs (%)			.293
No	55.2	56.3	
Yes	38.3	36.1	
Missing information	6.5	7.6	

SD: standard deviation

^aMen > 7 portions and women > 4 portions.

the study population according to the amount, frequency, and use over the risk limit of alcohol.

Statistical analyses

Relative risks (RRs) along with 95% confidence intervals (95% CI) were estimated using zero-inflated regression models with the probit option. In these models, the association between different alcohol use measures and the number of teeth with deepened periodontal pockets is estimated in two parts: a standard negative binomial model (covariates and the offset option) and a zero-inflated part with the inflate option (covariates). The covariates added into the regression models were age (continuous variable), gender, level of education, toothbrushing frequency, the presence of plaque, dental attendance pattern, BMI

(continuous variable), the occurrence of diabetes, the use of lipid-lowering drugs and the use of NSAIDs. The number of teeth in a log form was used as an offset variable in the analyses to take into account the number of teeth at risk. Subjects with missing data in any of the variables (except the use of lipid-lowering drugs and the use of NSAIDs, for which a missing information category was created) were automatically excluded during the regression analyses.

Stratified analyses were performed to examine the association between different alcohol use measures and the number of teeth with deepened periodontal pockets in different categories of age, gender, and education level. To study the role of SEP, subsequent stratified analyses by age and gender within different socioeconomic groups (subjects in the basic or intermediate level education groups and subjects in the higher education group) were also performed.

Table 3. Association between alcohol use and the number of teeth with deepened (≥ 4 mm) periodontal pockets in the study population and stratified according to gender and age.

Alcohol use	Overall (<i>n</i> = 2942) RR (95 % CI)	Gender		Age	
		Males (<i>n</i> = 1282) RR (95% CI)	Females (<i>n</i> = 1660) RR (95% CI)	(30 – 49 years) (<i>n</i> = 1740) RR (95% CI)	(50 – 65 years) (<i>n</i> = 1202) RR (95% CI)
g/week	1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)	1.0 (1.0 – 1.0)
g/week					
Non-users	1	1	1	1	1
0.1 – 23.8	1.0 (0.8 – 1.1)	1.0 (0.8 – 1.2)	0.9 (0.8 – 1.1)	0.9 (0.7 – 1.1)	1.0 (0.8 – 1.2)
23.9 – 79.4	1.1 (0.9 – 1.2)	1.2 (1.0 – 1.5)	1.0 (0.8 – 1.2)	1.0 (0.8 – 1.2)	1.1 (0.9 – 1.4)
79.5 – 1303.5	1.1 (1.0 – 1.3)	1.2 (1.0 – 1.4)	1.0 (0.8 – 1.3)	1.0 (0.8 – 1.2)	1.2 (1.0 – 1.5)
Frequency					
Never	1	1	1	1	1
Seldom	1.0 (0.9 – 1.3)	1.1 (0.9 – 1.4)	1.0 (0.8 – 1.3)	1.1 (0.8 – 1.5)	1.0 (0.8 – 1.2)
Often	1.1 (0.9 – 1.3)	1.3 (1.0 – 1.6)	1.0 (0.7 – 1.3)	1.1 (0.8 – 1.5)	1.1 (0.9 – 1.4)
Over the risk limit					
No	1	1	1	1	1
Yes	1.1 (1.0 – 1.2)	1.1 (1.0 – 1.2)	1.0 (0.9 – 1.2)	1.0 (0.8 – 1.1)	1.2 (1.0 – 1.4)

Adjusted relative risk (RR) with 95% confidence interval (CI).

Adjusted for age (continuous), gender, level of education, toothbrushing frequency, the presence of plaque, dental attendance pattern, BMI (continuous), the occurrence of diabetes, use of lipid-lowering drugs, use of non-steroidal anti-inflammatory drugs (NSAIDs) and number of teeth as an offset variable (log form). Statistically significant values are in bold.

Table 4. Association between alcohol use and the number of teeth with deepened (≥ 4 mm) periodontal pockets stratified according to the level of education.

Alcohol use	Basic education RR (95% CI) (<i>n</i> = 735)	Intermediate education RR (95% CI) (<i>n</i> = 1044)	Higher education RR (95% CI) (<i>n</i> = 1163)
g/week	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
g/week			
Non-users	1	1	1
0.1–23.8	1.0 (0.8–1.2)	1.1 (0.8–1.3)	0.9 (0.7–1.1)
23.9–79.4	1.1 (0.9–1.4)	1.2 (0.9–1.5)	0.9 (0.7–1.2)
79.5–1303.5	1.2 (0.9–1.6)	1.2 (1.0–1.5)	1.0 (0.7–1.2)
Frequency			
Never	1	1	1
Seldom	1.3 (1.0–1.7)	1.2 (0.9–1.5)	0.8 (0.6–1.1)
Often	1.2 (0.9–1.6)	1.4 (1.1–1.8)	0.8 (0.6–1.1)
Over the risk limit			
No	1	1	1
Yes	1.1 (0.9–1.4)	1.1 (0.9–1.3)	1.0 (0.8–1.2)

Adjusted relative risk (RR) with 95% confidence interval (CI).

Adjusted for age (continuous), gender, level of education, toothbrushing frequency, the presence of plaque, dental attendance pattern, BMI (continuous), the occurrence of diabetes, use of lipid-lowering drugs, use of non-steroidal anti-inflammatory drugs (NSAIDs) and number of teeth as an offset variable (log form).

Statistically significant values are in bold.

Supplementary analyses and additional stratified analyses were performed with identical restrictions in a population including both non-smokers and smokers. All statistical analyses were performed using STATA V.13.0 (Stata Corp, College Station, TX), which allowed us to take into account the complex survey design (two-stage stratified cluster-sampling design) and the post-stratum analysis weights to correct for the effect of non-response.

Results

Total population

No consistent association was found between any of the alcohol use measures and the number of teeth with deepened (≥ 4 mm) periodontal pockets in the non-smoking

population analysed as a whole. The RR estimates varied from 1.0 to 1.1 (Table 3).

Stratified analyses by gender, age and education

In the gender-stratified analyses, all risk estimates were slightly higher among men than among women. Among women, none of the alcohol use variables associated with the number of teeth with deepened periodontal pockets. Among men, the RR estimates varied between 1.0 and 1.3 (Table 3). In the age-stratified analyses, the amount of alcohol and use over the risk limit associated weakly with the number of teeth with deepened periodontal pockets among older participants (50–65 years) (Table 3).

In the stratified analyses, according to the level of education, all alcohol use variables associated, although weakly and in most cases statistically non-significantly with the number of teeth with deepened periodontal pockets among subjects with basic and intermediate education. Among the participants belonging to the higher educational group, practically no association between alcohol use (all variables) and the number of teeth with deepened periodontal pockets was found (Table 4).

Stratified analyses by age and gender within education groups

In the subsequent stratified analyses, all alcohol use variables (amount, frequency, and use over the risk limit) associated weakly although in many cases statistically significantly with the number of teeth with deepened periodontal pockets among the combined group (basic and intermediate educational group). In this combined group, the RR estimates varied among men between 1.1 and 1.4 and among women between 0.9 and 1.1. Among the older participants (50–65 years) of the combined group (basic and intermediate educational group), a positive association was found

Table 5. Association between alcohol use and the number of teeth with deepened (≥ 4 mm) periodontal pockets stratified according to gender and age among those with basic or intermediate education and among those with higher education.

	Basic education & intermediate education RR (95% CI) (n = 1779)					Higher education RR (95% CI) (n = 1163)				
	Overall	Gender		Age		Gender		Age		
		Males	Females	(30–49 years)	(50–65 years)	Males	Females	(30–49 years)	(50–65 years)	
	(n = 1779) RR (95% CI)	(n = 866) RR (95% CI)	(n = 913) RR (95% CI)	(n = 922) RR (95% CI)	(n = 857) RR (95% CI)	(n = 416) RR (95% CI)	(n = 747) RR (95% CI)	(n = 818) RR (95% CI)	(n = 345) RR (95% CI)	
Alcohol use										
g/week	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	
g/week										
Non-users	1	1	1	1	1	1	1	1	1	
0.1–23.8	1.0 (0.8–1.2)	1.1 (0.8–1.4)	1.0 (0.8–1.2)	0.9 (0.7–1.2)	1.1 (0.9–1.4)	1.0 (0.6–1.6)	0.9 (0.7–1.2)	0.8 (0.6–1.2)	0.8 (0.6–1.1)	
23.9–79.4	1.1 (0.9–1.3)	1.3 (1.0–1.7)	0.9 (0.7–1.2)	1.0 (0.8–1.4)	1.2 (1.0–1.5)	1.0 (0.6–1.5)	1.0 (0.8–1.4)	0.9 (0.6–1.3)	1.0 (0.7–1.4)	
79.5–1303.5	1.2 (1.0–1.4)	1.3 (1.1–1.6)	1.1 (0.8–1.4)	1.0 (0.8–1.3)	1.4 (1.1–1.7)	1.1 (0.7–1.7)	0.9 (0.6–1.3)	0.9 (0.6–1.4)	0.9 (0.6–1.3)	
Frequency										
Never	1	1	1	1	1	1	1	1	1	
Seldom	1.2 (1.0–1.4)	1.2 (1.0–1.6)	1.1 (0.8–1.5)	1.3 (1.0–1.7)	1.1 (0.9–1.4)	0.8 (0.4–1.6)	0.8 (0.5–1.2)	0.8 (0.5–1.3)	0.6 (0.4–1.0)	
Often	1.3 (1.1–1.6)	1.4 (1.1–1.8)	1.1 (0.8–1.6)	1.4 (1.0–1.9)	1.3 (1.0–1.6)	1.0 (0.6–1.9)	0.7 (0.4–1.0)	0.6 (0.4–1.1)	0.8 (0.5–1.3)	
Over the risk limit										
No	1	1	1	1	1	1	1	1	1	
Yes	1.1 (1.0–1.3)	1.1 (1.0–1.3)	1.1 (0.9–1.3)	1.0 (0.8–1.2)	1.2 (1.0–1.4)	1.1 (0.8–1.5)	0.9 (0.6–1.2)	1.0 (0.8–1.3)	1.1 (0.8–1.4)	

Adjusted relative risk (RR) with 95% confidence interval (CI).

Adjusted for age (continuous), gender, level of education, toothbrushing frequency, the presence of plaque, dental attendance pattern, BMI (continuous), the occurrence of diabetes, use of lipid-lowering drugs, use of non-steroidal anti-inflammatory drugs (NSAIDs) and number of teeth as an offset variable (log form).

Statistically significant values are in bold.

between all alcohol use variables and the number of teeth with deepened periodontal pockets. Among the higher educational group, men had slightly higher risk estimates than women. In this higher educational group, the RR estimates were in most cases below 1.0 and did not exceed 1.1 (Table 5).

Supplementary analyses

Supplementary analyses with the same restrictions in the population including both non-smokers and smokers were also performed. Those results (Tables S3 and S5) followed a similar pattern as in the analyses among non-smokers: men had higher risk estimates than women and risk estimates were higher in the combined group (basic and intermediate educational group) than in the higher educational group. In most cases, the risk estimates were higher among the older age group than the younger age group (Tables S3 and S5).

Discussion

Statement of principal findings and overall comparison with other studies

Earlier studies using pocket depth as an outcome have reported an association between high alcohol use and periodontal pockets [8,24–26]. Similar results have also been reported among the non-smoking population [27]. A recent meta-analysis by Wang et al. [10] reported that alcohol use is associated with periodontal disease and this association follows a dose–response pattern. In contrast to those studies, we did not observe a consistent association between various measures of alcohol use and the number of teeth with deepened (≥ 4 mm) periodontal pockets in this study. Our findings are in line with the study by Okamoto et al. [3], who reported no association between alcohol consumption and periodontal disease development based on community

periodontal index (CPI) scores. On the other hand, we found various measures of alcohol use to be associated with the number of teeth with deepened periodontal pockets among men, older participants, and adults with basic or intermediate education levels. These findings are discussed below in relation to previous studies and the results of stratified analyses of this study.

The results of stratified analyses

In this study, we observed that risk estimates were somewhat higher among older adults. These results are partly in line with the findings by Sakki et al. [24], who reported alcohol use to be associated with poor periodontal health among older people. However, subsequent stratified analyses in these data showed that there was a positive association with the number of teeth with deepened periodontal pockets only in the combined group (basic and intermediate educational groups), whereas alcohol use was not associated with poor periodontal health in the higher educational group. This inconsistency, either harmful or even beneficial effects depending on SEP, supports the idea that the association between alcohol use and periodontal health is confounded by SEP or related factors. This is not surprising, as earlier studies have shown SEP to associate with both alcohol use [28] and oral health [29,30].

The observation that alcohol use was associated with the number of teeth with deepened periodontal pockets among males, but not among females, is in line with the study by Kim et al. [27], who reported that harmful alcohol use was associated more strongly with CPI scores among men than women. In this context, it is worth remembering that the results are in many cases conflicting. For example, a study among men by Okamoto et al. [3] reported no association between alcohol use and the development of periodontal disease, measured as CPI scores, while another study

reported beneficial effect of alcohol use, particularly wine, among men [11]. One of the explanations for the gender differences in alcohol effects in this study can be attributed to the differences between genders in alcohol pharmacokinetics [31,32] and different drinking habits [33]. However, when we examined these data in more detail, the positive association among men was found only in the combined group (basic and intermediate education group), but not among those men belonging to the higher educational group, analogous to what was found in relation to age.

The role of SEP is unclear and its role has not been studied systematically. Earlier studies among Japanese factory workers have shown alcohol to be associated with poor periodontal condition [8,34] or worsening of periodontal condition [26]. These studies [8,26] also suggest that the aldehyde dehydrogenase (ALDH) genotype determines the effects of alcohol. Apart from the genotype finding, these above-mentioned findings concur with the finding of this study in the sense that the harmful effect of alcohol use on periodontium was observed among basic and intermediate educational groups. This is not by any means surprising, because earlier studies suggest that the health effects of alcohol use are dependent on one's socioeconomic status [14]. In contrast to these earlier-mentioned studies, a study conducted among male health professionals reported that alcohol intake was associated with self-reported periodontitis [7].

One possible explanation for the findings of the present study is differences in drinking patterns or type of beverages, or both which may possibly determine whether alcohol use has beneficial or harmful effects. An alternative explanation can be that the health habits associate differently with alcohol use in different socioeconomic groups. In this case, it implies the inability to control these behavioural factors in the analyses. Based on the above-mentioned aspects, it is self-evident that it is difficult to provide a definite explanation for why the effects of alcohol use on periodontal health – harmful, none, or beneficial – appear to depend mostly on one's SEP. However, the lack of a plausible biological explanation related to the role of SEP lends support to the conception that the findings can be attributed to confounding. It is worth emphasizing that the variation in results between studies can also be a result of many other factors, such as the variation in the methods of assessment of alcohol use, cut-off points of alcohol variables, periodontal condition measurement and the study design.

We performed supplementary analyses among this population including smokers. It is worth noting that in spite of the fact that the results of these analyses are quite well in line with the results of analyses that were conducted in a non-smoking population, the supplementary analyses are subjected to bias due to smoking-related residual confounding. It is also important to acknowledge that the risk estimates were more conservative, i.e. closer to one, in these supplementary analyses. This could relate to large heterogeneity in the general population, together with the inability to adjust for the confounding effect of smoking and other variables by means of statistical methods.

Strengths and limitations

One of the strengths of this study was that it was based on a large, nationally representative sample of the Finnish non-smoking adult population. The external validity (generalizability) was increased by using post-stratum weights to correct for non-response, and internal validity was increased by using restrictions and multivariate regression models to control for confounding. Despite being representative, it should be pointed out that the participants of this survey were fairly healthy (based on dental health behaviours such as tooth-brushing and dental attendance pattern), which makes it challenging to detect the association between alcohol use and periodontal condition. This healthiness could be related at least partly to the absence of a smoking habit.

There are some aspects related to the measurements that should also be pointed out. First, self-reported alcohol use may result in underreporting of alcohol intake, which is of course a limitation, but is almost unavoidable in epidemiological studies that focus on the adverse effects of alcohol. On the other hand, one of the strengths was that alcohol use variables covered various dimensions: amount, frequency, and use over the risk limit. The use over the risk limit variable had gender-specific cut-off values to take into account the different biological effects of alcohol between genders [35].

There are also limitations related to measurement of periodontal condition. Because the outcome variable was based only on pocket depth measurements and was recorded from four predetermined sites only, it may underestimate the actual extent of periodontal inflammation. Additionally, the moderate inter-examiner reliability for periodontal pocket measurement (percentual agreement of 77%, kappa value 0.41) and the fact that the field dentists reported fewer teeth with deepened periodontal pockets than the reference dentist most likely have led to a bias towards zero, which can be considered as one of the limitations. In contrast, the quite high intra-examiner reliability (kappa value 0.83), on the other hand, suggests that the repeatability of the measurements was at an acceptable level [20]. Another limitation is the use of only one periodontal disease parameter, i.e. periodontal pocket depth, instead of combining it with clinical attachment loss (CAL). It must be kept in mind that pocket depth does not correspond with clinically diagnosed chronic periodontitis. However, it is important to note that periodontal pocket depth reflects the present inflammatory condition while measures using combined criteria including CAL and pocket depth put more weight to the disease history [36]. Despite a certain level of robustness, the pocket variable used in this study has been shown to be associated fairly strongly, or at least in an expected way, with BMI [20], insulin resistance [37] and smoking [38]. Regarding the 4 mm cut-off value for deepened periodontal pocket used in this study, it is worth mentioning that this cut-off value is commonly used in epidemiological [39] and clinical practice.

Lastly, it is self-evident that no inferences about causality can be drawn due to the cross-sectional design of the study.

Future questions

The social gradient in alcohol effects on periodontal health could be attributed to a number of factors, including different drinking patterns, different beverage intake or different health behaviours between different socioeconomic groups. Hence, future longitudinal studies are warranted to investigate the role of drinking patterns and type of beverage in the association between alcohol use and periodontal health. Also, the role of SEP should be taken into account in the analyses, either in confounding control or in study design, to obtain unbiased results.

Conclusion

This study suggests that an association between alcohol use and periodontal health is confounded by individual characteristics such as age, gender and especially one's SEP.

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Disclosure statement

The authors declare no conflicts of interests and have nothing to disclose in this study.

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