Community Dent Oral Epidemiol 2008; 36: 523–531

Community Dentistry and Oral Epidemiology

Prevalence of hyposalivation in relation to general health, body mass index and remaining teeth in different age groups of adults

Håkan Flink[1,2], Maud Bergdahl[3], Åke Tegelberg[1,4], Andreas Rosenblad[1] and Folke Lagerlöf[2]

[1]Centre for Clinical Research, Uppsala University, Central Hospital, Västerås, Sweden, [2]Karolinska Institutet, Institute of Odontology, Huddinge, Sweden, [3]Institute of Clinical Dentistry, Faculty of Medicine, University of Tromsø, Tromsø, Norway, [4]Faculty of Odontology, Malmö University, Malmö, Sweden

Flink H, Bergdahl M, Tegelberg Å, Rosenblad A, Lagerlöf F. Prevalence of hyposalivation in relation to general health, body mass index and remaining teeth in different age groups of adults. Community Dent Oral Epidemiol 2008; 36: 523–531. © 2008 The Authors. Journal compilation © 2008 Blackwell Munksgaard

Abstract – *Objectives:* Several studies have been conducted on the prevalence of hyposalivation in older adults but no population-based studies in younger adults. Therefore, our aims were to determine the prevalence of very low and low unstimulated (UWSFR) and stimulated (SWSFR) whole salivary flow rates in different age groups between 20 and 69 years, and to analyse the relationship between hyposalivation, subjective oral dryness and predictors of reduced flow rate. *Methods:* A randomized and stratified cross-sectional study including 1427 dental patients was conducted. UWSFR and SWSFR were measured, numbers of remaining teeth recorded and a questionnaire answered regarding subjective oral dryness, general diseases, use of drugs, body mass index (BMI) and use of tobacco. *Results:* The prevalence of very low (<0.1 ml/min) and low (0.10–0.19 ml/min) UWSFR was similar for different age groups up to 50 years, ranging between 10.9–17.8% and 17.3–22.7%, respectively. The prevalence of very low UWSFR was significantly higher for women aged 50–69 years than for younger women. For men, prevalence of very low UWSFR was higher at 60–69 years. The prevalence of very low (<0.7 ml/min) and low (0.70 – 0.99 ml/min) SWSFR was between 0–5.5% and 0.8–8.2%, respectively, for the different age groups 20–69 years. Multiple logistic regression revealed that age above 50 years, female gender, having fewer than 20 teeth, and taking xerogenic drugs significantly increased the risk of very low UWSFR. For very low SWSFR, only having fewer than 20 teeth and taking more than two drugs were significant. In the younger individuals (<50 years) only BMI > 25 for very low UWSFR and diagnosed disease for very low SWSFR were found significant. In this younger subset, female gender combined with having fewer than 27 teeth was significant for low UWSFR. *Conclusions:* Hyposalivation is prevalent in younger adults, among whom it is associated with diagnosed disease and high BMI, while after age 50 years it is associated with medication. It is also associated with gender and with fewer remaining teeth.

Key words: hyposalivation; stimulated whole saliva; unstimulated whole saliva; xerostomia

Håkan Flink, Centre for Clinical Research, Central Hospital, SE-721 89 Västerås, Sweden
Tel: +46 224 58060
Fax: +46 211 73733
e-mail: hakan.flink@ltv.se

Submitted 18 September 2007; accepted 6 December 2007

Hyposalivation, defined as an objectively measured abnormal reduction in salivary flow, has been associated with the symptom xerostomia, defined as the subjective perception of oral dryness (1, 2). Other symptoms of hyposalivation are thirst, difficulties in speaking and in eating dry food (3). Hyposalivation can lead to dental diseases, such as caries (4), and to inflammatory conditions in the oral cavity (3). Measurement of salivary flow rates has been used in the diagnosis of Sjögren's syndrome (5) and for caries risk assessment (6).

doi: 10.1111/j.1600-0528.2008.00432.x

There is general agreement in the literature that the upper limit for a very low unstimulated whole salivary flow rate (UWSFR) is 0.1 ml/min (6–8). Rates between 0.1 and 0.2 ml/min have been suggested as low and those above 0.2 ml/min have been considered normal (8). For stimulated whole saliva, flow rates less than 1.0 ml/min have been regarded as low and rates below 0.7 ml/min as very low (6, 7). A significant correlation has been reported between unstimulated and stimulated whole salivary flow rates (SWSFR) (8, 9).

Hyposalivation may be caused by many factors, e.g. some systemic diseases (10) and several drugs (11). The prevalence of hyposalivation is more common among women than men (9, 12) and increases with age, mainly because of an increased prevalence of diseases and consequently more frequent use of prescribed drugs that affect saliva secretion (13). There are several studies of salivary flow rates in older adults (14–16), and in individuals with medical conditions associated with a high prevalence of hyposalivation, such as Sjögren's syndrome (17) and human immunodeficiency virus (HIV) (18). Hyposalivation has, however, also been found in self-reported healthy individuals (19), as well as among younger adults (8). Few studies of salivary flow rate are based on large general populations that include persons under 50 years of age (9, 12, 20–22). These studies have shown a wide range of individual salivary flow rates. To the best of our knowledge, no population-based study has presented the prevalence of hyposalivation in young and middle-aged adults. Furthermore, very little is known about the causes of hyposalivation in these age groups and no permanent treatment is known to increase salivary flow in these patients.

There is evidence that being overweight, measured as body mass index (BMI), is a common risk factor for diseases such as diabetes, cardiovascular diseases, cancer, osteoporosis and caries, all chronic diseases that are related to diet and nutrition (23). It is possible that being overweight is also a determinant of hyposalivation and thus increases the risk of caries (4). Caries is the most common cause of tooth loss throughout adult life, and caries experience is possibly indicated by the number of remaining teeth (24).

The aim of the present study was to determine the prevalence of hyposalivation in different age groups of adults aged 20–69 years. A secondary aim was to analyze the relationship between hyposalivation and subjective oral dryness, presence of general diseases, regular use of prescribed drugs, BMI, number of remaining teeth, and use of tobacco.

Material and methods

Study population

After approval by the Ethics Committee at Umeå University, Sweden, a total of 1000 men and 1000 women, aged 20–69 years, were randomly selected from a population of 48 500 patients attending 14 dental clinics in two counties in northern Sweden with approximately half a million inhabitants. The selection was stratified into 10 groups, each spanning 5 years and containing 100 men and 100 women. In the subsequent statistical analyses these groups were merged into five age groups (with 10-year intervals). A description of the study, together with an appointment time between 9 am and 11 am, was mailed to each selected individual. If the individual did not attend the first appointment, one reminder was sent.

Of the invited individuals, 1427 (70%) volunteered to participate in the study and gave their informed consent. Of the 573 non-participants, all but 69 were reached by telephone and agreed to a short interview. The following reasons for non-attendance were given: unwillingness to participate (45%), moved from the area (33%), lack of time (10%), too ill to attend (9%), or unable to read or understand the language in the communication (3%). Women had a slightly higher attendance rate than men, and for both genders, the participation rate increased with age from slightly less than 50% to more than 80% (Table 1). Because of missing data in some variables, the number of individuals reported in the results may be lower than the numbers given in Table 1.

Determination of salivary flow rate and dental status

The staff at the clinics were given thorough information about the study and practical training in the measurement of salivary flow rate. The subjects were requested to refrain from eating, drinking, tooth brushing and tobacco use for at least 1 h before saliva collection. No collection was performed during acute illness. Removable dentures were worn during the procedure.

Unstimulated saliva was collected, with the participant in a relaxed position leaning slightly forward. After swallowing, saliva was passively drained for 10 min into a glass centrifuge tube

Table 1. Descriptive data of the population regarding prevalence of different predictor variables used in regression analyses

Sex	Age	n	<27 teeth, n (%)	<20 teeth, n (%)	Drug use, n (%)	Risk drugs, n (%)	>2 drugs, n (%)	Disease, n (%)	BMI > 25, n (%)	Smoking, n (%)	Snuff, n (%)
Males	20–29	90	6 (6.7)	0 (0)	0 (0)	0 (0)	0 (0)	4 (4.4)	28 (32.6)	7 (7.8)	25 (27.8)***
	30–39	120	9 (7.7)	0 (0)	8 (6.7)	6 (5)	0 (0)	23 (19.5)	55 (47.0)**	22 (18.3)	31 (25.8)***
	40–49	139	38 (28.1)	7 (5.2)	26 (18.7)	21 (15.1)	5 (3.6)	32 (23.0)	67 (48.9)**	24 (17.3)	37 (26.6)***
	50–59	155	97 (64.7)	24 (16.0)	37 (23.9)	29 (18.7)	7 (4.5)	41 (26.6)	85 (57.4)**	31 (20.0)	19 (12.3)***
	60–69	165	141 (87.6)	79 (49.1)	92 (56.8)	81 (49.1)	17 (10.5)	94 (57.7)	91 (56.9)	22 (13.3)	15 (9.1)***
	All	669	291 (44.6)	110 (16.9)	163 (24.5)	137 (20.5)	29 (4.4)	194 (29.2)	326 (50.3)***	106 (15.8)	127 (19.0)***
Females	20–29	110	12 (10.9)	0 (0)	32[a] (29.4)***	5 (4.5)*	0 (0)	14 (13.0)*	26 (24.3)	16 (14.5)	8 (7.3)
	30–39	157	25 (16.3)*	0 (0)	30[a] (19.1)**	21 (13.4)*	5 (3.2)*	41 (26.1)	48 (31.2)	43 (27.4)	6 (3.8)
	40–49	161	42 (26.3)	5 (3.1)	36[a] (22.4)	18 (11.2)	3 (1.9)	40 (24.8)	51 (32.3)	41 (25.5)	2 (1.2)
	50–59	158	98 (63.2)	25 (16.1)	84 (53.5)***	46 (29.1)*	8 (5.1)	67 (43.5)**	60 (39.2)	37 (23.4)	1 (0.6)
	60–69	172	156 (92.3)	87 (51.5)	100 (58.8)	77 (44.8)	27 (15.9)	86 (51.8)	89 (53.3)	22 (12.8)	1 (0.6)
	All	758	333 (44.6)	117 (15.7)	282 (37.4)***	167 (22.0)	43 (5.7)	248 (33.2)	274 (37.1)	159 (21.0)*	18 (2.4)
Total		1427	624 (44.6)	227 (16.2)	445 (31.4)	304 (21.3)	72 (5.1)	442 (31.3)	600 (43.3)	265 (18.6)	145 (10.2)

*$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$ significant difference between sexes.

Risk drugs = any drugs from the Anatomical Therapeutical Chemical (ATC) classification system's categories: cardiovascular system (C), musculo-skeletal system (M), nervous system (N) or respiratory system (R); Disease, diagnosed general disease according to ICD-10; BMI, body mass index.

[a]Subcategory: hormonal contraceptives (G03A) taken by 24 in the 20–29 year group, taken by six in the 30–39 year group, and taken by two in the 40–49 year group.

graded in 0.1-ml increments up to 10 ml (WVR, Stockholm, Sweden). Extreme flow rates led to 5 min being subtracted from the collection time for 58 individuals and added for 54 individuals. Directly after the collection of unstimulated saliva, the participants chewed a piece of paraffin to softness. After a swallow, the masticatorily stimulated saliva produced was delivered into a graduated glass centrifuge tube for 3 min. In some cases the collection time was reduced to 1.5 min (in 94 individuals) or extended to 5 min (in nine individuals). A pilot study was performed on 100 healthy individuals. A majority of these participants filled the 10-ml test tube in 5 min. Therefore, for practical reasons the collection time was set to 3 min. After the saliva tests, the number of remaining teeth was recorded.

Questionnaire

After the saliva sampling, the subjects received a questionnaire that included diagnosed diseases, regularly prescribed drugs or over-the-counter medication, use of tobacco, and self-assessed weight and height. The question 'Does your mouth usually feel dry?' was used as an indicator of subjective oral dryness.

Based on the answers in the questionnaire, each participant was interviewed by specially trained dental personnel regarding current diseases and ongoing medication. Systemic diseases were classified according to International Statistical Classification of Diseases and Related Health Problems (ICD-10). Drugs were classified according to the WHO guidelines for the Anatomical Therapeutical Chemical (ATC) classification system. Questions were also asked about other topics that have been reported elsewhere, such as complaints of oral lesions, taste disturbances, burning mouth (25, 26), and symptoms associated with Sjögren's syndrome, such as eye dryness and muscle or joint pain (12).

Statistical methods

Differences in prevalence between age groups and genders were tested by chi-squared tests. Gender differences in salivary flow rates were tested by the Mann–Whitney *U*-test. Gender, presence of diagnosed general disease, regular use of drugs and tobacco, together with variables created by dichotomization (age >50 years; risk drugs; drugs >2; remaining teeth <20, remaining teeth <27 and BMI > 25) were used as independent variables in multiple logistic regression with stepwise

backward elimination, with the low and very low flow rates for unstimulated and stimulated saliva as dependent variables. An omnibus test of model coefficients was used to evaluate how well the models performed. Cox and Snell R^2 and Nagelkerke R^2 were used to estimate the fit of the models. Correlations between UWSFR and SWSFR were tested by the Spearman rank correlation test. All tests were two-sided and *P*-values below 5% were considered significant. Statistical software (SPSS version 14.0; SPSS, Chicago, IL, USA) was used.

Results

Mean and median flow rates

The mean and median UWSFR and SWSFR are shown in Table 2. For UWSFR, significant gender differences were found for ages above 40 years, as they were for all age groups in the case of stimulated whole saliva. The distribution of UWSFR in the sample was highly skewed (skewness = 1.7) and less skewed for stimulated whole saliva (skewness = 0.7) (Table 2).

Prevalence of very low and low UWSFR

The prevalence of very low (<0.1 ml/min) and low (0.10–0.19 ml/min) UWSFR in five different age groups between 20 and 69 years is shown in Table 3, together with age-group and gender differences. Applying multiple logistic regression models to all participants yielded significant odds ratios for very low and low UWSFR for the variables seen in Table 4. When multiple logistic regression models were fitted to the subset of individuals under 50 years of age, BMI > 25 was significant (OR 1.56, 95% CI 1.01–2.40, $P = 0.047$) for very low flow rates. For low salivary flow rates, the interaction women × teeth <27 was also found to be significant (OR 2.78, 95% CI 1.66–4.67, $P < 0.001$).

Prevalence of very low and low SWSFR

The proportions of individuals with very low (<0.7 ml/min) or low (0.70–0.99 ml/min) SWSFR (Table 3) were markedly lower than for those having very low or low unstimulated flow rates. Multiple logistic regression models for all participants gave significant odds ratios for very low and low stimulated whole saliva flow as shown in Table 5. In the subset of individuals under 50 years of age, having a diagnosed disease was the only variable with a significant odds ratio for a very low SWSFR (OR 3.90, 95% CI 1.18–10.30, $P = 0.009$). The odds ratio for female gender remained significant in the low flow rates (OR 3.03, 95% CI 1.30–7.10, $P = 0.011$).

Xerostomia and salivary flow rates

Using the question 'Does your mouth usually feel dry?' as an indicator of subjective oral dryness (xerostomia) gave statistically significant gender differences in all but the youngest age group (Table 3). The participants with salivary flow rates below any of the four different limits used for very low and low flow rates had xerostomia frequencies that were statistically significantly different from

Table 2. Mean and median values of unstimulated and stimulated whole saliva flow rates in different age groups according to sex

		Unstimulated whole saliva				Stimulated whole saliva			
Sex	Age	*n*	Mean (SD)	Median	(Q_1; Q_3)	*n*	Mean (SD)	Median	(Q_1; Q_3)
Males	20–29	90	0.35 (0.27)	0.30	(0.14; 0.48)	88	2.39 (1.11)	2.15	(1.60; 2.80)
	30–39	120	0.35 (0.28)	0.27	(0.17; 0.45)	119	2.50 (0.91)	2.53	(1.83; 3.03)
	40–49	137	0.40 (0.33)	0.31	(0.18; 0.54)	135	2.68 (1.15)	2.63	(1.73; 3.33)
	50–59	153	0.32 (0.22)	0.27	(0.15; 0.46)	154	2.58 (0.97)	2.52	(1.83; 3.33)
	60–69	163	0.26 (0.22)	0.22	(0.10; 0.39)	162	2.33 (1.10)	2.28	(1.50; 3.08)
	All	663	0.33 (0.26)	0.26	(0.14; 0.45)	658	2.50 (1.06)	2.47	(1.73; 3.20)
Females	20–29	110	0.30 (0.21)	0.26	(0.16; 0.40)	109	2.02 (0.71)	1.90*	(1.50; 2.48)
	30–39	157	0.31 (0.24)	0.25	(0.13; 0.45)	154	2.17 (1.00)	2.10**	(1.40; 2.80)
	40–49	161	0.30 (0.22)	0.25*	(0.16; 0.40)	160	2.15 (0.97)	2.03***	(1.40; 2.77)
	50–59	157	0.22 (0.19)	0.17***	(0.09; 0.31)	156	1.98 (0.94)	1.83***	(1.20; 2.50)
	60–69	172	0.19 (0.17)	0.15**	(0.07; 0.25)	169	1.84 (0.89)	1.77***	(1.20; 2.40)
	All	757	0.26 (0.21)	0.21***	(0.11; 0.35)	748	2.03 (0.93)	1.93***	(1.33; 2.60)
Total		1420	0.29 (0.24)	0.24	(0.12; 0.40)	1406	2.25 (1.02)	2.17	(1.50; 2.87)

*$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$ significant difference between sexes.

Table 3. Prevalence of very low (<0.1 ml/min) and low (0.10–0.19 ml/min) unstimulated whole salivary flow rates, very low (<0.7 ml/min) and low (0.70–0.99 ml/min) stimulated whole salivary flow rates and xerostomia in different age groups according to sex

		Unstimulated whole saliva			Stimulated whole saliva			Xerostomia	
Sex	Age	*N*	<0.1 ml/min, *n* (%)	0.10–0.19 ml/min, *n* (%)	*N*	<0.7 ml/min, *n* (%)	0.70–0.99 ml/min, *n* (%)	*N*	*n* (%)
Males	20–29	90	13 (14.4)	16 (17.8)	88	0 (0)†	2 (2.3)	90	11 (12.2)†
	30–39	120	14 (11.7)††	22 (18.3)	119	2 (1.7)	1 (0.8)	120	10 (8.3)†††
	40–49	137	15 (10.9)††	24 (17.5)	135	4 (3.0)	4 (3.0)	139	16 (11.5)††
	50–59	153	18 (11.8)††	32 (20.9)	154	0 (0)††	4 (2.6)	155	22 (14.2)†
	60–69	163	39 (23.9)	35 (21.5)	162	9 (5.6)	7 (4.3)	165	42 (25.5)
	All	663	99 (14.9)	129 (19.5)	658	15 (2.3)	18 (2.7)	669	101 (15.1)
Females	20–29	110	12 (10.9)†††	25 (22.7)	109	1 (0.9)	4 (3.7)	108	15 (13.9)†††
	30–39	157	28 (17.8)††	30 (19.1)	154	7 (4.5)	9 (5.8)*	157	40 (25.5)***††
	40–49	161	21 (13.0)†††	36 (22.4)	160	3 (1.9)	12 (7.5)	161	42 (26.1)***†
	50–59	157	44 (28.0)***	43 (27.4)*	156	4 (2.6)*	13 (8.3)*	157	52 (33.1)***
	60–69	172	58 (33.7)**	48 (27.9)*	169	9 (5.3)	12 (7.1)	172	67 (39.0)**
	All	757	163 (21.5)***	182 (24.0)**	748	24 (3.2)	50 (6.7)***	755	216 (28.6)***
Total		1420	262 (18.5)	311 (21.9)	1406	39 (2.8)	68 (4.8)	1424	317 (22.3)

*$P < 0.05$, **$P < 0.01$ and ***$P < 0.001$ difference between sexes.
$^{\dagger}P < 0.05$, $^{\dagger\dagger}P < 0.01$ and $^{\dagger\dagger\dagger}P < 0.001$ compared with ages 60–69 years.

Table 4. Multiple logistic regression for all participants with very low (*n* = 247) and low (*n* = 293) unstimulated whole salivary flow rates in relation to age, sex, risk drugs and number of teeth. Data controlled for disease, >2 drugs, BMI and tobacco use. Ref. cat: normal unstimulated whole saliva (*n* = 805)

	Very low <0.1 ml/min				Low 0.10–0.19 ml/min				Normal ≥0.2 ml/min
	n	OR	95% CI	*P*	*n*	OR	95% CI	*P*	*n*
Age over 50 years	147	1.78	1.27–2.50	0.001	148	1.45	1.07–1.96	0.018	308
Females	156	1.94	1.44–2.63	<0.001	175	1.70	1.28–2.24	<0.001	392
Teeth <20	64	1.84	1.22–2.77	0.003	59	1.57	1.05–2.35	0.029	90
Risk drugs	77	1.67	1.17–2.39	0.005	68			ns	130
Nagelkerke R^2				0.100				0.045	

Risk drugs = any drugs from the Anatomical Therapeutical Chemical (ATC) classification system's categories: cardiovascular system (C), musculo-skeletal system (M), nervous system (N) or respiratory system (R).

Table 5. Multiple logistic regression for all participants with very low (*n* = 34) and low (*n* = 62) stimulated whole salivary flow rates in relation to, sex, >2 drugs and number of teeth. Data controlled for disease, risk drugs, BMI and tobacco use. Ref. cat: normal stimulated whole saliva (*n* = 1235)

	Very low <0.7 ml/min				Low 0.70 – 0.99 ml/min				Normal ≥1.0 ml/min
	n	OR	95% CI	*P*	*n*	OR	95% CI	*P*	*n*
Teeth <20	12	2.36	1.10–5.05	0.027	13				184
>2 drugs	8	5.52	2.29–13.31	<0.001	6			ns	51
Females	21			ns	47	2.82	1.56–5.10	0.001	647
Nagelkerke R^2				0.071				0.040	

those with normal flow rates (Table 6). The frequencies of xerostomia were significantly higher for women than for men at all levels of UWSFR (Table 6).

Correlation unstimulated and stimulated whole saliva

There was a statistically significant correlation between UWSFR and SWSFR (r_s = 0.524,

Table 6. Xerostomia (Does your mouth usually feel dry? n = 317) in relation to salivary flow rate groups according to sex

Salivary flow rates		Total	No, n (%)	Yes, n (%)	P higher flow rates	P sex
Unstimulated whole saliva ≥0.2 ml/min	Males	435	386 (89)	49 (11)		0.012
	Females	410	339 (83)	71 (17)		
0.10–0.19 ml/min	Males	129	105 (81)	24 (19)	0.029[a]	0.003
	Females	182	120 (66)	62 (34)	<0.001[a]	
<0.1 ml/min	Males	99	71 (72)	28 (28)	0.084[a] (<0.001[b])	<0.001
	Females	162	79 (49)	83 (51)	0.001[a] (<0.001[b])	
Stimulated whole saliva ≥1.0 ml/min	Males	625	539 (86)	86 (14)		<0.001
	Females	671	496 (74)	175 (26)		
0.70–0.99 ml/min	Males	18	10 (56)	8 (44)	<0.001[a]	0.796
	Females	50	26 (52)	24 (48)	0.001[a]	
<0.7 ml/min	Males	15	9 (60)	6 (40)	0.797[a] (0.004[b])	0.170
	Females	24	9 (38)	15 (63)	0.242[a] (<0.001[b])	

[a]Difference from the group having unstimulated or stimulated whole saliva flow rates larger than this group.
[b]Difference compared with normal flow rates.

$P < 0.001$), which explains 27% of the variation in the data ($R^2 = 0.27$).

Discussion

In the present population-based study of randomly selected dental patients in different age groups, ranging from 20 to 69 years, the prevalence of low UWSFR among adults under 50 years of age was around 30% (including a prevalence of more than 10% for very low flow rates). Earlier studies of general populations that include younger adults have only reported mean or median salivary flow rates in different age groups, not the prevalence of very low and low flow rates (9, 20–22). Knowledge of the prevalence of hyposalivation is of importance for the diagnosis and management of oral diseases such as dental caries. The unexpectedly high prevalence in the younger age groups indicates that this factor may be of significance for oral health in these groups.

The four different limits for low and very low salivary flow rates used in this study are based on recommendations by Ericsson and Hardwick (7), and others (8, 27). The validity of these limits does not seem to have been established. Especially the limit for low UWSFR has been discussed. With reference to xerostomia, a limit at 0.2 ml/min has been proposed (8, 27, 28) and was used in the present study. Even lower limits have been considered in the context of an increased caries risk (29–31). Arbitrary limits, used in the present study and in most of the literature, are open for discussion. In medicine, reference values are often defined as a certain deviation from the average, sometimes a multiple of the standard deviation or a confidence interval. Further studies of salivary flow rate are needed to establish valid reference values. It seems possible that the reference values should be stratified for gender and age, besides their purpose.

The relationship between UWSFR and SWSFR has been reported to be correlated (8, 9) and this was the case in the present study. Reduced flow rates were more common in unstimulated than in stimulated whole saliva, which is in agreement with other studies (28, 32). This finding is important in that the UWSFR has been proposed to be a more sensitive measure than SWSFR in relation to xerostomia (8, 28). Furthermore, mild symptoms of xerostomia have been reported to be associated with low UWSFR, while more severe symptoms were related to very low UWSFR combined with very low SWSFR (28). This is in agreement with the findings in the present study, where the highest proportion of individuals experiencing xerostomia was found among those whose SWSFR were reduced compared with other groups (Table 6).

In the multiple logistic regression models used in this study, the total rates of explanation for the variance in low and very low salivary flow rates expressed by Nagelkerke R^2 were low. In the best model, predicting very low UWSFR for all individuals (Table 3), the independent variables explained only 10% of the difference in salivary flow rates between individuals. These findings indicate that knowledge about causes of hyposalivation, especially among young and middle-aged adults, is still scanty. The rather consistent prevalence of low and very low UWSFR found between 20 and 50 years of age may indicate that

hyposalivation develops even earlier, during adolescence. If so, hyposalivation may fit into the 'Life course perspective' (33), an epidemiologic model that has received growing attention in explaining etiological factors for chronic diseases (23). According to this concept, during growth the individual passes through critical periods when socioeconomic and biological factors may affect the development of organs and body tissues. Deficiencies in these factors may lead to a permanently reduced function of the salivary glands and to increased susceptibility to disease during adulthood.

The predictive variable for low and very low salivary flow rates that was found most frequently in the eight different regression models used in the present study was gender, followed by number of remaining teeth. The effect of gender on salivary flow rates has been described by several authors (9, 12, 20). This effect has been related to differences in salivary gland size (34), a finding that may suggest the adoption of different limits for men and women when it comes to low and very low salivary flow rates. The results from the present study, showing significant gender differences in the prevalence of xerostomia and fewer remaining teeth among women in the younger subset, may indicate increased limits for hyposalivation in men rather than decreased limits in women. It should be noted, however, that such an adjustment of the limits would give a higher prevalence of low and very low flow rates among men.

The clearest gender difference concerned the prevalence of low and very low UWSFR, which was higher in women aged 50–69 years compared with men. A similar higher prevalence among women compared with men in an older population has been reported (15) and might also correspond to the lower mean flow rates for women aged 45–54 and 55–64 years, described by Yeh et al. (20). This clear gender difference in older age groups deserves the dental profession's special attention in order to prevent disease adequately. The etiologies of the gender difference in dental caries have recently been discussed from an anthropological perspective, combined with clinical research findings of saliva and hormonal fluctuations in puberty, menstruation and pregnancy (35). Interest in these gender-specific burdens has also been focused on the etiology of other diseases in relation to nutrition (36). Menopause may reduce salivary flow rate, which is indicated by the effect of hormonal replacement therapy (37, 38). In the present study no question was asked about the menopause. However, statistical analyses showed that hormonal replacement therapy did not significantly affect the prevalence of hyposalivation, and nor did use of hormonal contraceptives.

Teeth can be lost for various reasons but caries is the most important cause throughout adult life (24). The relationship between caries and hyposalivation has been difficult to confirm in cross-sectional studies, except when the salivary flow rate is very low (4, 39). A difficulty in studies of this kind has been the lack of information about actual flow rates during the development of caries cavities (39). Longitudinal studies are needed to monitor the eventual progress of caries in association with hyposalivation (40). However, some evidence has been found of an association between hyposalivation and the DMF index (22, 41).

Evidence-based reports support the notion that a very low salivary flow rate is an indicator of a significant risk of developing new caries lesions (4). In addition, the finding in the present study that the prevalence of very low UWSFR was consistent and above 10% in younger adults indicates a need for salivary flow measurement in patients with recurrent caries disease. This is important, because acknowledgment of hyposalivation by both patient and dentist identifies a need for more extensive prevention and attempts to control other risk factors in order to avoid caries, as no treatment is known to permanently increase the salivary flow in these patients (42).

The increased prevalence of hyposalivation caused by diseases and intake of drugs in aged patients is well known (13) and is of growing concern as number of lost teeth is decreasing in older people (43). The relationship between hyposalivation and use of drugs was also evident in this study, though it was not found in the subset under 50 years. Instead, a probable predisposing factor for disease, BMI above 25, and presence of diagnosed disease showed significant odds ratios for very low unstimulated and stimulated salivary flow rates, respectively. The global epidemic of overweight and obesity is linked to the growing medical problem of chronic diseases related to diet and nutrition (23). A factor that may compromise salivary gland function is malnutrition (44). However, malnutrition and its effect on saliva in humans have mainly been addressed in groups that are undernourished (45–47). The association found in this study between high BMI and prevalence of hyposalivation may be due to

malnutrition as an effect of a fat- and carbohydrate-rich diet. The relationship between being overweight and dental caries has been studied but the results so far are inconclusive (48). Self-reported height, weight and BMI have been reported to be valid in younger adults (49, 50), even if weight is generally underestimated especially among heavier men and women.

The indication above that disease can be an initial cause of hyposalivation in younger individuals and that this may lead to the need and use of drugs in older ages has been discussed (21). Well-designed longitudinal studies have been proposed to increase our understanding of the presence of xerostomia, changes in flow rate and the association with diseases and drug use over time in aging people (21).

The low participation rate (approximately 50%) in the youngest age group raises the question of selection bias in this age group. However, the prevalence of hyposalivation in this age group did not differ significantly from that in the other two groups of young and middle-aged adults.

The prevalence of hyposalivation presented in this study is limited to a relatively homogenous Swedish population. However, in the absence of information about hyposalivation in young and middle-aged adults, the present study seems to offer the only available randomized population-based data. Future longitudinal studies are needed to learn more about hyposalivation: (i) in adolescents and young adults; (ii) in relation to dental caries, and (iii) in aging people and its relation to gender, diseases and drug use.

Conclusions

Hyposalivation is prevalent in younger adults and related to diagnosed disease and high BMI, while after age 50 years it is related to medication. Hyposalivation is also related to gender and to fewer remaining teeth.

Acknowledgments

We wish to thank Professor Ingegerd Johansson, Department of Cariology, School of Dentistry, Umeå University, for initiating the study design. The study was supported by grants from the County Council of Västernorrland, the School of Dentistry, Umeå University, the Swedish Dental Association and the Centre for Clinical Research, Uppsala University.

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