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Overweight and obesity weakly predict the development of periodontal infection

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Abstract

Aim: The aim of this study was to investigate the association between body weight and periodontal infection in a longitudinal setting.

Material and methods: This study was based on a subpopulation of the Health 2000 Survey that included dentate, non-diabetic subjects aged 30–59 years, who had never smoked and who had participated in the Follow-Up Study on Finnish Adults' Oral Health approximately 4 years later ($n = 396$). The number of new teeth with deepened (4 mm deep or deeper) periodontal pockets in the follow-up examination was used as the outcome variable. Body weight was measured using body mass index, categorized into three categories: <25.0 (normal weight), 25.0–29.9 (overweight) and 30.0 or more (obesity). Incidence rate ratios were estimated using Poisson's regression models.

Results: Body weight was weakly, but not statistically significantly, associated with the number of new teeth with deepened periodontal pockets among subjects who were periodontally healthy in the baseline examinations, whereas only a minuscule association was found among subjects who had periodontal infection at baseline.

Conclusions: The results of this follow-up study do not provide evidence that overweight and obesity can be considered significant risk factors in the pathogenesis of periodontal infection.

Key words: body mass index; body weight; periodontal infection; periodontitis

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Conflict of Interest and Source of Funding Statement

The authors declare that there are no conflicts of interest.

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 partly supported by The Finnish Dental Society Apollonia and The Finnish Dental Association. The Follow-Up Study on Finnish Adults' Oral Health was organized and funded by the National Institute for Health and Welfare and the Social Insurance Institution of Finland (KELA). A personal grant from the Finnish Dental Society Apollonia and the Finnish Dental Association is acknowledged by Tuomas Saxlin.

Body weight has been suggested to be associated with periodontal infection in many recent studies (Saito et al. 2001, Al-Zahrani et al. 2003, Dalla Vecchia et al. 2005, Ekuni et al. 2008, Ylöstalo et al. 2008, Khader et al. 2009). However, these studies were cross-sectional, which means that any interpretations about causality could not be made, mainly due to the indistinctness of the temporal sequence between the supposed cause and effect. Recent studies have proposed several possible biological mechanisms that could mediate the association between body weight and periodontal infection, but it is still unclear whether being overweight or obese truly precedes periodontal infection.

It is also possible that the direction of the relation might be the opposite to what is commonly assumed, i.e. from periodontal infection to overweight and obesity. This is supported by a study by D'Aiuto et al. (2008), in which periodontal infection was shown to be associated with the metabolic syndrome, and also with obesity as an individual component of the condition. However, it is also possible that there is no causal relation between body weight and periodontal infection, and the association, which is often observed, is due to confounding related to a number of shared risk factors.

Longitudinal studies are warranted to obtain more knowledge about the role of overweight and obesity as possible risk

factors for periodontal infection. The aim of this study was to investigate the association between body weight and periodontal infection among an adult population in a longitudinal setting.

Material and Methods

The Health 2000 Survey was conducted by the National Institute for Health and Welfare (THL) [former National Public Health Institute (KTL) of Finland] in the years 2000 and 2001. This survey included 8028 subjects aged 30 years or older living in continental Finland. The data for this survey were collected by clinical oral and health examinations, from laboratory analyses, from self-administered questionnaires and by interviews. Of the study population, 79% ($n = 6335$) participated in the clinical oral health examination. Additional information about the Health 2000 Survey is available in a report published by Aromaa & Koskinen (2004).

In 2000, the National Institute for Health and Welfare launched a series of population studies in collaboration with the Social Insurance Institution of Finland (KELA) to evaluate the effects of the dental care reform that had been implemented in Finland in 2001 and 2002. The data were collected using specially designed postal questionnaires about self-rated oral health, need for dental care and dental care utilization. The first survey occurred before the reform in spring 2001 and was followed by similar surveys after the first phase of the reform (autumn 2002), and later again, when the reform had been fully implemented (spring 2004) (Kiiskinen et al. 2005). To assess the short-term effects of the reform in clinically determined oral health too, the Follow-Up Study on Finnish Adults' Oral Health was conducted in 2004–2005. For this survey, 2000 subjects were randomly selected from participants who had attended the clinical oral health examinations in the Health 2000 Survey (Suominen-Taipale 2005). From this sample, edentulous subjects and persons from public dental service units, which included <15 participants, were excluded from the survey. The final sample of the follow-up examinations consisted of 1248 subjects who were invited to a clinical oral health re-examination similar to the one conducted in the Health 2000 Survey, the participation rate of the follow-up examinations being 84% ($n = 1049$).

The present study was based on dentate subjects who participated both in the baseline examinations (the Health 2000 Survey) and the examinations after the follow-up (the Follow-Up Study on Finnish Adults' Oral Health), who were non-diabetic, who had never smoked and who were aged <60 years ($n = 396$). The length of the follow-up period was approximately 4 years (mean 1504 days; minimum 1327 days, maximum 1696 days). Subjects who had been diagnosed with diabetes or had some indication of the disease were excluded because of the complex interrelations of diabetes with obesity and periodontal infection. Diabetes was determined on the basis of the information obtained from the health examination and the health interview. Smokers and former smokers were excluded due to the strong association between smoking and periodontal infection, which is difficult to control. Age restriction was used to reduce age-related confounding.

Informed consent was obtained from the participants for both the Health 2000 Survey and the Follow-Up Study on Finnish Adults' Oral Health. Both studies received approval from the Ethical Committee for Epidemiology and Public Health of the Hospital District of Helsinki and Uusimaa.

Outcome variables

Clinical oral examinations of the subjects included the assessment of the condition of periodontium and teeth, and were performed identically in the baseline examinations and after the follow-up. The baseline clinical oral examinations were performed by five dentists in a dental chair using a headlamp, mouth mirror and a WHO periodontal probe in line with the WHO instructions. The examiners were calibrated in advance. The follow-up examinations were performed by one dentist, who was also one of the five dentists performing the baseline examinations. In the baseline examinations, the percentual agreement for deepened periodontal pockets was 77% (κ-value 0.41) in the parallel measurements, where the assessments of the field examiners were individually compared with those of the reference examiner in field circumstances (Vehkalahti et al. 2008, p. 19). The results for intra-examiner reliability assessments concerning periodontal pocket measurements in the baseline examinations showed a κ-value of 0.83 (Vehkalahti et al. 2004, p. 29).

The periodontal pocket depth on probing was measured in millimetres for all teeth except third molars and radices. It was measured on four surfaces of each tooth (distobuccal, midbuccal, mid-oral, mesio-oral) and the deepest measurement on each tooth was recorded as follows: no pathologically deepened periodontal pocket, periodontal pocket with a depth of 4–5 mm and periodontal pocket with a depth of 6 mm or more. Subjects were considered to be periodontally healthy if they had no teeth with pathologically deepened (4 mm deep or deeper) periodontal pockets, whereas if they had at least one tooth with deepened periodontal pocket, they were considered to have periodontal infection.

The number of new teeth with deepened (4 mm deep or deeper) periodontal pockets in the examinations after the follow-up was used as the outcome variable to measure the devel-

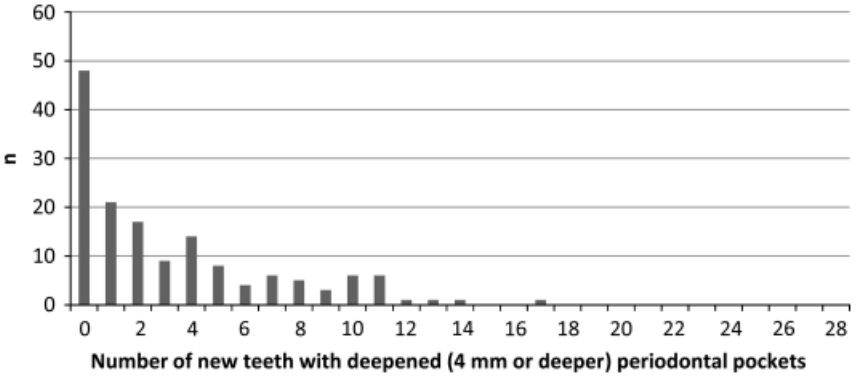

Fig. 1. Number of subjects with new teeth with deepened (4 mm or deeper) periodontal pockets among subjects who had no teeth with deepened periodontal pockets in the baseline examinations ($n = 162$).

opment of periodontal infection among subjects who were periodontally healthy during the baseline examinations ($n = 162$), and to measure the progression of periodontal infection among subjects who had periodontal infection at baseline ($n = 228$). The number of new teeth with deepened periodontal pockets could not be assessed for 16 subjects for medical reasons (need for antibiotic prophylaxis before periodontal examination; two subjects in the baseline examinations, four subjects both at baseline and after the follow-up and 10 subjects after the follow-up) and for 15 subjects for other reasons. The distribution of the number of new teeth with deepened periodontal pockets after about 4 years' follow-up among subjects who were periodontally healthy during the baseline examinations is presented in Fig. 1. Respectively, the distribution of the number of new teeth with deepened periodontal pockets among subjects who had periodontal infection at baseline is presented in Fig. 2.

We also used the change of pocket depth among subjects who had periodontal infection at baseline as an outcome variable. This variable included deepening or shallowing of existing deepened (4 mm deep or deeper) periodontal pockets, shallowing of existing deep (6 mm deep or deeper) periodontal pockets and formation of new periodontal pockets (''deepening of the pocket depth of teeth with no periodontal pockets at baseline''). Each tooth was given a score (no change in pocket depth was given the value 0, any deepening of pocket depth was given the value 1 and any reduction of pocket depth was given the value -1) and these scores were then added together to produce one score for each subject. The distribution of this variable followed a normal distribution.

Explanatory variable

Body weight was assessed in the baseline examinations using body mass index (BMI), which is a measure of weight in relation to height (kg/m^2). Information about weight and height was obtained primarily from the health examination. In some situations this was not possible, in which case information from a questionnaire was used. BMI was categorized into three categories according to the WHO classification: <25.0 (normal weight), 25.0–29.9 (overweight) and 30.0 or more (obesity).

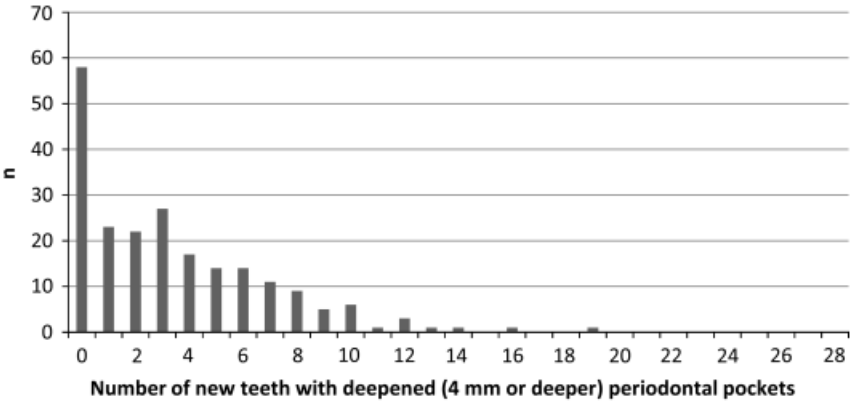

Fig. 2. Number of subjects with new teeth with deepened (4 mm or deeper) periodontal pockets among subjects who had teeth with deepened periodontal pockets in the baseline examinations ($n = 228$).

Table 1. Basic characteristics of the study population; proportions/means and their standard deviations (in parentheses) among subjects who were periodontally healthy [no teeth with deepened (4 mm or deeper) periodontal pockets] in the baseline examinations, categorized according to number of new teeth with deepened periodontal pockets (none *versus* 1 or more) after 4 years' follow-up

	Subjects with number of new teeth with periodontal pockets of 4 mm or deeper	
	None ($n = 48$)	1 or more ($n = 103$)
Age at baseline, mean (SD) ($n = 151$)	39.2 (8.3)	43.1 (8.1)
Gender, % ($n = 151$)		
Males	16.7	32.0
Females	83.3	68.0
Educational level, % ($n = 151$)		
Basic	8.3	12.6
Intermediate	31.2	35.9
High	60.4	51.5
Number of teeth at baseline, mean (SD) ($n = 151$)	26.1 (5.8)	26.4 (4.7)
Number of new teeth with periodontal pockets $\geqslant 4$ mm, mean (SD) ($n = 151$)	0	4.8 (3.7)
Presence of dental plaque at baseline, % ($n = 150$)		
No plaque	70.2	53.4
Plaque on gingival margins only	29.8	42.7
Plaque also elsewhere	0	3.9
Dental attendance pattern at baseline, % ($n = 147$)		
Regular check-ups	76.1	67.3
No regular check-ups	23.9	32.7
Toothbrushing frequency at baseline, % ($n = 146$)		
Twice a day or more	78.3	67.0
Once a day	21.7	29.0
Less frequently	0	4.0
Any hygiene phase periodontal treatment during the last 12 months before the follow-up examinations, % ($n = 151$)		
No	50.0	52.4
Yes	43.8	42.7
Missing information	6.2	4.9
Body mass index at baseline, % ($n = 151$)		
<25.0	68.8	50.5
25.0–29.9	20.8	32.0
30.0 or more	10.4	17.5

BMI was also used as a continuous variable in the analyses.

Table 2. Basic characteristics of the study population; proportions/means and their standard deviations (in parentheses) among subjects who were periodontally healthy [no teeth with deepened (4 mm or deeper) periodontal pockets] in the baseline examinations by categories of body mass index (BMI)

	BMI		
	<25.0 ($n = 89$)	25.0–29.9 ($n = 47$)	30.0 or more ($n = 26$)
Age at baseline, mean (SD) ($n = 162$)	40.0 (7.8)	43.4 (7.9)	47.4 (9.3)
Gender, % ($n = 162$)			
Males	25.8	36.2	19.2
Females	74.2	63.8	80.8
Educational level, % ($n = 162$)			
Basic	6.7	19.1	11.5
Intermediate	37.1	36.2	30.8
High	56.2	44.7	57.7
Number of teeth at baseline, mean (SD) ($n = 162$)	27.2 (4.1)	25.3 (6.3)	24.4 (1.2)
Number of new teeth with periodontal pockets ⩾4 mm, mean (SD) ($n = 151$)	3.0 (3.5)	3.6 (3.6)	3.7 (5.0)
Presence of dental plaque at baseline, % ($n = 161$)			
No plaque	62.5	53.2	57.7
Plaque on gingival margins only	37.5	38.3	34.6
Plaque also elsewhere	0	8.5	7.7
Dental attendance pattern at baseline, % ($n = 158$)			
Regular check-ups	72.4	75.6	50.0
No regular check-ups	27.6	24.4	50.0
Toothbrushing frequency at baseline, % ($n = 157$)			
Twice a day or more	69.8	71.1	80.8
Once a day	29.1	22.2	19.2
Less frequently	1.2	6.7	0
Any hygiene phase periodontal treatment during the last 12 months before the follow-up examinations, % ($n = 162$)			
No	55.1	44.7	57.7
Yes	42.7	42.6	38.5
Missing information	2.2	12.8	3.8

Confounding variables

Age at the time of baseline examinations was included into the analyses as a continuous variable. Education was categorized into three categories. Basic education included subjects who had not graduated from high school and who had no vocational qualifications. Intermediate education included those who had graduated from high school. Highest education included subjects with a university degree or who had graduated from polytechnics. Oral health behavioural factors included dental attendance pattern and toothbrushing frequency. Dental attendance patterns were categorized as follows: those who regularly had dental check-ups *versus* those who used dental services in a symptom-based manner or had never used them. Toothbrushing frequency was categorized into three categories as follows: twice a day or more, once a day, or less frequently. We also used any hygiene phase periodontal treatment during the last 12 months before the follow-up examinations as a confounding variable categorized into three categories: no, yes and the third category being missing information.

The presence of dental plaque was measured using a modified version of the method described by Silness & Löe (1964). The presence of dental plaque was measured from three 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 presence of dental plaque was categorized into three categories: no visible plaque (given value 0), visible plaque on gingival margins only (given value 1), or visible plaque also elsewhere (given value 2). The highest value of any of the indicator teeth was recorded. The percentual agreement for the presence of dental plaque was 58% (κ-value 0.36) in the parallel measurements between the five examiners and the reference examiner in field circumstances in the baseline examinations (Vehkalahti et al. 2008, p. 19). The results for intra-examiner reliability assessments related to the presence of dental plaque in the baseline examinations showed a κ-value of 0.79 (Vehkalahti et al. 2004, p. 29).

The basic characteristics of the study population, among subjects who were periodontally healthy in the baseline examinations, according to the number of new teeth with deepened periodontal pockets (0 *versus* 1 or more) after about 4 years' follow-up are presented in Table 1 and according to the categories for BMI in Table 2. Respectively, the basic characteristics of the study population among subjects who had periodontal infection at baseline are presented in Tables 3 and 4.

Statistical methods

Incidence rate ratios (IRR) with 95% confidence intervals (95% CI) for the association between body weight and the number of new teeth with deepened (4 mm deep or deeper) periodontal pockets were estimated using Poisson's regression models with DSCALE option. The analyses were carried out in two groups: among subjects who were periodontally healthy in the baseline examinations and among subjects who had periodontal infection at baseline. Linear regression analyses for the association between body weight and the change of pocket depth among subjects who had periodontal infection at baseline were performed using generalized linear models with identity link function and normal distribution. The number of teeth in the baseline examinations (continuous variable) was treated as the offset variable in the Poisson regression models. The selection of covariates was based on current knowledge of potential risk factors for periodontal infection. The statistical analyses were performed using SPSS version 16.0 (Tables 1–4, SPSS Inc., Chicago, IL, USA) and SAS version 9.2 (Tables 5–7, SAS Institute Inc., Cary, NC, USA).

Results

Among subjects who were periodontally healthy [no teeth with deepened (4 mm deep or deeper) periodontal pockets] in

Table 3. Basic characteristics of the study population; proportions/means and their standard deviations (in parentheses) among subjects who had periodontal infection [teeth with deepened (4 mm or deeper) periodontal pockets] in the baseline examinations, categorized according to number of new teeth with deepened periodontal pockets (none *versus* 1 or more) after 4 years' follow-up

	Subjects with number of new teeth with periodontal pockets of 4 mm or deeper	
	None ($n = 58$)	1 or more ($n = 156$)
Age at baseline, mean (SD) ($n = 214$)	43.6 (8.4)	44.9 (7.6)
Gender, % ($n = 214$)		
Males	31.0	45.5
Females	69.0	54.5
Educational level, % ($n = 214$)		
Basic	17.2	22.4
Intermediate	37.9	32.1
High	44.8	45.5
Number of teeth at baseline, mean (SD) ($n = 214$)	26.2 (5.1)	26.6 (4.3)
Number of teeth with periodontal pockets $\geqslant 4$ mm at baseline, mean (SD) ($n = 214$)	4.8 (4.6)	4.9 (4.4)
Number of new teeth with periodontal pockets $\geqslant 4$ mm, mean (SD) ($n = 214$)	0	4.7 (3.3)
Presence of dental plaque at baseline, % ($n = 213$)		
No plaque	31.6	31.4
Plaque on gingival margins only	59.6	60.9
Plaque also elsewhere	8.8	7.7
Dental attendance pattern at baseline, % ($n = 208$)		
Regular check-ups	66.1	73.0
No regular check-ups	33.9	27.0
Toothbrushing frequency at baseline, % ($n = 208$)		
Twice a day or more often	73.2	70.4
Once a day	21.4	24.3
Less frequently	5.4	5.3
Any hygiene phase periodontal treatment during the last 12 months before the follow-up examinations, % ($n = 214$)		
No	48.3	50.0
Yes	46.6	45.5
Missing information	5.2	4.5
Body mass index (BMI) at baseline, % ($n = 214$)		
<25.0	43.1	38.5
25.0–29.9	34.5	39.1
30.0 or more	22.4	22.4

the baseline examinations, the incidence of new teeth with deepened periodontal pockets over the approximately 4-year follow-up among normal weight subjects was 3.0 and among overweight and obese subjects 3.6 and 3.7, respectively. The corresponding incidences per year were 0.75 among normoweight subjects and about 0.9 among overweight and obese subjects. The IRR of teeth with deepened periodontal pockets was 1.2 (95% CI 0.7–1.8) for overweight and 1.3 (95% CI 0.7–2.1) for obese subjects compared with normoweight subjects, after adjusting for confounding factors such as age, gender, education, presence of dental plaque, dental attendance pattern, toothbrushing frequency and the number of teeth (offset variable). The corresponding risk estimate for the continuous variable of BMI was 1.04 (95% CI 0.99–1.08).

Among subjects who had periodontal infection [teeth with deepened (4 mm deep or deeper) periodontal pockets] in the baseline examinations, only a slight difference was found in the incidence of new teeth with deepened periodontal pockets between normoweight, overweight and obese subjects over the 4-year follow-up, the incidences being 3.3, 3.6 and 3.5, respectively. The adjusted IRR was 1.0 (95% CI 0.7–1.4) for overweight and 1.1 (95% CI 0.8–1.7) for obese subjects compared with normoweights. The adjusted risk estimate for the continuous variable of BMI was 1.01 (95% CI 0.97–1.04). We found no statistically significant association between body weight and the change of periodontal pocket depth (Table 7).

Discussion

The aim of this study was to investigate the association between body weight and periodontal infection in a longitudinal setting. According to the results of this study, body weight was weakly, but not statistically significantly, associated with the incidence of deepened (4 mm deep or deeper) periodontal pockets among subjects who were periodontally healthy (no teeth with deepened periodontal pockets) during the baseline examinations. The association between body weight and new teeth with deepened periodontal pockets among subjects who had periodontal infection (teeth with deepened periodontal pockets) at baseline was practically nonexistent, as was the association between body weight and the change of periodontal pocket depth. The results of this study suggest that body weight weakly predicts the development of periodontal infection, but poorly the progression of existing periodontal infection.

Numerous recent cross-sectional studies have suggested that there is an association between body weight and periodontal infection (Saito et al. 2001, Al-Zahrani et al. 2003, Dalla Vecchia et al. 2005, Ekuni et al. 2008, Ylöstalo et al. 2008, Khader et al. 2009). Although the findings of the earlier studies do not prove causality, they do, however, within the limits of cross-sectional design, support the conception that an association exists between body weight and periodontal infection. The results of the present study provide evidence that the direction of this association is from overweight and obesity to periodontal infection, but the strength of the association may be weaker than suggested in previous studies.

Among subjects who had periodontal infection in the baseline examinations, no consistent association between body weight and new teeth with deepened periodontal pockets was found. This could mean that existing periodontal infection is such a strong predictor for the progression of the condition that it may prevent weaker determinants, such as body weight, from manifesting their effects. This interpretation is in accordance with the finding that commonly accepted risk indicators, such as dental plaque for example, was also found to

Table 4. Basic characteristics of the study population; proportions/means and their standard deviations (in parentheses) among subjects who had periodontal infection [teeth with deepened (4 mm or deeper) periodontal pockets] in the baseline examinations by categories of body mass index (BMI)

	BMI		
	<25.0 ($n = 90$)	25.0–29.9 ($n = 87$)	30.0 or more ($n = 51$)
Age at baseline, mean (SD) ($n = 228$)	43.6 (7.9)	44.9 (8.2)	46.9 (6.9)
Gender, % ($n = 228$)			
Males	33.3	54.0	33.3
Females	66.7	46.0	66.7
Educational level, % ($n = 228$)			
Basic	12.2	23.0	33.3
Intermediate	30.0	32.2	39.2
High	57.8	44.8	27.5
Number of teeth at baseline, mean (SD) ($n = 228$)	27.2 (3.8)	26.3 (4.7)	24.6 (6.0)
Number of teeth with periodontal pockets ⩾4 mm at baseline, mean (SD) ($n = 228$)	4.2 (3.9)	6.0 (5.2)	5.3 (5.5)
Number of new teeth with periodontal pockets ⩾4 mm, mean (SD) ($n = 214$)	3.3 (3.2)	3.6 (3.8)	3.5 (3.4)
Presence of dental plaque at baseline, % ($n = 227$)			
No plaque	40.0	28.7	20.0
Plaque on gingival margins only	51.1	63.2	70.0
Plaque also elsewhere	8.9	8.0	10.0
Dental attendance pattern at baseline, % ($n = 222$)			
Regular check-ups	76.4	66.7	65.3
No regular check-ups	23.6	33.3	34.7
Toothbrushing frequency at baseline, % ($n = 222$)			
Twice a day or more	82.0	66.7	59.2
Once a day	15.7	29.8	28.6
Less frequently	2.2	3.6	12.2
Any hygiene phase periodontal treatment during the last 12 months before the follow-up examinations, % ($n = 228$)			
No	44.4	57.5	47.1
Yes	50.0	36.8	51.0
Missing information	5.6	5.7	2.0

Table 5. Association between body mass index (BMI) and number of new teeth with deepened (4 mm or deeper) periodontal pockets after 4 years' follow-up among subjects who were periodontally healthy (no teeth with deepened periodontal pockets) in the baseline examinations. Unadjusted and adjusted* incidence rate ratios (IRR) with 95% confidence intervals (CI)

	New teeth with periodontal pockets of 4 mm or deeper	
	Unadjusted IRR (95% CI)	Adjusted IRR (95% CI)
BMI		
<25.0	1.0	1.0
25.0–29.9	1.3 (0.9–2.0)	1.2 (0.7–1.8)
30.0 or more	1.4 (0.8–2.3)	1.3 (0.7–2.1)
Continuous variable	1.05 (1.01–1.09)	1.04 (0.99–1.08)

*Adjusted for gender, age (continuous variable), education, presence of dental plaque, dental attendance pattern, toothbrushing frequency, periodontal treatment and number of teeth (offset variable). Effective $n = 145$.

be associated with the incidence of teeth with deepened periodontal pockets in an exposure–response manner among subjects who were periodontally healthy during the baseline examinations, whereas no consistent association was found among subjects who had periodontal infection at baseline (data not shown).

Possible explanations

This study was not aimed to study the possible mechanism explaining the association between body weight and periodontal infection. However, several possible biological mechanisms mediating the association between body weight and periodontal infection have been suggested. One proposed explanation for the linking of body weight and periodontal infection has been the bioactive substances secreted by adipose tissue, also known as adipokines. These substances are suggested to have a role in inflammation and immune responses (Trayhurn & Wood 2004). For instance, an increased serum level of an adipokine called resistin has been proposed to be associated with periodontitis (Saito et al. 2008). In addition, an earlier study carried out by our group using these Health 2000 data suggested that another pro-inflammatory cytokine produced by adipose tissue, interleukin 6, could also mediate the association between body weight and periodontal infection (Saxlin et al. 2009). Also, increased oxidative stress, a condition that is suggested to be associated with obesity (Urakawa et al. 2003), could play a mediating role in the association between body weight and periodontal infection (Tsai et al. 2005).

Other potential mechanism that has been suggested to mediate the association between body weight and periodontal infection is insulin resistance (Genco et al. 2005). Furthermore, an overgrowth of *Tannerella forsythia* in the subgingival biofilms of periodontally healthy overweight and obese individuals, which was reported by Haffajee & Socransky (2009), has also been suggested to be a possible link between body weight and periodontal infection. This overgrowth may put overweight and obese individuals at risk of an onset and progression of periodontal disease (Haffajee & Socransky 2009).

Methodological considerations

The development and progression of periodontal infection in this study were measured using the number of new teeth with deepened (4 mm deep or deeper) periodontal pockets. The cut-off point of 4 mm reflects the current conception of what is commonly considered to be the boundary value for pathological periodontal pocket depth. The advantage in using a continuous variable is that it provides count data, which produces risk estimates, IRRs, which can be interpreted in a probabilistic manner.

Table 6. Association between body mass index (BMI) and number of new teeth with deepened (4 mm or deeper) periodontal pockets after 4 years' follow-up among subjects who had periodontal infection (teeth with deepened periodontal pockets) in the baseline examinations. Unadjusted and adjusted* incidence rate ratios (IRR) with 95% confidence intervals (CI)

	New teeth with periodontal pockets of 4 mm or deeper	
	Unadjusted IRR (95% CI)	Adjusted IRR (95% CI)
BMI		
< 25.0	1.0	1.0
25.0–29.9	1.1 (0.8–1.5)	1.0 (0.7–1.4)
30.0 or more	1.2 (0.8–1.7)	1.1 (0.8–1.7)
Continuous variable	1.01 (0.98–1.04)	1.01 (0.97–1.04)

*Adjusted for gender, age (continuous variable), education, presence of dental plaque, dental attendance pattern, toothbrushing frequency, periodontal treatment and number of teeth (offset variable). Effective $n = 207$.

Table 7. Results of linear regression analyses*

	Regression coefficient (95% CI)	*p*-value
BMI		
< 25.0	0	
25.0–29.9	− 0.14 (− 1.8–1.5)	0.87
30.0 or more	0.07 (− 1.9–2.0)	0.94
Continuous variable	− 0.03 (− 0.20–0.14)	0.73

Regression coefficients and 95% confidence intervals (CI) between body mass index (BMI) and change of periodontal pocket depth among subjects who had periodontal infection [teeth with deepened (4 mm or deeper) periodontal pockets] at baseline.
*Adjusted for gender, age (continuous variable), education, presence of dental plaque, dental attendance pattern, toothbrushing frequency and periodontal treatment.
Effective $n = 208$.

The number of new teeth with deepened (4 mm deep or deeper) periodontal pockets as an outcome variable has also certain limitations. Although the presence of deepened periodontal pockets is a widely used method to assess periodontal infection in research and in clinical work, it incorporates only one component of the condition. Clinical attachment loss was not assessed, which is considered to be a limitation. The outcome variable also underestimates, in particular, the progression of periodontal infection due to the fact that it does not take into account the deepening of existing periodontal pockets. Nor does it take into account cases where a deepened periodontal pocket is formed on a tooth that already had a deepened periodontal pocket or pockets already in the baseline examinations.

We also used the change of periodontal pocket depth among subjects who had periodontal infection at baseline as an outcome variable. Although it improves the ability to analyse the progression of periodontal infection, it also has certain limitations. Because the probing pocket depths were recorded only one depth per tooth, the deepening of pocket depth may be due to either deepening of a previously present periodontal pocket or formation of a new one. It also does not take into account the deepening of deep (6 mm deep or deeper) periodontal pockets.

The distribution of the number of new teeth with deepened periodontal pockets was slightly overdispersed due to the large number of subjects who had no new teeth with deepened periodontal pockets. This was seen both among subjects who were periodontally healthy (no teeth with deepened periodontal pockets) in the baseline examinations and among subjects who had periodontal infection (teeth with deepened periodontal pockets) at baseline. Owing to this slight zero-inflation, we performed regression analyses using Poisson's regression models with and without the DSCALE option, and also using negative binomial regression models. Based on the goodness-of-fit statistics we chose to use Poisson's regression models with the DSCALE option in the final analyses, although there were no essential differences in the estimates between these regression models (data not shown).

We used BMI measured in the baseline examinations as the explanatory variable. We acknowledge that changes in the body weight of some of the subjects may have occurred during the follow-up, but this should not have a major effect on these results. This is because normally the changes in body weight are quite moderate, especially because the time span of the follow-up was fairly short, about 4 years. In addition, BMI is a relative measure of body weight. Therefore, the number of subjects who would shift from one BMI category to another, i.e. from normal weight to overweight, for instance, due to age-related habitual weight gain during the follow-up, is likely to be small. It should also be noted that BMI has certain shortcomings as a measure of overweight and obesity, but in this study population BMI correlated fairly well with other measures of overweight and obesity, namely waist circumference and waist-to-hip ratio, the Pearson correlations being 0.85 and 0.42, respectively.

The restriction to never-smokers is a strength for several reasons. One of them is that the control of the effect of smoking may otherwise be insufficient when studying associations between other diseases and periodontal infection (Hujoel et al. 2002). In addition, smoking has been reported to be associated with lower body weight (Albanes et al. 1987) and the cessation of smoking has been suggested to be associated with weight gain (Flegal et al. 1995). These aspects emphasize the importance of restricting the study subjects to never-smokers.

Diabetes often coexists with obesity and periodontal infection (Nishimura et al. 2003). Diabetic as well as pre-diabetic subjects were excluded from this study because the control of the complex interrelations of diabetes with obesity and periodontal infection might otherwise have been incomplete. The possibility that some undiagnosed diabetes exists cannot be totally excluded, but the number of such subjects is most likely to be small and therefore the effect of undiagnosed diabetes should be minimal. In addition, we cannot exclude the possibility of the confounding effect of other diseases or

medications, but their effect in this low-risk population is most likely to be small.

The relatively short time span of the follow-up in relation to worsening of periodontal condition can be considered to be a limitation. This is because chronic periodontal infection is a relatively stable condition. Therefore, to obtain a more thorough conception of the association between body weight and periodontal infection in a longitudinal study, a longer follow-up period would be advantageous.

Power calculations were not performed beforehand, because the Health 2000 Survey and the Follow-Up Study on Finnish Adults' Oral Health are multi-purpose studies and were not specifically designed for the demands of this study. The size of the study population is rather small due to the restrictions (age, smoking, diabetes), which were made in order to decrease the effect of confounding, and thus increasing the validity of the study. The number of subjects in analyses became lesser, because we performed separate analyses according to disease history, which is known to be one of the most important indicators of the future disease progression. With these choices, we were able to perform this study in a manner that allowed studying the known effect of disease history and to obtain profound control of confounders, although at the same time the number of subjects in these groups became smaller than in the original data set, and thus may have decreased the statistical power of the study.

Conclusions

The aim of this study was to investigate the association between body weight and periodontal infection in a longitudinal setting. In this low-risk population, body weight seemed to weakly predict the development of periodontal infection, but not the progression of existing periodontal infection. The strength of the association was weaker than reported in earlier cross-sectional studies and this study does not provide evidence that overweight and obesity can be considered strong risk factors in the pathogenesis of periodontal infection. However, the results of this study must be interpreted cautiously, because the chance related to the small study size may account for the findings. Intervention studies and longitudinal studies with longer follow-up periods are warranted to further examine this association.

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Clinical Relevance

Scientific rationale for the study: Body weight has been suggested to be associated with periodontal infection in many cross-sectional studies recently. However, any interpretations about causality cannot be made because it is not feasible to assess the temporal sequence between supposed cause and effect. Longitudinal studies are therefore needed.

Principal findings: Body weight was weakly, statistically insignificantly, associated with the development of deepened (4 mm deep or deeper) periodontal pockets among subjects who were periodontally healthy in the baseline examinations. Only a minuscule association between body weight and periodontal infection was found among subjects who had periodontal infection at baseline.

Practical implications: The association between body weight and periodontal infection was weaker than in previous cross-sectional studies. The role of overweight and obesity as causal factors for periodontal infection remains obscure. Further studies are therefore needed.