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Prediction of xerostomia in a 75-year-old population: A 25-year longitudinal study

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ABSTRACT

Objectives: To follow the same individuals from age 50 up to 75 years to report on prevalence, persistence, progression, remission, incidence and predictors for xerostomia.
Methods: A questionnaire was distributed to all 50-years-olds (1992) in two Swedish counties ($N = 8888$) and repeated at the age of 65 (2007) and 75 years (2017). 3060 individuals responded on all three occasions (response rate 42.5%). Xerostomia was assessed with two questions. Additional questions addressed inter alia general/oral health and oral function.
Results: Reported prevalence of daytime xerostomia were 23.3% and 14.7%, and 39.5% and 27.5% in women and men, age 50 and 75, respectively. Night-time prevalence was higher. At age 50, 27.4% women and 24.0% men reported having dry mouth, and at age 75, 61.0% and 53.8%, respectively. At all time points, women reported significantly more xerostomia than men. Progression (deterioration) was common, and persistence (continuing presence) was high, while 25-year incidence for daytime xerostomia was 16.2% and 12.8%, and 33.6% and 29.8% at night-time, for women and men, respectively. Based on reports at age 50, regression analyses showed that prediction for developing xerostomia during the observation period, and reporting xerostomia at age 75 years, were female gender, impaired general health, chewing, jaw opening and intraoral problems, dissatisfaction with dental appearance, low education and having white/plastic filling.
Conclusions: Xerostomia is common in older people, especially at night and in women. It can be predicted by diverse factors reported earlier in life.
Clinical Significance: Clinicians need to be made aware of that elderly often suffers from dry mouth so that they can recommend effective measures to eliminate or ease the patients accompanying symptoms and also exclude or lessen possible negative impact on oral health related to xerostomia.

1. Introduction

In 2015, people over 60 years of age comprised 12% of the world's population. By 2050 it is predicted that their proportion of the world's inhabitants would have nearly doubled to as much as 22%. Thus, individuals over 60 years of age will make up nearly a quarter of the world's population. This coming change in demographic structure has heightened the importance and necessity for knowledge and understanding about the oldest in society and their future specific conditions and healthcare needs. Whether this expected longer lifespan will be associated more with accompanying improvements in well-being and social activity, or instead with deteriorations in sickness and helplessness has been discussed [1]. Currently medical research remains still largely focused on increasing the *quantity* of life, rather than the *quality* of life, and this has been questioned with the suggestion that such an emphasis could have negative impacts not only on health but also the economy [2]. To ensure that the future health and welfare social systems are capable of handling a growing group of older individuals it is

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important to understand their needs and demands in order to be able to maintain for them a sense of well-being and health. This will apply equally to the oral health and dental setting.

A recent study of Swedes who were 75 years of age in 2017, reported significantly improved general health and dental status compared to those who were 75 years old a decade earlier. A substantial decrease of edentulousness, from 7.8% to 2.3%, as well as improved chewing efficiency were also found [3]. But, in contrast with such positive findings, an increased prevalence of xerostomia (self-reported dry mouth) has been reported with increasing age and especially so amongst women and at night [4]. Besides being related to ageing, xerostomia is related to medication side-effects and to some extent also to smoking. Xerostomia may also have a negative effect on both speaking and chewing and influence the individual's choice of food and their oral health-related quality of life (OHRQoL) [5,6]. It has recently been shown that patients with dry mouth, defined as both xerostomia and hyposalivation, had shorter survival times of their restorations than those who did not report any type of dry mouth. Life expectancy for large composite restorations was only half in dry mouth patients compared to that in non-dry mouth patients [7].

Taken together, a growing elderly population who retain more of their teeth than did earlier generations, and having a high prevalence of xerostomia increases the likelihood of a greater need for of dental care. In this regard, it is important to understand the development of xerostomia over time, and especially as it pertains to older people, as well as its relationship to general and oral health.

The aim of this study was to follow the *same* individuals over 25 years, from the age of 50, through 65 and to 75 years of age in a longitudinal sample in order to report on prevalence, persistence, progression, remission and incidence of xerostomia and to predict its occurrence at age 75 years with tentative associated factors.

2. Material and methods

2.1. Sample selection

In 1992 a questionnaire was mailed to all 50-year-olds (i.e. born in 1942), living in the two Swedish counties Örebro and Östergötland (N_{50} = 8888). The survey was repeated 15 and 25 years later: firstly, in 2007, when the sample had become 65-year-olds (N_{65} = 8313), and secondly, in 2017 (viz. 25 years after the first survey), when the sample had become 75-year-olds (N_{75} = 7204). The response rates at age 50, 65 and 75 years of age were 71.4%, 73.1% and 70.7%, respectively. Individuals not responding within two weeks were given a reminder by letter. If still not answering, a new questionnaire was sent but after that they were not given any further notice.

Those who responded on all three survey occasions in 1992, 2007 and in 2017, are henceforth called the "panel", constituted 3060 individuals (1635 women and 1425 men) corresponding to a response rate of 42.5% based of the total eligible population in 2017

2.2. Questionnaire

The questionnaire was about socio-economic conditions (viz. age, gender, occupation), general health (e.g. physician visits, tobacco habits, drug consumption), oral conditions (e.g. self-reported dry mouth daytime and night-time, wounds, blisters, toothache), oral function (e.g. number of teeth, chewing problems), satisfaction with teeth/dental appearance and restorations (e.g. types of fillings, crowns, dentures). There were two focused questions regarding self-reported dry mouth, xerostomia, during the day and at night-time. The answers to these two questions had four response alternatives: yes often, yes sometimes, no seldom, no.

2.3. Statistical methods

All statistical analyses were performed using the IBM Statistical Package for Social Sciences (SPSS, Release 26). Domains for longitudinal variations in reported dry mouth were defined as follows:

Prevalence: The percentage of panel participants reporting "yes often/yes sometimes" regarding daytime and at night-time dry mouth at ages 50, 65 and 75 years.

Persistence: The percentage of panel participants reporting "yes often/yes sometimes" regarding continued presence of daytime and night-time dry mouth within age spans: 50 to 65 years, 65 to 75 years and 50 to 75 years.

Progression: The percentage of panel participants reporting a change in daytime and night-time dry mouth from "no, never/no, seldom" to "yes often/yes sometimes" over the age spans: 50 to 65 years, 65 to 75 years, and over the entire follow-up period of 50 to 75 years of age.

Remission: The percentage of panel participants reporting a change in daytime and night-time dry mouth from "yes often/yes sometimes" to "no never/no seldom" within age spans: 50 to 65 years, 65 to 75 years, and over the entire follow-up period of 50 to 75 years of age.

Incidence: Yearly mean percentage of panel participants reporting daytime and night-time dry mouth progression from "no never/no seldom" dry mouth to "yes often/yes sometimes" from over the time spans: 50 to 65 years, 65 to 75 years, over the entire follow-up period of 50 to 75 years of age.

Gender differences were analysed by Pearson's Chi-square test. Unadjusted logistic regression was computed using daytime and night-time xerostomia as dependant variables in two different ways:

A. Persistence of "no seldom/no never" dry mouth at ages 50 and 75 years vs. progression from "no seldom/no never" to "yes sometimes/yes often" at ages 50 and 75 years.

B. "Yes, often" dry mouth at 75 years vs. "no, never" dry mouth at 75 years.

Independent variables were collected from the dichotomized responses to the questionnaire at age 50 years in 1992 (Table 1). In the adjusted logistic regression model (Forward Conditional Method), independent variables with $p \leq 0.05$ was entered.

2.4. Ethical considerations

The Ethics Committee in Uppsala, Sweden, approved the study (Dnr 2016/424). An informed consent was obtained from all participants.

Results

Analysis of non-responders could be analysed only in regard to gender and county. Of the total population in 2017, 51.4% were women (n = 3701) and 48.6% men (n = 3503). The corresponding figures for the panel were 53.4% for women and 46.6% for men, thus representing a slight overrepresentation of women. As regards the two counties, 59.3% of the total population in 2017 lived in Östergötland and 40.7% in Örebro. The respective figures for "the panel" were 60.5% from Östergötland and 39.5% from Örebro, and thus a slight overrepresentation of responders from the county of Östergötland.

Prevalence of frequently reported xerostomia ("yes often") increased steadily by age, and was also statistically higher in women compared to men ($p < 0.001$) at all three time points (50, 65 and 75 years). This gender difference was especially pronounced for daytime dry mouth with women reporting more than double the frequency of "yes often" dry mouth compared to men at all three time points. At age 75 years, 9.6% of women had frequent daytime xerostomia compared to 4.2% of the men (Table 2). A similar pattern was seen for night-time dry mouth, whereas the gender difference was less pronounced at age 50 years, but which increased by about 50% in women compared to men at 65 75 years of age. The figures for frequent xerostomia ("yes often") at age 75 years were 22.4% and 16.3% in women and men, respectively (Table 3).

Table 1
Complete list of all examined dichotomized variables in the unadjusted/adjusted regression analysis.

Variable	Dichotomization
Gender	Gender: 1=woman; 2=man
Education	Education: 1=university; 2=other (elementary school, high school, upper secondary school, other)
Birthplace	Birthplace: 1=Sweden; 2=other country
Residency	Residency: 1=large city; 2=small city/countryside
Profession	Profession: 1=blue-collar workers, non-academic entrepreneurs, farmer, lower white-collar workers; 2=middle/high white-collar workers, managers, academic entrepreneurs
Marital status	Marital status: 1=married/cohabiting; 2=unmarried, divorced, widowed
Health	Health good: 1=yes, absolutely; 2=yes, for the most part, no, not especially, no, absolutely not
Health vs. peers	Health compared to same-aged peers: 1=much better, better; 2=equal, worse, much worse
Medication	Medication usage last 14 days: 1=yes; 2=no
Doctor contact	Doctor visit last 3 months: 1=yes; 2=no
Smoking	Smoking: 1=Daily/occasional/smoking; 2=stopped, never smoked
Chewing	Chewing all kind of food: 1=very good; 2=fairly good, less good, bad
Appearance	Appearance: 1=very satisfied; 2=to large extent satisfied, not especially, absolutely not
Teeth number	Number of teeth: 1=all teeth left; 2=missing single tooth, rather many, edentulous
Burning mouth	Burning mouth: 1=no problems; 2=some, rather much, great problems
Wounds, blisters	Wounds/blister intraorally: 1=no problems; 2=some, rather much, great problems
Taste changes	Taste changes: 1=no problems; 2=some, rather much, great problems
TMJ pain	TMJ pain: 1=no problems; 2=some, rather much, great problems
TMJ sounds	TMJ sounds: 1=no problems; 2=some, rather much, great problems
Jaw opening	Jaw opening: 1=no problems; 2=some, rather much, great problems
Bruxism	Bruxism: 1=no problems; 2= some, rather much, great problems
Bleeding	Gingival bleeding: 1=no problems; 2=some, rather much, great problems
Bad breath	Bad breath: 1=no problems; 2=some, rather much, great problems
Dental material	Dental material side effects: 1=no problems; 2=some, rather much, great problems
Sensitive teeth	Sensitive teeth: 1=no problems; 2=some, rather much, great problems
Toothache	Toothache - during the last 3 months, last year, more than 1 year ago: 1=yes; 2=no
Gold	Gold restorations - presence: 1=yes; 2=no
Amalgam	Amalgam restorations - presence: 1=yes; 2=no
Porcelain	Porcelain restorations - presence: 1=yes; 2=no
Titanium/steel	Titanium/steel or restorations - presence: 1=yes; 2=no
Temporary fillings	Temporary restorations - presence: 1=yes; 2=no
White/plastic fillings	White or plastic restorations:1=yes; 2=no
Partial denture	Partial denture - presence: 1=yes; 2=no
Complete denture both jaws	Complete denture, both jaws - presence: 1=yes; 2=no
Complete denture/ one jaw	Complete denture, one jaw - presence: 1=yes; 2=no

When "yes often" and "yes sometimes" dry mouth were combined, the statistically significant gender differences remained. Daytime dry mouth at age 50 years for these categories of responses were 23.3% in women and 14.7% in men ($p < 0.001$), 30.8% and 19.7% respectively at age 65 years ($p < 0.001$), and 39.5% and 27.5% ($p < 0.001$), respectively at age 75 years. At night-time, the combined prevalence of xerostomia was higher. At age 50 years, 27.4% of women and 24.0% of men reported having dry mouth ($p = 0.04$), at age 65 years it was 51.1% and 44.2%, respectively ($p < 0.001$), while at 75 years it was 61.0% and 53.8% ($p < 0.001$), respectively

Persistence of xerostomia reporting, defined as "yes often" and "yes sometimes" dry mouth over age spans 50 to 65 years, 65 to 75 years, and from 50 to 75 years, was statistically higher for women than for men both at daytime and night-time ($p = 0.01$ to $p < 0.001$). For women, persistence ranged from 60.9% to 69.0% at daytime and 78.9% to 85.8% at night-time, and the corresponding figures for men were 49.3% to 54.6% and 74.5% to 78.5%, respectively (Table 4).

Progression, defined as a change from "no never/no seldom" to "yes often/yes sometimes" dry mouth, was statistically higher for women than men, ranging from 21.7% to 30.3% during daytime for women and 14.5% to 23.0% for men ($p = 0.04$ to $p = 0.001$). Progression of night-time xerostomia was considerably higher, and again higher for women than men, but not statistically so, ranging from 40.7% to 50.8% in women and from 35.9% to 45.9% in men (Table 5).

Remission, or regression, defined as participants reporting a change from "yes, often/yes, sometimes" to "no, never/no, seldom" dry mouth was more common amongst men both during daytime and night-time, but the gender difference being not statistically different except for the daytime between the ages of 65 and 75 years ($p = 0.03$). Remission in women ranged from 31.0% to 39.1% during daytime and from 14.2% to 21.1% at night-time, and correspondingly in men from 41.2% to 50.7% and 21.5% to 25.5 (Table 6).

The *25-year incidence* from age 50 to 75 years, determined as a change from "no never/no seldom" dry mouth to "yes often/yes sometimes", was higher for women than for men, the daytime incidences being 16.2% and 12.8%, respectively. The night-time corresponding figures were 33.6% and 29.8%. These figures correspond to an average yearly daytime incidence of 0.65% for women and 0.51% for men over the 25-year period, and 1.3% and 1.2% at night-time for women and men, respectively. For daytime mouth dryness, the yearly incidence was considerably higher between ages 65 and 75 years (women = 0.87%; men = 0.78%) compared to between ages 50 and 65 years (women = 0.50%; men = 0.33%). Night-time incidence for dry mouth was about double that of daytime dry mouth. In contrast to daytime dry mouth, the yearly incidence for night-time xerostomia was about 50% higher for the period 50 to 65 years than between 65 and 75 (Table 7).

Persistence of "no never/no seldom" dry mouth responses from age 50 to 75 vs. progression from "no never/no seldom" to "yes sometimes/yes often" dry mouth (dependant variable) yielded numerous significant independent variables (as reported at age 50) in the unadjusted analysis both at daytime and night-time. In the adjusted model, predictive factors for consistently reporting having no problem regarding dry mouth during daytime were good health (OR 1.6, CI 1.3–1.9), absence of jaw opening problems (OR 1.5, CI 1.1–2.2) and sensitive teeth (OR 1.2, CI 1.0–1.5), while female gender (OR 0.74, CI 0.6–0.91) and smoking (OR 0.76, 0.6–0.97) predicted progression from "no never/no seldom" to "yes sometimes/yes often" dry mouth, at age 75. For night-time dry mouth, reported better health than same aged peers (OR 1.5, CI 1.2–1.8), satisfaction with dental appearance (OR 1.5, 1.2–2.0), all teeth remaining (OR 1.3, CI 1.0–1.6), and absence of sensitive teeth (OR 1.3, CI 1.1–1.6) were predictive for remaining free of the symptom of dry mouth during the observation period (Table 8).

With the dependant variable as "yes, often" dry mouth vs. "no, never" dry mouth reported at age 75, numerous significant independent variables based on responses at age 50 in the unadjusted analysis were again exhibited. In the adjusted model, predictive factors for having daytime xerostomia at age 75 were: female gender (OR 2.4, CI 1.5–3.7), medication (OR 1.7, CI 1.1–2.6), visiting doctor (OR 1.6, CI 1.0–2.4), lower education (OR 0.53, CI 0.30–0.91), not feeling healthy (OR 0.34, CI 0.21–0.56), worse health than peers (OR 0.47, CI 0.27–0.81), problems with chewing (OR 0.57, CI 0.36–0.89), wounds/blisters (OR 0.54, CI 0.33–0.91), taste changes (OR 0.43, CI 0.22–0.84) and bruxism (OR 0.49, CI 0.31–0.78). Having night-time dry mouth at age 75 were predicted by several factors reported at age 50: not feeling healthy (OR 0.58, CI 0.43–0.79), medication (OR 1.5, CI 1.1–2.1), problems with chewing (OR 0.41, CI 0.28–0.60), TMJ pain (OR 0.47, CI 0.27–0.84),

Table 2
Prevalence: Reported daytime mouth dryness in the longitudinal panel ($n = 3060$) at ages 50 (1992), 65 (2007) and 75 (2017) divided by gender (women $n = 1635$; men $n = 1425$).

	50 year			65 year			75 year		
	Women % (n)	Men % (n)	Total % (n)	Women % (n)	Men % (n)	Total % (n)	Women % (n)	Men % (n)	Total % (n)
Yes often	3.3 (53)	1.1 (15)	2.3 (68)	6.7 (107)	2.9 (41)	4.9 (148)	9.6 (147)	4.2 (57)	7.1 (204)
Yes sometimes	20.0 (322)	13.6 (191)	17.1 (513)	24.1 (386)	16.8 (235)	20.7 (621)	29.9 (456)	23.2 (314)	26.8 (770)
No seldom	34.9 (561)	44.0 (616)	39.1 (1177)	33.4 (535)	41.3 (578)	37.1 (1113)	31.7 (483)	40.8 (551)	35.9 (1034)
No never	41.7 (670)	41.3 (579)	41.5 (1249)	35.9 (575)	39.0 (546)	37.3 (1121)	28.8 (440)	31.8 (429)	30.2 (869)
n total	1606	1401	3007	1603	1400	3003	1526	1351	2877
p	<0.001			<0.001			<0.001		

N.B. Some missing data at the different examination points explains why n (gender) differs from the total (3060).
p denotes gender differences (Pearson's Chi-square test).

Table 3
Prevalence: Reported night-time mouth dryness in the longitudinal panel ($n = 3060$) at ages 50 (1992), 65 (2007) and 75 (2017) divided by gender (women $n = 1635$; men $n = 1425$).

	50 year			65 year			75 year		
	Women % (n)	Men % (n)	Total % (n)	Women % (n)	Men % (n)	Total % (n)	Women % (n)	Men % (n)	Total % (n)
Yes often	4.8 (74)	4.0 (55)	4.4 (129)	16.5 (266)	11.1 (157)	14.0 (423)	22.4 (320)	16.3 (207)	19.5 (527)
Yes sometimes	22.6 (348)	20.0 (275)	21.4 (623)	34.7 (560)	33.1 (468)	33.9 (1028)	38.6 (553)	37.5 (478)	38.1 (1031)
No seldom	29.4 (453)	37.8 (519)	33.3 (972)	23.3 (377)	30.4 (430)	26.7 (807)	20.5 (293)	26.9 (342)	23.5 (635)
No never	43.3 (667)	38.2 (524)	40.9 (1191)	25.5 (412)	25.3 (358)	25.4 (770)	18.5 (265)	19.3 (246)	18.9 (511)
n total	1542	1373	2915	1615	1413	3028	1431	1273	2704
p	<0.001			<0.001			<0.001		

N.B. Some missing data at the different examination points explains why n (gender) differs from the total (3060).
p denotes gender differences (Pearson's Chi-square test).

Table 4
Persistence: Percentage of participants consistently reporting: *"yes often/yes sometimes"* dry mouth at ages 50 to 65, 65 to 75 and 50 to 75 divided by gender (women $n = 1635$; men $n = 1425$).

	Daytime			**Night-time**		
Age span	50 – 65 %	65 – 75 %	50 – 75 %	50 – 65 %	65 – 75 %	50 – 75 %
Women	60.9	66.8	69.0	78.9	82.4	85.8
Men	49.3	58.8	54.6	74.5	76.3	78.5
P	<0.001	<0.001	<0.001	0.01	<0.001	0.001

p denotes gender differences (Pearson's Chi-square test).

Table 5
Progression: Percentage of participants reporting a change from "*no, never/no seldom*" to "*yes, often/yes sometimes*" dry mouth in age spans 50 to 65, 65 to 75 and 50 to 75 divided by gender (women $n = 1635$; men $n = 1425$).

	Daytime			**Night-time**		
Age span	50 – 65 %	65 – 75 %	50 – 75 %	50 – 65 %	65 – 75 %	50 – 75 %
Women	21.7	27.1	30.3	40.7	37.3	50.8
Men	14.5	19.5	23.0	35.0	36.2	45.9
p	0.001	0.04	0.02	NS	NS	NS

p denotes gender differences (Pearson's Chi-square test).

sensitive teeth (OR 0.65, CI 0.48–0.89) and reporting presence of white/plastic fillings (OR 1.5, CI 1.1–2.1) (Table 9).

Discussion

The life expectancy at birth in Sweden has nearly doubled over the past 200 years, from close to 40 years in 1816–1840 to just over 80 years in 2020 [8]. This demographic change poses challenges for society in a number of ways, not the least of which is provision of adequate medical care and social welfare for the elderly. The main finding from this study was that xerostomia is common in older people and especially so at night and in women. In individuals who reported dry mouth at age 50 years, the condition persisted largely to age 75 years and especially so in women who also exhibited generally greater progression compared to men. The incidence of reported daytime xerostomia was higher between the ages of 65 and 75 while the opposite was found for night-time xerostomia where the incidence was higher between ages 50 and 65. In the regression analyses, predictors for developing xerostomia during the observation period of 25 years or having xerostomia at age 75, based on reports at age 50 years, were female gender, impaired general health, chewing and jaw opening problems, and a number of reported intraoral problems. Dissatisfaction with dental appearance, low education and having white/plastic fillings at age 50 were additional factors predictive of xerostomia at age 75.

In the whole of Sweden the total population of 75-year-olds in 2017 was 90,457 of which 51.5% were women and 48.5% were men [9]. This distribution correlates well with that of the two counties from which the study population was drawn (51.4% women, 48.6% men), although the panel who comprised this study had a slight overrepresentation of

Table 6
Remission: Percentage of participants reporting a change from "*yes, often/sometimes*" dry mouth to "*no, never/no seldom*" in age spans 50 to 65, 65 to 75 and 50 to 75 divided by gender (women $n = 1635$; men $n = 1425$).

	Daytime			**Night-time**		
Age span	50 – 65 %	65 – 75 %	50 – 75 %	50 – 65 %	65 – 75 %	50 – 75 %
Women	39.1	33.2	31.0	21.1	17.6	14.2
Men	50.7	41.2	45.4	25.5	24.1	21.5
p	NS	0.03	NS	NS	NS	NS

p denotes gender differences (Pearson's Chi-square test).

Table 7
Average yearly incidence: Yearly percentage of participants reporting dry mouth progression from "*no, never/seldom*" dry mouth to "*yes, often/yes sometimes*" from ages 50 to 65, 65 to 75 and 50 to 75 divided by gender (women $n = 1635$; men $n = 1425$). Δ refers to the difference in reported prevalence between the different time points.

	Daytime						**Night-time**					
	Prevalence difference			Incidence/year			Prevalence difference			Incidence/year		
	Δ 50–65 %	Δ 65–75 %	Δ 50–75 %	50–65 %	65–75 %	50–75 %	Δ 50–65 %	Δ 65–75 %	Δ 50–75 %	50–65 %	65–75 %	50–75 %
Women	7.5	8.7	16.2	0.50	0.87	0.65	23.7	9.9	33.6	1.6	0.99	1.3
Men	5.0	7.8	12.8	0.33	0.78	0.51	20.2	9.6	29.8	1.4	0.96	1.2

Table 8
Unadjusted and adjusted (Forward Conditional Method) logistic regression model for daytime and night-time xerostomia. dependant variable: 1=Persistence of *seldom/never* dry mouth between 50 and 75 ($n = 1675$ and $n = 991$ for daytime and night-time respectively); 2=Progression from *seldom/never* to *sometimes/often* in 50–75 ($n = 609$ and $n = 929$ for day and night respectively). Selection of independent variables were made based on those found significantly correlated ($p < 0.05$) to either day- or night-time xerostomia in unadjusted analysis using all variables according to Table 1.

	Daytime					Nighttime				
	Unadjusted		Adjusted			Unadjusted		Adjusted		
	p	OR	*p*	OR	CI	*p*	OR	*p*	OR	CI
Gender (ref. female)	<0.001	0.69	0.004	0.74	0.6–0.91	0.03	0.82	–	–	–
Birthplace (ref. Sweden)	NS	–	–	–	–	0.04	0.60	–	–	–
Profession (ref. blue collar)	0.03	0.81	–	–	–	NS	–	–	–	–
Marital status (ref. married)	0.05	1.3	–	–	–	NS	–	–	–	–
Healthy (ref. yes, absolutely)	<0.001	1.9	<0.001	1.6	1.3–1.9	0.001	1.4	–	–	–
Health vs peers (ref. much better/better	0.001	1.4	–	–	–	0.001	1.4	<0.001	1.5	1.2–1.8
Medication (ref. yes)	<0.001	0.62	–	–	–	0.01	0.78	–	–	–
Doctor contact (ref. yes, last 3 months)	<0.001	0.61				0.007	0.77	–	–	–
Smoking (ref. daily/occasional)	0.008	0.75	0.03	0.76	0.6–0.97	NS	–	–	–	–
Chewing (ref. very good)	0.02	1.3	–	–	–	0.06	1.3	–	–	–
Appearance (ref. very satisfied)	0.01	1.4	–	–	–	<0.001	1.7	0.002	1.5	1.2–2.0
Teeth number (ref. all teeth left)	NS	–	–	–	–	0.003	1.4	0.02	1.3	1.0–1.6
Burning mouth (ref. no)	0.07	1.6	–	–	–	NS	–	–	–	–
Wounds/blisters (ref. no)	0.03	1.3	–	–	–	NS	–	–	–	–
TMJ pain (ref. no)	<0.001	1.8	–	–	–	0.02	1.5	–	–	–
TMJ sounds (ref. no)	0.05	1.3	–	–	–	NS	–	–	–	–
Jaw opening (ref. no)	0.01	1.5	0.02	1.5	1.1–2.2	0.02	1.5	–	–	–
Bleeding gingival (ref. no)	0.009	1.3	–	–	–	0.05	1.2	–	–	–
Bad breath (ref. no)	0.03	1.3	–	–	–	NS	–	–	–	–
Dental material (ref. no)	0.001	1.6	–	–	–	0.04	1.3	–	–	–
Sensitive teeth (ref. no)	<0.001	1.5	<0.05	1.2	1.0–1.5	0.01	1.3	0.01	1.3	1.1–1.6
Toothache (ref. yes)	NS	–	–	–	–	0.04	0.82	–	–	–
White/plastic fillings (ref. yes)	0.02	0.78	–	–	–	0.03	0.79	–	–	–

female responders (53.4%), and which has to be taken into account when interpreting our data, given the slight gender bias. Other analysis of non-response could not be performed due to restrictions set by the ethical approval.

The response rate for the panel included in this study, that is those who responded at all three examination time points at ages 50, 65 and 75 years. was 42.5% while the response rates at each of the three examination time points were all around 70%. In an earlier study, responders aged of 50, 65 and 70 years, had an almost identical cross-sectional prevalence as the longitudinal sample of reported dry mouth, when responding "yes often/yes sometimes" [5]. Therefore, it seems that despite the lower response rate in this longitudinal sample compared to the higher in the cross-sectional data, the reported dry mouth may be considered not prone to bias.

A large systematic review concluded that the overall prevalence of xerostomia in elderly people was 27.2% [10], which is higher than that reported in this study which reported a prevalence 19.5% responding "yes often" for night-time dry mouth at age 75 years However, if "yes sometimes" dry mouth is included in addition to "yes often", the prevalence figures are considerably higher in this study for 75 year-olds than in the systematic review, i.e. 33.9% daytime and 57.6% night-time. The difference is probably due to the different criteria used for scoring reported dry mouth, but it can be confidently concluded that xerostomia is a common condition amongst the elderly.

There are a limited number of reports found in the literature on longitudinal studies on xerostomia in older people. Locker published a three-year follow up in 1995 on community dwelling adults aged 50 years and above and found an increase of reported xerostomia of 14.0% (from 15.5 to 29.5%) over the observation period. The three-year incidence was reported as 22.5% and was associated with older subjects, chronic medical conditions and poor general health [11]. In our study and with xerostomia defined as "yes often/ yes sometimes" dry mouth, the 25-year incidence was lower for reported daytime dry mouth (women 16.2%, men 12.8%) but higher for night-time dry mouth (33.6% and 29.8% for women and men, respectively). Associated factors for development of xerostomia were similar to the findings of Locker, i.e. impaired general health, chewing and mandibular function problems, as well as intraoral problems.

In another longitudinal study following a population aged 60 and above, the prevalence of xerostomia (defined as "frequently" or "always") was 24.8% [12]. The study did not distinguish between night and day xerostomia but the figures are relatively similar to what we found for night-time dry mouth at age 75 years (women 22.4% and men 16.3%). Also in the same study, remission of xerostomia was more common amongst women which differs with our findings. In this study, at all time points, remission was more common amongst men and especially during daytime between the ages of 50 and 65, where over 50% of the men who had reported dry mouth at age 50 did not do so at age 65 years. For night-time dry mouth, gender differences were smaller but still with more remission amongst men than women. The gender

Table 9
Unadjusted and adjusted (Forward Conditional Method) logistic regression model for daytime and night-time xerostomia. dependant variable: 1= *Often dry mouth* at 75 ($n = 204$ and $n = 527$ for daytime and night-time respectively); 2=*Never dry mouth* at 75 ($n = 869$ and $n = 511$ for daytime and night-time respectively). Selection of independent variables were made based on those found significantly correlated ($p < 0.05$) with either daytime or night-time xerostomia in unadjusted analysis using all variables according to Table 1.

	Daytime					Nighttime				
	Unadjusted		Adjusted			Unadjusted		Adjusted		
	p	OR	*p*	OR	CI	*p*	OR	*p*	OR	CI
Gender (ref. female)	<0.001	2.51	<0.001	2.4	1.5–3.7	0.04	1.44	–	–	–
Education (ref. university)	0.001	0.48	0.02	0.53	0.30–0.91	0.05	0.74	–	–	–
Profession (ref. blue collar)	0.001	1.8	–	–	–	0.02	1.4	–	–	–
Marital status (ref. married)	<0.001	0.50	–	–	–	NS	–	–	–	–
Healthy (ref. yes, absolutely)	<0.001	0.17	<0.001	0.34	0.21–0.56	<0.001	0.41	0.001	0.58	0.43–0.79
Health. vs. peers (ref. much better/better	<0.001	0.31	0.007	0.47	0.27–0.81	<0.001	0.59	–	–	–
Medication.last.14days (ref. yes)	<0.001	3.5	0.02	1.7	1.1–2.6	<0.001	2.0	0.02	1.5	1.1–2.1
Doctor contact (ref. yes, last 3 months)	<0.001	3.1	0.04	1.6	1.0–2.4	<0.001	1.8	–	–	–
Smoking (ref. daily/occasional)	0.002	1.7	–	–	–	NS	–	–	–	–
Chewing (ref. very good)		0.35	0.01	0.57	0.36–0.89	<0.001	0.33	<0.001	0.41	0.28–0.60
Appearance (ref. very satisfied)	0.02	0.60	–	–	–	<0.001	0.48	–	–	–
Teeth number (ref. all teeth left)	0.05	0.69	–	–	–	0.01	0.69	–	–	–
Burning mouth (ref. no)	<0.001	0.29	–	–	–	0.01	0.43	–	–	–
Wounds/blisters (ref. no)	<0.001	0.43	0.02	0.54	0.33–0.91	<0.001	0.48	–	–	–
Taste changes (ref. no)	<0.001	0.22	0.01	0.43	0.22–0.84	<0.001	0.25	–	–	–
TMJ pain (ref. no)	<0.001	0.24	–	–	–	<0.001	0.26	0.01	0.47	0.27–0.84
TMJ sounds (ref. no)	0.003	0.56	–	–	–	<0.001	0.49	–	–	–
Jaw opening (ref. no)	<0.001	0.44	–	–	–	0.005	0.53	–	–	–
Bruxism (ref. no)	<0.001	0.37	0.003	0.49	0.31–0.78	0.004	0.63	–	–	–
Bleeding gingival (ref. no)	0.001	0.56	–	–	–	<0.001	0.60	–	–	–
Bad breath (ref. no)	0.001	0.55	–	–	–	0.001	0.61	–	–	–
Dental material (ref. no)	<0.001	0.36	–	–	–	<0.001	0.43	–	–	–
Sensitive teeth (ref. no)	<0.001	0.41	–	–	–	<0.001	0.46	0.007	0.65	0.48–0.89
Toothache (ref. yes)	0.009	1.5	–	–	–	0.002	1.5	–	–	–
Porcelain (ref. yes)	NS		–	–	–	0.04	1.3	–	–	–
White plastic fillings (ref. yes)	0.05	1.5	–	–	–	0.002	1.5	0.02	1.5	1.1–2.1

differences regarding remission were, however, not statistically different except for daytime xerostomia between the ages of 65 and 70 years ($p = 0.03$).

Persistence, that is the percentage of participants who had consistent dry mouth reported from age 50 and throughout the observation period, was high, and ranged from 49.3% to 85.8%, and significantly higher for women. It can, therefore, be concluded that the likelihood that reported dry mouth at age 50 persists into older age is high and especially so for women.

A short-term longitudinal study in 427 older adults aged 65 years showed that reported dry mouth significantly increased the risk for social withdrawal during the 2-year observation period [13]. Thus, apart from the more direct effects of xerostomia such as oral discomfort, swallowing and eating problems it may also have a negative impact on the social well-being interaction of older people which adds another dimension to this very common condition amongst the elderly. In this respect, a 5-year longitudinal study amongst community-dwelling Japanese aged 60 years and older showed that worsening of dry mouth significantly predicted poorer OHRQoL at follow-up [14]. Considering that a great proportion of the individuals in this study reported progression (worsening) of dry mouth, these individuals may well be at increased risk of impaired OHRQoL.

Good health, male gender, non-smoking, absence of jaw opening problems and sensitive teeth, all teeth remaining and satisfaction with dental appearance were all predictors for remaining as “never or seldom” dry mouth throughout the 25-year observation period. On the other hand, seemingly opposite relationship predicted progression to dry mouth. Similar findings have been shown in other studies [15,16].

As regards factors reported at age 50 that predicted presence vs. absence of xerostomia at age 75, several significant variables were detected in the adjusted analysis. Health parameters, gender, medication, intraoral and chewing problems, TMJ pain, and low education were, as has been shown before, significant predictors of xerostomia [5,17,18,19,20,21,22]. As regards chewing problems, the association may be explained by the impaired lubricating and masticatory ability caused by reduced salivary secretion. The association between TMJ pain and xerostomia is not clear but it has been speculated that orofacial pain could have a neuropathological background [20], while another speculation is that TMD patients often experience impaired general health, as well as may suffer from anxiety/depression, and may thus medicate with substances that cause dry mouth, e.g. antidepressants. The correlation between dry mouth and low education is more difficult to elaborate on but it has been speculated that low education and low income could result in socioeconomic differences in health status [23]. In this regard, in arterial hypertension coronary heart disease patients, low income is associated with more anxiety and depressive symptoms [24], and similarly the correlation between xerostomia and low income could be an indirect one (as with TMD), viz. to impaired general health and antidepressant medication. Our finding that the presence of white/-plastic filling were also predictive for presence of xerostomia may be speculated as the participants in this study having higher numbers of fillings because of increased caries activity at age 50. Such a correlation has previously been reported upon [22].

Conclusion

Xerostomia is common in older people, and especially so at night and in women. Women also reported greater progression than men. To a large extent xerostomia persisted from the age of 50 to the age of 75 and especially so in women. Incidence of xerostomia was higher at night-time between the age of 50 and 65 and during the daytime between the age 65 and 75. Predictive factors at the age 50 for having xerostomia at the age 75 were: female gender, impaired general health, jaw opening and chewing problems, several intraoral problems and having white/plastic fillings, as well as low education and dissatisfaction with dental appearance.

Conflict of interest statement

The authors report no conflicts of interests in relation to this paper.

CRediT authorship contribution statement

Ann-Katrin Johansson: Conceptualization, Formal analysis, Methodology, Writing – review & editing. **Ridwaan Omar:** Conceptualization, Methodology, Writing – review & editing. **Berit Mastrovito:** Conceptualization, Data curation, Funding acquisition, Investigation, Writing – review & editing. **Josefin Sannevik:** Conceptualization, Data curation, Funding acquisition, Investigation, Writing – review & editing. **Gunnar E. Carlsson:** Conceptualization, Methodology, Writing – review & editing. **Anders Johansson:** Conceptualization, Formal analysis, Methodology, Writing – review & editing.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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