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# Serum cholesterol ratios and periodontal infection: results of the Health 2000 Survey

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***Abstract***

**Aim:** The aim of this cross-sectional study was to investigate whether serum total cholesterol/high-density lipoprotein cholesterol (TC/HDL) ratio and low-density lipoprotein cholesterol/high-density lipoprotein cholesterol (LDL/HDL) ratio are associated with periodontal infection.

**Materials and Methods:** This study was based on a subpopulation of the Health 2000 Survey, which included dentate, non-diabetic subjects who had never smoked and who were aged between 30 and 49 years ($n = 1297$). The numbers of teeth with deepened (4 mm deep or deeper) and with deep (6 mm deep or deeper) periodontal pockets were used as outcome variables, as well as the presence of gingival bleeding.

**Results:** We found no consistent associations between TC/HDL or LDL/HDL ratios and the number of teeth with deepened periodontal pockets or the presence of gingival bleeding among normal weight subjects. Nor were there any consistent associations between TC/HDL or LDL/HDL ratios and the number of teeth with deepened periodontal pockets or the presence of gingival bleeding among subjects whose body mass index was 25 or more.

**Conclusions:** This study does not provide evidence that unfavourable lipid composition can be considered as an important risk for periodontal infection in a general adult population.

Key words: lipids; periodontal infection

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It has been proposed that elevated serum lipid levels cause a pro-inflammatory state, which leads to an increase in oxidative stress, resulting in an imbalance between the production of highly reactive molecular species and antioxidant defences, consequently predisposing one to infections (Bullon et al. 2009). Earlier studies have produced inconsistent results as to whether altered lipid composition, characterized by the excess of serum total cholesterol, low-density lipoprotein cholesterol (LDL) and triglycerides and by the decreased high-density lipoprotein cholesterol (HDL), in the blood has an effect on periodontal condition. Several studies (Lösche et al. 2000, Katz et al. 2001, Buhlin et al. 2003, Pussinen et al. 2004, Lösche et al. 2005) reported an association between different subfractions of serum lipids and an increased likelihood of periodontal infection. On the other hand, contradictory findings have also been reported by Machado et al. (2005) and partly by Saxlin et al. (2008).

In cardiovascular medicine, it has been proposed that the overall balance between atherogenic lipoproteins and anti-atherogenic lipoproteins relates more strongly to lipoprotein-related risk than individual lipoprotein levels, which has led to the use of ratio measures, such as total cholesterol (TC)/HDL ratio and LDL/HDL ratio, to express this balance (Natarajan et al. 2003). In periodontology, the role of serum lipids has been studied during the last decade, but despite the known anti-inflammatory properties of HDL, no studies exist on the role of the balance between anti-inflammatory and inflammatory serum lipid subfractions in the development of periodontal infection.

**Conflict of interest and sources of funding statement**

The authors declare that there are no conflicts of interests.

The present study is part of the Health 2000 Survey, organized by the National Institute for Health and Welfare (THL) [former National Public Health Institute (KTL) of Finland] (http://www.terveys2000.fi), and is partly supported by The Finnish Dental Society Apollonia and The Finnish Dental Association. A personal grant from the Finnish Dental Society Apollonia and the Finnish Dental Association is acknowledged by Tuomas Saxlin.

On the basis of observations in earlier studies, we hypothesized that unfavourable ratios of lipoprotein subfractions have a more deleterious impact on the development of periodontal infection than any of the lipid subfractions alone. The aim of this cross-sectional study was therefore to investigate whether different ratios of lipid fractions commonly used in cardiovascular medicine, that is, TC/HDL ratio and LDL/HDL ratio, are associated with periodontal infection.

## Materials and Methods

### Study design

The Health 2000 Survey was carried out in 2000 and 2001 by the National Institute of Health and Welfare (THL), formerly known as National Public Health Institute of Finland (KTL). The survey included 8028 individuals aged 30 years or older living in continental Finland. Data were collected through clinical oral and health examinations, laboratory analyses, self-administered questionnaires and by interviews (Aromaa & Koskinen 2004).

This study was based on a subpopulation of subjects who were dentate, non-diabetic, aged under 50 years and who had never smoked ($n = 1297$). Diabetics and subjects without a diabetes diagnosis but whose fasting glucose was $\geqslant 7.0$ mmol/l or whose glucose tolerance test was $\geqslant 11.1$ mmol/l were excluded because of the complex association between diabetes and dyslipidaemia.

Informed consent was obtained from the participants of the survey. The study protocol was approved by the Ethical Committee for Epidemiology and Public Health of the Hospital District of Helsinki and Uusimaa.

### Outcome variables

The clinical oral examinations were performed by five calibrated dentists who used a dental chair, a headlamp, a mouth mirror and a WHO periodontal probe in line with WHO instructions (Suominen-Taipale et al. 2004). Periodontal pocket depth was measured on four surfaces of each tooth (distobuccal, mid-buccal, mid-oral, mesio-oral), except third molars and radices. The deepest probing depth measurement on each tooth was recorded as ''no deepened periodontal pocket depth'', ''pocket depth of 4–5 mm'', and ''pocket depth of 6 mm or more''. On the basis of these measurements, two variables were formed: the extent of periodontal infection, which was defined by means of the number of teeth with deepened periodontal pockets (4 mm deep or deeper), and the extent of more severe periodontal infection, which was defined by means of the number of teeth with deep periodontal pockets (6 mm deep or deeper). The distributions of the number of teeth with deepened periodontal pockets are presented in Fig. 1.

During the field stage, the reliability of clinical measurements was assessed by means of parallel ($n = 269$) and repeat ($n = 111$) measurements. In the case of periodontal pocket depth measurements, the parallel measurements, which aimed to assess inter-examiner reliability, i.e. concordance between examiners and the reference examiner, resulted in a percentual agreement of 77% ($\kappa$ 0.41), and for intra-examiner reliability, which assesses repeatability within examiners, the $\kappa$ value was 0.83 (Vehkalahti et al. 2004, 2008).

Bleeding on probing was used as a secondary outcome variable. It was observed immediately after the measurement of periodontal pockets and the observations were recorded by sextants. The parallel measurements of the presence of gingival bleeding resulted in a percentual agreement of 66% ($\kappa$ 0.36), and for intra-examiner reliability the $\kappa$ value was 0.66 (Vehkalahti et al. 2004, 2008).

### Explanatory variables

Serum HDL and LDL cholesterols were measured by using direct methods based on immunocomplex separation, followed by enzymatic cholesterol determination (Roche Diagnostics, Mannheim, Germany) (Reunanen et al. 2004). Serum TC/HDL ratio was categorized into quartiles as follows: TC/HDL $\leqslant 3.3$, $3.3 <$ TC/HDL $\leqslant 4.0$, $4.0 <$ TC/HDL $\leqslant 5.0$ and TC/HDL $> 5.0$. The LDL/HDL ratio was also categorized into quartiles: LDL/HDL $\leqslant 1.9$, $1.9 <$ LDL/HDL $\leqslant 2.5$, $2.5 <$ LDL/HDL $\leqslant 3.4$ and LDL/HDL $> 3.4$.

### Other covariates

We used gender, age, education and factors related to dental health behaviour as covariates in the multivariate models. Education was categorized into three categories (basic, intermediate, higher). The basic level consisted of subjects with educational qualifications lower than high school and who had no formal vocational qualifications. The intermediate level included those who had graduated from high school or vocational school. The highest category comprised those who had graduated from university or polytechnics.

Dental behavioural factors included tooth brushing frequency, dental attendance patterns and oral hygiene. Tooth brushing frequency was categorized into three categories: twice a day or more often, once a day or more seldom. Dental attendance pattern was dichotomized: those who had dental check-ups regularly *versus* those who used dental services only in case of pain or toothache, or had never used them.

The presence of visible plaque was recorded by tooth using a scale modified from the index by Silness & Löe (1964) as ''no visible plaque'', ''plaque on gingival margins only'', and ''plaque elsewhere also''. The presence of dental

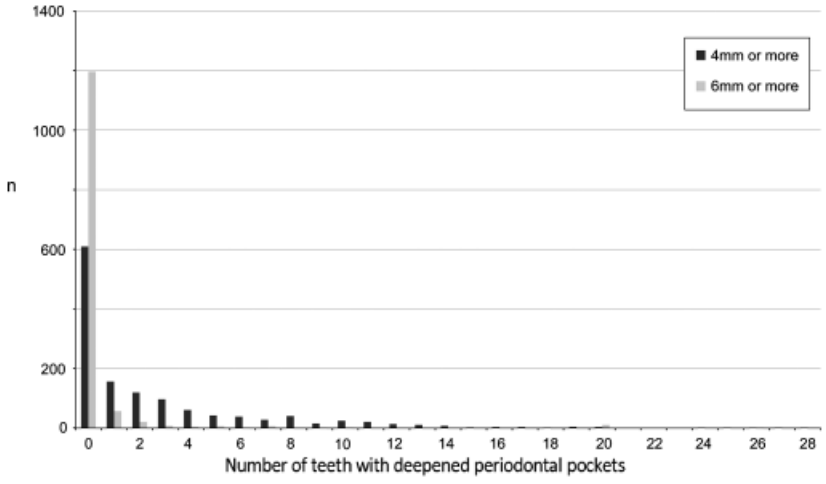


*Fig. 1.* Number of subjects with teeth with deepened periodontal pockets in the whole study population.

plaque was measured from indicator teeth on one surface each as follows: buccal surface on the most posterior tooth on the upper right side, lingual surface on the most posterior tooth on the lower left side and buccal surface on the lower left canine. The highest recordings of any of the indicator teeth described a subject's plaque status. The percentual agreement for the presence of dental plaque between the examiners and the reference examiner in the parallel measurements was 58% ($\kappa$ 0.36) and the $\kappa$ value for intra-examiner reliability was 0.79 (Vehkalahti et al. 2004, 2008).

Information about lipid-lowering medication, non-steroidal anti-inflammatory drugs (NSAID) as well as about alcohol consumption was obtained from a health interview and from the questionnaire. The use of lipid-lowering medication was categorized into three categories: yes/no/missing data, as well as the use of NSAID. Alcohol consumption was treated as a continuous variable (estimated amount of alcohol per week, in grams) in the multivariate analyses.

Body weight was measured by using body mass index (BMI), which is a measure of body weight in relation to height (kg/m$^2$). Information about weight and height was collected primarily in clinical examinations, but information from a questionnaire was used where data were not recorded in the clinical examination. BMI was divided into two categories in the analyses according to the WHO definition for overweight, where BMI of $<25$ is defined as normal weight subjects and BMI of 25 or over is classified as overweight/obese subjects. The basic characteristics of the study population are presented in Tables 1, 2 and 3.

### Statistical methods

Relative risks and odds ratios with 95% confidence intervals were estimated using Poisson's regression and logistic regression models, respectively. The number of teeth as a continuous variable was treated as the offset variable in the Poisson's regression models. The selection of covariates was based on the criteria for the confounder. Firstly, they are predictive for the outcome, periodontal infection. Secondly, they are unequally distributed across the categories of the explanatory variables (Tables 2 and 3). Thirdly, they are not an intermediate step in a causal path between the exposure variable and the outcome variable.

In order to exclude the possible confounding effect of body weight, stratified analyses according to BMI (BMI $<25$ *versus* 25 or over) were performed.

A stratified two-stage cluster sampling design was used in the survey. Owing to cluster sampling and weighting, the data were analysed using a REPEATED option and the independent working correlation matrix (Cole 2001). The weighting of the sample was based on post-stratification according to gender, age and region. SAS version 9.2 statistical software (SAS Institute Inc., Cary, NC, USA) was used in the analyses.

## Results

Among the total population, a weak and statistically insignificant association of serum TC/HDL ratio with the number of teeth with deepened (4 mm deep or deeper) periodontal pockets was found after adjusting for confounding factors such as gender, age, education, tooth brushing frequency, dental attendance pattern, presence of dental plaque, the use of lipid medication, the use of NSAID medication and BMI (Table 4). Otherwise, there were no consistent associations of the serum TC/HDL or LDL/HDL ratios with the number of teeth with deepened periodontal pockets or with the number of teeth with deep (6 mm deep or deeper) periodontal pockets. Nor were there any consistent associations between the TC/HDL or LDL/HDL ratios with gingival bleeding (Table 4).

The results of the stratified analyses showed that there were no consistent associations of the TC/HDL or LDL/HDL ratios with the number of teeth with deepened (4 mm deep or deeper) or deep (6 mm deep or deeper) periodontal pockets among normal weight subjects (BMI $<25$) (Table 4). There were no consistent associations of the TC/HDL or LDL/HDL ratios with gingival bleeding among normal weight subjects either (Table 4).

Among overweight or obese subjects (BMI 25 or more), there were weak, inconsistent and statistically insignificant associations of the TC/HDL and LDL/HDL ratios with the number of teeth with deepened (4 mm deep or deeper) periodontal pockets and with the number of teeth with deep (6 mm deep or deeper) periodontal pockets. There was also a weak, insignificant association of the TC/HDL ratio, but not of the LDL/HDL ratio, with gingival bleeding (Table 4).

## Discussion

We hypothesized that ratios of serum lipids, which reflect anti-inflammatory and pro-inflammatory balance, that is, serum TC/HDL or LDL/HDL, could be associated with periodontal infection. This hypothesis was based on the well-known anti-inflammatory properties of HDL (Ansell et al. 2005, Navab et al. 2007) as well as on previous observations according to which single lipids were also found to be associated with periodontal infection (Lösche et al. 2000, Katz et al. 2001, Buhlin et al. 2003, Pussinen et al. 2004, Lösche et al. 2005). Despite a seemingly credible hypothesis, we had to reject it and conclude that among normal weight subjects there were no consistent associations either of the TC/HDL ratio or the LDL/HDL ratio with the number of teeth with deepened periodontal pockets or gingival bleeding, and that among overweight or obese subjects (BMI 25 or more) there was a weak, inconsistent and statistically insignificant association of the TC/HDL and LDL/HDL ratios with the number of teeth with deepened periodontal pockets.

Our findings are in accordance with the earlier study of our research group, where serum lipids, separately studied, were not associated with an increased likelihood of periodontal infection among normal weight subjects, but were associated with the presence of deepened periodontal pockets among overweight subjects (Saxlin et al. 2008). The results of this study add to our knowledge by suggesting that neither TC/HDL nor LDL/HDL ratios, which are commonly used parameters in cardiovascular medicine and which reflect the anti-inflammatory/inflammatory balance in serum lipids, are important risks for periodontal infection among normal weight subjects.

In these data, we found TC/HDL and LDL/HDL ratios to be associated with the number of teeth with deepened periodontal pockets among overweight subjects; but these associations were fairly weak and more importantly, inconsistent. Yet, based on the results

*Table 1.* Mean number of teeth with deepened (4 mm deep or deeper) and deep (6 mm deep or deeper) periodontal pockets

| | *n* | Mean number with standard error of | |
|---|---|---|---|
| | | teeth with periodontal pockets ⩾4 mm | teeth with periodontal pockets ⩾6 mm |
| Total | 1297 | 2.6 (0.2) | 0.2 (0.0) |
| Gender | | | |
| Male | 509 | 3.2 (0.2) | 0.3 (0.1) |
| Female | 788 | 2.1 (0.2) | 0.1 (0.0) |
| Age | | | |
| 30–39 years | 679 | 2.1 (0.2) | 0.1 (0.0) |
| 40–49 years | 618 | 3.0 (0.2) | 0.3 (0.1) |
| Education | | | |
| Basic | 153 | 3.6 (0.4) | 0.5 (0.2) |
| Intermediate | 472 | 2.7 (0.2) | 0.3 (0.1) |
| Higher | 672 | 2.2 (0.2) | 0.1 (0.0) |
| Tooth brushing frequency | | | |
| Twice a day or more often | 872 | 2.4 (0.2) | 0.2 (0.0) |
| Once a day | 332 | 2.7 (0.3) | 0.3 (0.1) |
| More seldom | 49 | 4.9 (0.8) | 0.6 (0.2) |
| Dental attendance pattern | | | |
| Regular check-ups | 868 | 2.3 (0.2) | 0.1 (0.0) |
| Irregularly | 385 | 3.3 (0.3) | 0.4 (0.1) |
| Presence of dental plaque | | | |
| No plaque | 534 | 1.4 (0.2) | 0.1 (0.0) |
| Plaque at gingival margins only | 645 | 2.8 (0.2) | 0.2 (0.0) |
| Plaque also elsewhere | 115 | 6.6 (0.7) | 1.1 (0.3) |
| Number of teeth | | | |
| 1–20 | 54 | 2.1 (0.5) | 0.3 (0.1) |
| 21–25 | 115 | 3.0 (0.4) | 0.3 (0.1) |
| More than 25 | 1128 | 2.5 (0.2) | 0.2 (0.0) |
| Body mass index | | | |
| <25 | 657 | 2.0 (0.2) | 0.1 (0.0) |
| 25–29.9 | 454 | 2.9 (0.2) | 0.2 (0.1) |
| 30 or more 30 | 185 | 3.8 (0.4) | 0.6 (0.2) |
| Total cholesterol/HDL quartiles | | | |
| I (most favourable) | 343 | 2.0 (0.2) | 0.1 (0.0) |
| II | 301 | 2.3 (0.3) | 0.1 (0.0) |
| III | 317 | 2.6 (0.2) | 0.2 (0.0) |
| IV (most unfavourable) | 336 | 3.4 (0.3) | 0.4 (0.1) |
| LDL/HDL quartiles | | | |
| I (most favourable) | 356 | 1.9 (0.2) | 0.1 (0.0) |
| II | 302 | 2.8 (0.3) | 0.3 (0.1) |
| III | 318 | 2.3 (0.2) | 0.1 (0.0) |
| IV (most unfavourable) | 321 | 3.3 (0.3) | 0.3 (0.1) |
| Use of lipid medication | | | |
| No | 1174 | 2.5 (0.2) | 0.2 (0.0) |
| Yes | 16 | 3.2 (0.8) | 0.1 (0.1) |
| Missing data | 107 | 2.9 (0.4) | 0.3 (0.2) |
| Use of NSAID medication | | | |
| No | 507 | 2.7 (0.2) | 0.2 (0.1) |
| Yes | 683 | 2.4 (0.2) | 0.2 (0.0) |
| Missing data | 107 | 2.9 (0.4) | 0.3 (0.2) |
| Alcohol consumption | | | |
| None | 111 | 2.7 (0.5) | 0.4 (0.2) |
| Seldom | 654 | 2.5 (0.2) | 0.2 (0.1) |
| Often | 520 | 2.6 (0.2) | 0.2 (0.0) |

from the stratified analyses, we cannot totally exclude the possibility that unfavourable serum lipids among overweight and obese subjects have an adverse effect on periodontium. These adverse effects of serum lipids on periodontium could be explained by an increase in the production of pro-inflammatory cytokines and simultaneous inhibition of the production of several growth factors, such as platelet-derived growth factor, transforming growth factor $\beta$-1 and basic fibroblast growth factor, leading to a reduced capacity for tissue repair (Iacopino & Cutler 2000). On the other hand, it must be noted that it is well possible that the associations found among overweight or obese subjects could also be due to residual confounding, instead of showing any true interaction between body weight and lipid composition.

#### Strengths and limitations

The Health 2000 survey dataset was sampled from the Finnish general population and this fairly large data enabled us to try to create a fairly homogeneous study population by confining the

*Table 2*. Basic characteristics of the study population; proportions/means and their standard errors (in parentheses) categorized by the quartiles of total cholesterol/high-density lipoprotein cholesterol (TC/HDL) ratio

| | TC/HDL ratio | | | |
|---|---|---|---|---|
| | I quartile ($n = 343$) | II quartile ($n = 301$) | III quartile ($n = 317$) | IV quartile ($n = 336$) |
| Gender (%) (SE) | | | | |
| Male | 23.8 (2.3) | 29.3 (2.7) | 45.0 (3.3) | 68.7 (2.6) |
| Female | 76.2 (2.3) | 70.7 (2.7) | 55.0 (3.3) | 31.3 (2.6) |
| Age | | | | |
| Mean | 38.6 (0.3) | 38.7 (0.3) | 40.1 (0.3) | 40.6 (0.3) |
| 30–39 years (%) (SE) | 58.3 (2.5) | 59.9 (3.0) | 46.8 (2.8) | 43.8 (2.8) |
| 40–49 years (%) (SE) | 41.7 (2.5) | 40.1 (3.0) | 53.2 (2.8) | 56.2 (2.8) |
| Education (%) (SE) | | | | |
| Basic | 9.6 (1.7) | 12.2 (1.9) | 11.3 (1.7) | 14.2 (1.8) |
| Intermediate | 30.2 (2.5) | 31.3 (2.5) | 42.3 (2.9) | 42.6 (2.5) |
| Higher | 60.1 (2.6) | 56.6 (2.8) | 46.4 (2.8) | 43.2 (2.6) |
| Tooth brushing frequency (%) (SE) | | | | |
| Twice a day or more often | 78.0 (2.4) | 76.0 (2.8) | 68.2 (3.4) | 54.4 (2.9) |
| Once a day | 19.7 (2.1) | 20.4 (2.6) | 28.3 (3.0) | 38.5 (2.8) |
| More seldom | 2.3 (0.9) | 3.6 (1.2) | 3.5 (1.2) | 7.1 (1.5) |
| Dental attendance pattern (%) (SE) | | | | |
| Regular check-ups | 72.2 (2.6) | 73.3 (2.8) | 66.5 (2.5) | 65.0 (2.7) |
| Irregularly | 27.8 (2.6) | 26.7 (2.8) | 33.5 (2.5) | 35.0 (2.7) |
| Presence of plaque (%) (SE) | | | | |
| No plaque | 45.5 (2.8) | 47.9 (2.8) | 39.9 (2.5) | 31.0 (2.5) |
| Plaque at gingival margins only | 46.8 (2.7) | 44.6 (2.9) | 50.8 (2.7) | 56.7 (3.0) |
| Plaque also elsewhere | 7.7 (1.6) | 7.1 (1.6) | 9.4 (1.6) | 11.8 (1.9) |
| Missing data | 0 | 0.4 (0.4) | 0 | 0.6 (0.4) |
| Body mass index | | | | |
| Mean | 23.3 (0.2) | 24.8 (0.2) | 26.4 (0.2) | 28.1 (0.2) |
| $<25$ (%) (SE) | 77.5 (2.1) | 58.9 (2.6) | 39.3 (3.0) | 26.7 (2.5) |
| 25–29.9 (%) (SE) | 19.3 (2.0) | 33.5 (2.5) | 45.5 (3.1) | 43.5 (2.6) |
| 30 or more (%) (SE) | 3.2 (0.9) | 7.6 (1.5) | 15.2 (2.1) | 29.8 (2.3) |
| Number of teeth (mean) (SE) | 27.4 (0.2) | 27.3 (0.2) | 27.1 (0.2) | 27.0 (0.2) |
| Number of teeth with deepened periodontal pockets (mean) (SE) | | | | |
| 4 mm deep or deeper | 2.0 (0.2) | 2.3 (0.3) | 2.6 (0.2) | 3.4 (0.3) |
| 6 mm deep or deeper | 0.1 (0.0) | 0.1 (0.0) | 0.2 (0.0) | 0.4 (0.1) |
| Number of sextants with gingival bleeding (mean) | 2.1 (0.1) | 2.1 (0.1) | 2.3 (0.1) | 2.7 (0.2) |
| Use of lipid medication (%) (SE) | | | | |
| No | 94.0 (1.3) | 93.6 (1.4) | 88.8 (1.9) | 84.6 (2.1) |
| Yes | 0.3 (0.3) | 0.3 (0.3) | 1.0 (0.6) | 3.3 (1.0) |
| Missing data | 5.7 (1.3) | 6.0 (1.3) | 10.3 (1.9) | 12.1 (2.0) |
| Use of NSAID medication (%) (SE) | | | | |
| No | 54.4 (2.9) | 56.5 (2.8) | 48.6 (2.6) | 51.7 (2.7) |
| Yes | 40.0 (2.8) | 37.4 (2.7) | 41.1 (2.7) | 36.3 (2.9) |
| Missing data | 5.7 (1.3) | 6.0 (1.3) | 10.3 (1.9) | 12.1 (2.0) |
| Alcohol consumption (g/week) (mean) (SE) | 56.1 (4.2) | 52.6 (6.8) | 51.9 (4.7) | 77.2 (7.2) |

SE, standard error.

subjects to ones who had never smoked, who were non-diabetic and aged between 30–49 years. By confining the study to such a homogeneous population, we were able to reduce the effect of confounding related to some of the most important risk factors for periodontitis, i.e. tobacco smoking and diabetes. In addition, we controlled for the number of other potential confounders using multivariate models. However, in spite of the said restrictions and adjustments, it is always possible that residual confounding exists, especially related to factors that are difficult to measure, such as attitudinal factors, for example.

Confining the study sample to participants who had never smoked, who were non-diabetic and aged between 30–49 years was carried out in order to increase the validity of the study. An obvious disadvantage is that, based on this study, we cannot say whether age modified the relation between lipid composition and periodontal infection. Similarly, we cannot say how lipid composition relates to periodontal infection among diabetics or smokers. However, we consider it important to first study whether a relation between lipid composition and periodontal infection exists in a healthy population. Only after this, as a subsequent question, it is time to assess which factors might modify this relation. According to the literature, there are two alternatives when studying the effect modification: not to study it, and instead to confine the study to a homogenous subdomain of the potential modifier, or alternatively, to study it in a setting that ensures reasonable informativeness (Miettinen 1985, p. 39). We have chosen the first option, because we are not confident that the informativeness requirement can be fulfilled. This is due to the fact that diabetes is fairly uncommon in this age group. Furthermore in the case of smoking,

*Table 3.* Basic characteristics of the study population; proportions/means and their standard errors (in parentheses) categorized by the quartiles of low-density lipoprotein cholesterol/high-density lipoprotein cholesterol (LDL/HDL) ratio

| | LDL/HDL ratio | | | |
|---|---|---|---|---|
| | I quartile ($n = 356$) | II quartile ($n = 302$) | III quartile ($n = 318$) | IV quartile ($n = 321$) |
| Gender (%) (SE) | | | | |
| Male | 22.9 (2.3) | 31.7 (2.7) | 43.2 (3.1) | 71.0 (2.3) |
| Female | 77.1 (2.3) | 68.3 (2.7) | 56.8 (3.1) | 29.0 (2.3) |
| Age | | | | |
| Mean | 38.6 (0.3) | 38.7 (0.3) | 40.0 (0.3) | 40.8 (0.4) |
| 30–39 years (%) (SE) | 58.0 (2.5) | 59.0 (2.9) | 49.4 (2.9) | 41.8 (2.8) |
| 40–49 years (%) (SE) | 41.7 (2.5) | 40.1 (3.0) | 53.2 (2.8) | 58.2 (2.8) |
| Education (%) | | | | |
| Basic | 9.3 (1.7) | 11.9 (1.8) | 12.0 (1.9) | 14.3 (1.7) |
| Intermediate | 30.3 (2.5) | 32.5 (2.4) | 41.3 (3.0) | 42.9 (2.6) |
| Higher | 60.3 (2.7) | 55.5 (2.6) | 46.7 (2.9) | 42.9 (2.6) |
| Tooth brushing frequency (%) (SE) | | | | |
| Twice a day or more often | 78.9 (2.4) | 74.5 (2.9) | 67.8 (2.9) | 54.3 (3.0) |
| Once a day | 18.9 (2.2) | 22.3 (2.9) | 28.3 (2.6) | 38.4 (2.8) |
| More seldom | 2.2 (0.8) | 3.2 (1.2) | 3.9 (1.3) | 7.3 (1.6) |
| Dental attendance pattern (%) (SE) | | | | |
| Regular check-ups | 70.1 (2.6) | 74.4 (2.9) | 67.5 (2.6) | 65.0 (2.8) |
| Irregularly | 29.9 (2.6) | 25.6 (2.9) | 32.5 (2.6) | 35.0 (2.8) |
| Presence of plaque (%) (SE) | | | | |
| No plaque | 46.1 (2.7) | 46.8 (2.9) | 41.0 (2.7) | 29.7 (2.6) |
| Plaque at gingival margins only | 46.3 (2.7) | 44.3 (2.9) | 51.4 (2.9) | 57.3 (3.2) |
| Plaque elsewhere also | 7.6 (1.4) | 8.9 (1.7) | 7.2 (1.4) | 12.5 (1.9) |
| Missing data | 0 | 0 | 0.3 (0.3) | 0.6 (0.4) |
| Body mass index | | | | |
| Mean (SE) | 23.6 (0.2) | 25.0 (0.3) | 26.3 (0.2) | 27.9 (0.2) |
| $<25$ (%) (SE) | 73.5 (2.4) | 58.3 (2.9) | 39.2 (2.8) | 29.4 (2.6) |
| 25–29.9 (%) (SE) | 21.5 (2.2) | 32.4 (2.7) | 45.2 (3.0) | 43.3 (2.8) |
| 30 or more (%) (SE) | 5.0 (1.2) | 9.2 (1.8) | 15.5 (1.8) | 27.2 (2.3) |
| Number of teeth (mean) (SE) | 27.4 (0.2) | 27.5 (0.2) | 27.0 (0.3) | 26.9 (0.2) |
| Number of teeth with deepened periodontal pockets (mean) (SE) | | | | |
| 4 mm deep or deeper | 1.9 (0.2) | 2.8 (0.3) | 2.3 (0.2) | 3.3 (0.3) |
| 6 mm deep or deeper | 0.1 (0.0) | 0.3 (0.1) | 0.1 (0.0) | 0.3 (0.0) |
| Number of sextants with gingival bleeding (mean) (SE) | 2.0 (0.1) | 2.3 (0.1) | 2.2 (0.1) | 2.7 (0.1) |
| Use of lipid medication (%) (SE) | | | | |
| No | 95.0 (1.2) | 91.6 (1.6) | 89.0 (2.0) | 84.9 (2.0) |
| Yes | 0.5 (0.4) | 0.4 (0.4) | 1.6 (0.8) | 2.5 (0.9) |
| Missing data | 4.5 (1.1) | 8.0 (1.6) | 9.4 (1.9) | 12.5 (2.0) |
| Use of NSAID medication (%) (SE) | | | | |
| No | 54.8 (2.8) | 54.9 (2.9) | 50.0 (2.6) | 51.3 (2.7) |
| Yes | 40.7 (2.8) | 37.0 (2.9) | 40.1 (2.6) | 36.2 (2.7) |
| Missing data | 4.5 (1.1) | 8.0 (1.6) | 9.4 (1.9) | 12.5 (2.0) |
| Alcohol consumption (g/week) mean (SE) | 56.3 (4.4) | 50.2 (4.5) | 53.5 (6.9) | 78.7 (7.3) |

SE, standard error.

the measurement of the smoking history/habits of the respondents is not accurate enough to study whether the relation of lipid composition to periodontal infection is dependent on smoking status.

In this survey, quality procedures were aimed to standardize measurements and to avoid individual variation between examiners as well as to assess the quality of the data collected. Intra-examiner $\kappa$ values were fairly high, indicating high reproducibility, but the results of inter-examiner measurements were somewhat lower than intra-examiner measurements. A detailed analysis showed that field examiners reported lesser findings than the reference examiner in the registration of periodontal pockets, in the presence of gingival bleeding and in the presence of dental plaque (Vehkalahti et al. 2008, p. 19). This under-registration of periodontal pockets leads to a situation where the estimates of the association between lipid fraction and periodontal infection may be somewhat conservative.

The use of a continuous variable reflects the true pattern of periodontal infection better than classifying subjects into two categories based on an arbitrary cut-off point. An additional benefit is that the use of a continuous variable also made it possible for us to reduce the effect of misclassification due to measurement error. As pocket depth was recorded at tooth level according to deepest pocket depth (count data) and as the distribution approximately follows Poisson's distribution (see Fig. 1), we have used Poisson's regression analyses, although especially the number of teeth with deep periodontal pockets (6 mm or deeper) was affected by a large number of zeros. This may have a

*Table 4*. Association between serum total cholesterol/high-density lipoprotein cholesterol (TC/HDL) ratio and low-density lipoprotein cholesterol/high-density lipoprotein cholesterol (LDL/HDL) ratio with the number of teeth with deepened (4 mm or deeper) and deep (6 mm or deeper) periodontal pockets and the presence of gingival bleeding. Adjusted* relative risks (RR) and odds ratios (OR) with 95% confidence intervals (CI)

| | Teeth with periodontal pockets ⩾4 mm RR (95% CI) | Teeth with periodontal pockets ⩾6 mm RR (95% CI) | Presence of gingival bleeding OR (95% CI) |
|---|---|---|---|
| | | Among total population | |
| TC/HDL | (Effective $n = 1281$) | (Effective $n = 1281$) | (Effective $n = 1280$) |
| I quartile | 1.0 | 1.0 | 1.0 |
| II quartile | 1.1 (0.9–1.4) | 1.1 (0.5–2.2) | 1.0 (0.7–1.4) |
| III quartile | 1.1 (0.8–1.4) | 0.7 (0.3–1.6) | 0.9 (0.6–1.3) |
| IV quartile | 1.2 (0.9–1.5) | 1.0 (0.5–2.3) | 1.0 (0.7–1.6) |
| LDL/HDL | | | |
| I quartile | 1.0 | 1.0 | 1.0 |
| II quartile | 1.4 (1.1–1.7) | 2.3 (1.2–4.4) | 0.9 (0.7–1.3) |
| III quartile | 1.1 (0.8–1.4) | 0.8 (0.3–1.8) | 0.9 (0.6–1.2) |
| IV quartile | 1.2 (0.9–1.5) | 0.8 (0.4–1.8) | 1.2 (0.8–1.8) |
| | | Among subjects with body mass index (BMI) < 25 | |
| TC/HDL | (Effective $n = 651$) | (Effective $n = 651$) | (Effective $n = 651$) |
| I quartile | 1.0 | 1.0 | 1.0 |
| II quartile | 1.1 (0.8–1.4) | 0.7 (0.4–1.3) | 1.0 (0.7–1.6) |
| III quartile | 1.0 (0.7–1.5) | 1.5 (0.5–4.4) | 0.8 (0.5–1.3) |
| IV quartile | 0.8 (0.6–1.2) | 0.5 (0.1–2.3) | 1.2 (0.7–2.3) |
| LDL/HDL | | | |
| I quartile | 1.0 | 1.0 | 1.0 |
| II quartile | 1.5 (1.2–2.0) | 1.8 (0.8–3.8) | 1.0 (0.6–1.4) |
| III quartile | 1.0 (0.6–1.4) | 0.9 (0.4–2.4) | 0.9 (0.5–1.4) |
| IV quartile | 1.0 (0.7–1.4) | 0.5 (0.1–2.0) | 1.4 (0.8–2.5) |
| | | Among subjects with BMI ⩾ 25 | |
| TC/HDL | (Effective $n = 630$) | (Effective $n = 630$) | (Effective $n = 629$) |
| I quartile | 1.0 | 1.0 | 1.0 |
| II quartile | 1.3 (0.9–2.0) | 1.3 (0.4–4.7) | 1.0 (0.5–2.2) |
| III quartile | 1.2 (0.9–1.7) | 0.6 (0.2–2.0) | 1.1 (0.5–2.2) |
| IV quartile | 1.5 (1.1–2.0) | 1.0 (0.3–3.3) | 1.0 (0.5–2.1) |
| LDL/HDL | | | |
| I quartile | 1.0 | 1.0 | 1.0 |
| II quartile | 1.3 (0.9–1.8) | 1.3 (0.9–1.8) | 0.9 (0.5–1.8) |
| III quartile | 1.1 (0.8–1.5) | 1.1 (0.8–1.5) | 0.9 (0.5–1.7) |
| IV quartile | 1.2 (0.9–1.7) | 1.2 (0.9–1.7) | 1.0 (0.5–2.0) |

*Adjusted for gender, age (continuous variable), education, tooth brushing frequency, dental attendance pattern, presence of dental plaque, use of lipid medication, use of NSAID medication, body mass index (continuous variable) and number of teeth (offset variable).

certain effect on the variance of the estimates, but we do not consider this to be a major obstacle because the effect of this zero-inflation on the confidence limits of the estimates appeared to be fairly small (Saxlin et al. 2009) and because interpretation should not be based on statistical significance or on the lack of it, but rather on the overall judgement of the weight of evidence (Rothman & Greenland 2005).

Dental plaque was measured only from three indicator teeth by means of a modified version of the method described by Silness and Löe (1964). Although the measurement of dental plaque was robust, it associated in these data with the number of teeth with deepened periodontal pockets in an expected manner. Moreover, the use of dental plaque variable in multivariate regression models – despite its robust measurement – has in these data shown previously to be the better way to take into account the effect of oral hygiene than self-reported questions about tooth brushing frequency or dental visit pattern (Ylöstalo et al. 2008).

An unavoidable disadvantage of the exclusion of several known risk factors is that subjects have on average a fairly small number of teeth with pathologically deepened periodontal pockets, which increases the role of random occurrence and may thus lead to inconsistencies in risk estimates. Moreover, it is known that the use of ratio measures itself in regression models can cause abnormities in results, meaning that the interpretation of ratio measures should always be carried out cautiously.

Lastly, an obvious disadvantage of this study is the cross-sectional study design, which means that the temporal sequence between the supposed cause and effect remains unclear. From the point of view of our main finding that there was practically no association of the TC/HDL or LDL/HDL ratios with periodontal infection among normal weight subjects, we do not consider the cross-sectional study design as an essential limitation. However, from the point of view of a possible association among overweight subjects, the situation is different. A lack of knowledge about the temporal sequence means that the direction of the relation could well be the opposite to the one hypothesized i.e. that elevated pro-inflammatory cytokines, produced by chronic severe periodontitis, cause disturbances in lipid composition, as has been suggested earlier by Cutler et al. (1999).

#### Concluding remarks

The development and progression of periodontal diseases may require the presence of other risks, and it is possible that such coaction of different risks does not manifest itself in this low-risk study

population. This could be a possible explanation why the results of this study differ from those of other studies. In this respect, the findings warrant further studies on the factors, which, together with unfavourable lipid composition, may contribute to the development of periodontal infection. On the other hand, obesity associated with periodontal infection in this same subpopulation (Ylöstalo et al. 2008) meaning that lipid ratios could also associate if such an association truly and clearly exists. Another possible explanation why the results of this study differ from those of other studies is that there are methodological differences such as differences in study design and controlling of confounding factors.

It has been suggested that systemic inflammation predisposes subjects to periodontal infection. In this study, we did not find any evidence among normal weight subjects that low-grade systemic inflammation due to unfavourable composition of serum lipid subfractions could be considered an important risk for periodontal infection, irrespective of whether the inflammatory condition of periodontium was measured by means of the number of teeth with deepened periodontal pockets or gingival bleeding.

The aim was to investigate whether commonly used ratios of lipid fractions, TC/HDL and LDL/HDL are associated with periodontal infection. We conclude that within the limitations of this study, the results suggest that unfavourable serum lipid composition is not an important risk for periodontal infection, but evidently further studies are needed to confirm these findings and also to investigate of the role of serum lipids in the pathogenesis of periodontal infection among high-risk populations.

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### Clinical Relevance

*Scientific rationale for the study*: It has been suggested that the overall balance between atherogenic and anti-atherogenic lipoproteins relates more strongly to lipoprotein-related risk than to individual lipoprotein levels. This has led to the use of ratio measures, such as TC/HDL ratio and LDL/HDL ratio. It is possible that unfavourable ratios of lipoprotein subfractions might have a more deleterious impact on the development of periodontal infection than any of the lipid subfractions alone.

*Principal findings*: No consistent associations of TC/HDL or LDL/HDL ratios with the number of teeth with deepened periodontal pockets or gingival bleeding were found.

*Practical implications*: Despite the fact that lipid composition appeared not to be an important risk for periodontal infection among a low-risk population, further studies are needed to investigate the role of lipid composition in the pathogenesis of periodontal infection among high-risk populations.