The air we breathe: a study into the impact of historical socioeconomic changes on the respiratory health of past Dutch populations (ca. 470-1850 CE)

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CHAPTER 8

Exploring the Impact of Tobacco Consumption on the Respiratory Health of two Dutch Skeletal Populations (1300-1829 CE)

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14 In this version of the article, British English spelling and conventions from the original publication have been updated to American English to ensure consistency throughout this dissertation. All other content remains unchanged from the original article.

Abstract

This study explored the influence of tobacco consumption on the respiratory health of two historical Dutch populations (1300-1829 CE). We conducted a macroscopic examination of 235 skeletons for which tobacco consumption status was known, focusing on the presence of sinusitis, ear infection, and pulmonary inflammation. Our goal was to investigate the correlation between respiratory diseases and tobacco consumption. Despite all conditions being prevalent in the total sample (sinusitis: 50,2%, ear infection: 23,2%, pulmonary inflammation: 14,1%), almost no significant correlation was found between disease and tobacco consumption. Our findings suggest that additional factors, such as exposure to second-hand smoke and unsanitary living/working environments, may have also impacted respiratory health. However, our interpretations are difficult to confirm due to the limitations of macroscopic analysis in determining tobacco consumption status. Future research should consider employing biomolecular techniques and expand beyond respiratory diseases to enhance our understanding of historical health implications of tobacco use.

Keywords: Paleopathology; Chronic Maxillary Sinusitis; Ear Infection; Pulmonary Inflammation; Smoking

8.1. Introduction

Today, the global tobacco epidemic is considered to be one of the most extensive health hazards of the modern world, causing the death of over 8 million individuals annually (WHO, 2021). According to clinical science, tobacco consumption (i.e., smoking, chewing, snuffing, and vaping) causes cancer, heart disease, stroke, diabetes, and chronic obstructive pulmonary diseases (COPD), such as emphysema and chronic bronchitis (Bonnie et al., 2015; Ligthart et al., 2016; Pelkonen et al., 2019; Stallones, 2015; Vineis et al., 2004). Smoking may also increase the risk for tuberculosis, corneal infections, and immune system problems such as rheumatoid arthritis (Bates et al., 2007; Jetton et al., 2014; Manfredsdottir et al., 2006). Furthermore, tobacco does not only impact its primary user; chronic exposure to environmental tobacco smoke (also known as second-hand tobacco smoke) increases the risk of developing heart disease, lung cancer (Bhat et al., 2018; Dunbar et al., 2013; Kim et al., 2014; Vozoris & Lougheed, 2008). Recently, it was calculated that 1.3 million people died prematurely from exposure to second-hand smoke globally (Su et al., 2023). These significant health implications suggest that tobacco's arrival and popularization in Europe likely had a profound effect on the health of past populations, indicating that the burden of tobacco-induced disease may not solely be a modern phenomenon.

Originally introduced by Spanish sailors at the end of the 16th century, tobacco quickly spread across the European continent and, by 1630 CE, it had already permeated all strata of society (Goodman, 2005; Snelders, 2021). In the Netherlands specifically, local production made tobacco an extremely affordable product, resulting in widespread consumption among the population. (Brongers, 1964a; Roessingh, 1979). Tobacco was generally regarded as non-harmful when consumed in small quantities and often embraced by physicians as a remedy for various ailments, such as headaches and tooth pain (Brongers, 1964a; Fraga, 2010; Goodman, 2005). However, caution was still advised for women, children, and for individuals in poor health, as medical practitioners soon noted a correlation between tobacco consumption and the development of respiratory issues (Snelders, 2021). Already in 1602 CE British physicians were aware of the negative impact tobacco had on the respiratory system by "blocking" the lungs (Charlton, 2005). During this period, tobacco use was banned in public spaces in many Dutch cities and restricted to indoor establishments, as the pervasive smell of smoke was considered a nuisance and a threat to residents' wellbeing (Snelders, 2021).

Surprisingly, despite the presence of several historical sources that discuss the adverse effects of tobacco consumption, there remains a notable scarcity of (bio)archaeological studies on its impact on human health. Walker and Henderson (2010) analyzed 705 individuals from London (1843-1854 CE) and observed a high prevalence of evidence of tobacco consumption (i.e., pipe notches and dental lingual staining). Tobacco consumers were found to have a lower life expectancy, as well as an increased frequency of skeletal evidence for pulmonary inflammation (i.e., inflammatory periosteal bone formation on ribs) compared to the rest of the population (Walker & Henderson, 2010). However, despite these encouraging initial results, there has been limited research to further explore the various ways in which tobacco affected past human

health. This is problematic, as it leaves significant gaps in our understanding of how one of the world's most pervasive commodities influenced historical health outcomes and shaped societal development. To contribute filling this gap, we analyzed the presence of both upper and lower respiratory diseases (i.e., chronic maxillary sinusitis, infectious middle ear disease, and pulmonary inflammation) among 235 individuals from the Netherlands whose smoking status (i.e., tobacco consumer/tobacco non-consumer) was previously determined osteologically by Casna and colleagues (2024). As tobacco smoke has long been recognized as a major risk factor for human health, we hypothesized higher rates of lesions indicative of respiratory disease among individuals showing evidence of tobacco consumption.

8.1.1. Tobacco consumption in historic Netherlands

Unlike other trade substances like coffee and sugar, whose popularity initially stemmed from the upper classes, tobacco spread in the Netherlands began among sailors and lower-income individuals who frequented port inns and taverns after work (Snelders, 2021). From there, the rise of tobacco was rapid and, in just 50 years from its introduction, its consumption had become widespread and accessible to the whole population (Brongers, 1964a; Snelders, 2021). Although historically tobacco use was considered primarily a male habit (Brongers, 1964a), recent osteoarchaeological analyses have shown no significant difference in tobacco consumption rates between males and females, suggesting that smoking was a practice embraced by everyone (Casna, Davies-Barrett, et al., 2024). By the 18th century, tobacco's popularity had grown so significantly that it had become an important part of Dutch culture; smoking pipes were frequently gifted during weddings as a symbol of union, and it was common at funerals to offer tobacco not only to those who attended the function, but also to coffin bearers, constables, and to those who took care of digging the grave (Brongers, 1964a). Today, pipe fragments are among the most common findings in most Dutch excavations dating from 1650 CE onward, reflecting the ingrained nature of smoking in Dutch culture (Claeys et al., 2010; Duco, 1987; van der Lingen & Korpershoek, 2024). Since pipes provided a more efficient and enjoyable way to consume tobacco compared to other methods available at the time (e.g., chewing, snuffing), it has been argued that it was likely the introduction of the pipe in 1609 CE that caused a sudden surge in tobacco's popularity (Brongers, 1964a, 1964b; Claeys et al., 2010). However, recent bioarchaeological research into tobacco consumption in the Netherlands between 1300-1829 CE suggests that, at least in some port communities, tobacco may have become popular well before the 17th century (Casna, Davies-Barrett, et al., 2024). When analyzing prevalence rates of pipe-notches, Casna and colleagues (2024) observed significantly higher rates in populations dating to 1600 CE onwards when compared to earlier samples. However, when analyzing prevalence rates of dental lingual staining linked to tobacco consumption (Davies-Barrett & Inskip, 2024; Walker & Henderson, 2010), Casna and colleagues (2024) did not find significant variation between the two time periods under study. This suggests that, while tobacco consumption in certain populations may have been connected to the introduction and widespread use of clay pipes, in other cases tobacco had gained popularity much earlier, possibly through methods such as chewing or cigar smoking that would not cause notches in the dentition (Casna, Davies-Barrett, et al., 2024).

While much remains to be understood about the history of tobacco consumption in the Netherlands, preliminary research on its impact on human health has yielded intriguing results. For example, when studying the dental calculus of 41 individuals from a rural Dutch population dating to 1829-1866 CE, Bartholdy and colleagues (2024) observed a positive correlation between the presence of nicotine in the calculus and bony lesions indicative of chronic maxillary sinusitis, suggesting that tobacco consumption did indeed have an impact on the respiratory wellbeing of the sample under study. Furthermore, Inskip and colleagues (2023) compared dental disease (i.e., caries, calculus, tooth loss, periapical lesions, and periodontal disease) to the presence of pipe notches in two medieval and post-medieval Dutch assemblages, observing that pipe smoking led to a general decline in oral health among the skeletal population under study.

8.1.2. Respiratory health implications of tobacco use

According to clinical research, tobacco consumers are 11 times more likely to develop lung cancer than non-consumers, and 4 times more likely to develop chronic obstructive pulmonary diseases (Jayes et al., 2016). In addition, tobacco consumption was estimated to increase the risk for sinusitis by approximately 16% and increase the risk for ear infections by 50% (Lieu & Feinstein, 2000; Strachan & Cook, 1998).

Even if unprocessed, tobacco leaves contain harmful chemicals such as nicotine, cadmium, benzene, and nitrates (CDC, 2010). When tobacco is consumed (either smoked, snuffed, or chewed), these chemicals are released and absorbed into the body through the lungs, skin, and/or mucous membranes (van der Rijst & Garfield, 2023). There are several ways in which the absorption of these chemicals can impact human respiratory health. Inhalation of smoke, whether first-hand or second-hand, directly exposes the lungs to the chemicals inherent in tobacco leaves, as well as to additional harmful substances (e.g., tar) generated during tobacco combustion. This inflicts significant damage to lung tissues, leading to impaired breathing, chronic inflammation of the bronchial tubes (i.e., bronchitis), destruction of the alveoli (i.e., emphysema), and lung cancer (van der Rijst & Garfield, 2023). In addition, tobacco consumption may directly irritate and dry the mucous membranes of the entire respiratory tract, exacerbating respiratory symptoms and compromising immune function (Ramasamy & Sivapathasundharam, 2021). Irritation of the nasal passages and throat may lead to congestion, ultimately increasing susceptibility to inflammations, such as sinusitis and infectious middle ear disease (Corey et al., 2000; Reh et al., 2012). Furthermore, tobacco may impair the function of the mucociliary clearance mechanisms, reducing their ability to trap and eliminate pathogens, and, therefore, increasing an individual's vulnerability to upper respiratory tract infection (e.g., sinusitis) (Prasetyo et al., 2021). Pre-existing respiratory issues can also be further exacerbated by tobacco consumption, as chronic tobacco use significantly negatively impacts the immune system and triggers systemic inflammation, hence contributing to the progression of pre-established infectious disease (Jiang et al., 2020).

8.2. Materials

The two Dutch skeletal populations included in this study – Arnhem and Vlissingen (Figure 8.1) – were previously analyzed by Casna and colleagues (2024) for skeletal sex, age-at-death, and macroscopic oral evidence of tobacco consumption (i.e., pipe notches and dental lingual staining[15]). These sites were considered as ideal for investigating tobacco consumption in the Netherlands, as historical and archaeological records confirm the presence of tobacco in both cities (e.g., Claeys et al., 2010; Kuiper & Lengkeek, 1994; Roessingh, 1976; Zielman & Baetsen, 2020). Additionally, these sites span an extensive timeframe (1300-1829 CE) and are divided into two distinct periods: 'pre-tobacco' (i.e., before the widespread adoption of tobacco among Dutch populations) and 'post-tobacco' (i.e., after tobacco had become a widespread commodity) (Table 8.1). This division was highly relevant for studying the popularization of tobacco in the Netherlands, as it enabled a nuanced analysis of tobacco prevalence before and after its widespread adoption in the 17th century (Casna, Davies-Barrett, et al., 2024). As observed by Casna and colleagues (2024), in the 'post-tobacco' period, 43.7% of the population in Arnhem and 35.9% of the population in Vlissingen were scored as tobacco consumers (Supplementary Table 1). No disparities in tobacco consumption were identified between skeletal sex groups (Casna, Davies-Barrett, et al., 2024).

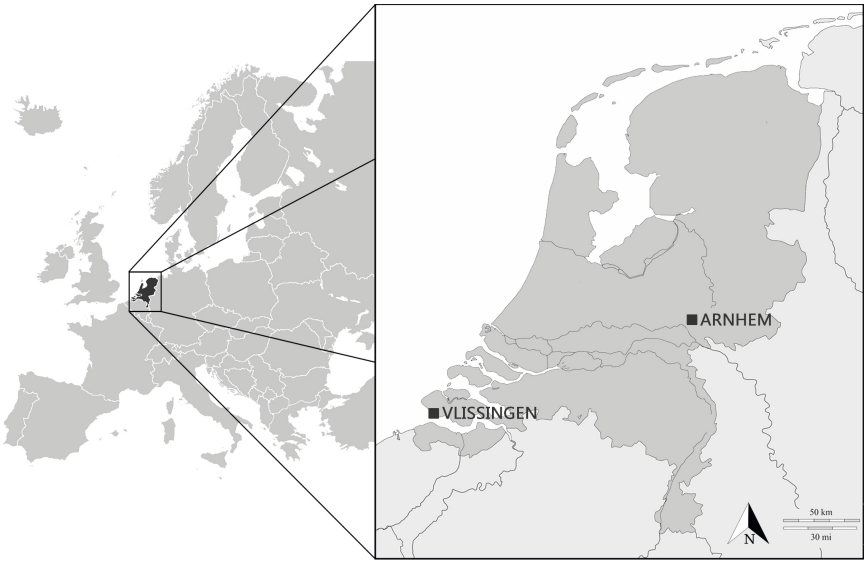


Figure 8.1. Map of the Netherlands showing the location of the sites under study. Figure originally published in Casna et al. (2024, Figure 1). Licensed for use by CC BY 4.0.

15 Davies-Barrett and Inskip (2024) define pipe notches as "semi-circular abrasions caused by habitual clenching of the teeth around the stem of a clay pipe while smoking" (p. 144), and dental lingual staining as "the adhesion to the tooth of a substance of variably light brown to black colour" (p. 145) whose appearance resembles that of a "'cracked ink' or 'dry riverbed'" (p. 146).

Table 8.1. Skeletal collections included in this study.

City	Skeletal Population	Dating	Subsistence Economy
Arnhem	Eusebiuskerk, 'pre-tobacco'	1330-1650 CE	Urban
	Eusebiuskerk, 'post-tobacco'	1650-1829 CE	Proto-Industrial
Vlissingen	Oude Markt	1300-1590 CE	Maritime
	Scheldekwartier	1600-1800 CE	Maritime

8.2.1. Historical Context

Even if largely comparable chronologically, the assemblages of Arnhem and Vlissingen are representative of two very different realities: while from 1300 CE onwards Arnhem was one of the most important and industrially-developed centers of the Dutch hinterland, the history and economic growth of Vlissingen have always been tied with its position on the Northern Sea (Kuiper & Lengkeek, 1994; van Cruyningen, 2012). According to Casna and colleagues (2024), such differences are also reflected in the way tobacco gained popularity in each of these centers. In Arnhem, tobacco was intricately intertwined with the city's industrial growth. In fact, up until the late 19th century, the whole province of Gelderland (where Arnhem is located) was a major hub for tobacco production, which offered several opportunities to migrants relocating to the area for work (Kuiper & Lengkeek, 1994; Roessingh, 1979; van Laar, 1966). The tobacco produced in Arnhem was notably of lower quality and larger affordability in contrast to the imported varieties from Southern Europe and the Americas (Roessingh, 1976). This suggests that the demographic cohort under study (representative of Arnhem's lower socioeconomic strata) likely had ample access to locally produced tobacco starting from 1650 CE onwards, as evidenced by the results presented in Casna and colleagues (2024) which show a significant increase in tobacco consumers in the 'post-tobacco' period as opposed to the 'pre-tobacco' one.

On the other hand, Vlissingen's economic power stemmed from its maritime activities. Since 1235 CE, Vlissingen had served as a pivotal harbor for the area where it is located, managing several commercial routes to South America and the Caribbean on behalf of the Dutch West India Company (van Cruyningen 2012). Because of its involvement with international trade, people in Vlissingen were likely among the first to start consuming tobacco as early as 1590 CE. Even if Claeys and colleagues (2010) report that most pipe fragments recovered from the excavation of Vlissingen, Scheldekwartier (1600-1800 CE) date to the second half of the 18th century, Casna and colleagues (2024) observed no statistically significant differences in the prevalence of tobacco consumers between Oude Markt ('pre-tobacco', 1300-1590 CE) and Vlissingen, Scheldekwartier ('post-tobacco', 1600-1800 CE), suggesting that tobacco may have been already a popular commodity by the start of the 17th century.

8.3. Methods

From an initial pool of 239 adult individuals of varying skeletal sex (male/female), age-at-death (young adult/middle adult/old adult), and tobacco consumption status (tobacco consumer/non-consumer), we specifically selected individuals for whom we could score the presence/absence of at least one of the following conditions: chronic maxillary sinusitis (CMS), infectious middle ear disease (IMED), or pulmonary inflammation in the form of periosteal bone formation on the visceral surface of ribs (IPR) (Figure 8.2).

The presence of CMS was observed in all individuals with at least one sinus partially preserved (i.e., more than 25% present). If the sinuses were intact and therefore not visible to the naked eye (i.e., no skull damage), they were examined using a flexible medical endoscope (Pentax, model: FNL-10RBS, ø=4mm; view angle=30°) inserted through minor fractures (refer to Casna et al., 2021 for details on how the endoscope was inserted in the skulls). CMS was considered 'absent' when sinus walls were smooth and/or presented minimal porosity. It was considered 'present' when either pitting or new bone formation was observed on any visible bony walls (Figure 8.2, A) (Boocock et al., 1995).

The presence of IMED was recorded using the criteria established by Floreanova and colleagues (2020) for all individuals with at least one complete and observable tympanic cavity. If ear ossicles were present, they were carefully removed, and the bony structures of the middle ear were cleaned using a wooden toothpick and water before examining the middle ear cavity with a medical endoscope. IMED was scored as 'present' if the medial wall of the middle ear exhibited either clear bony growth with well-defined edges or a general erosion of the distal wall bony surface (Figure 8.2, B). Conversely, it was classified as 'absent' in instances where the distal wall displayed a smooth, unaltered surface (Floreanova et al., 2020).

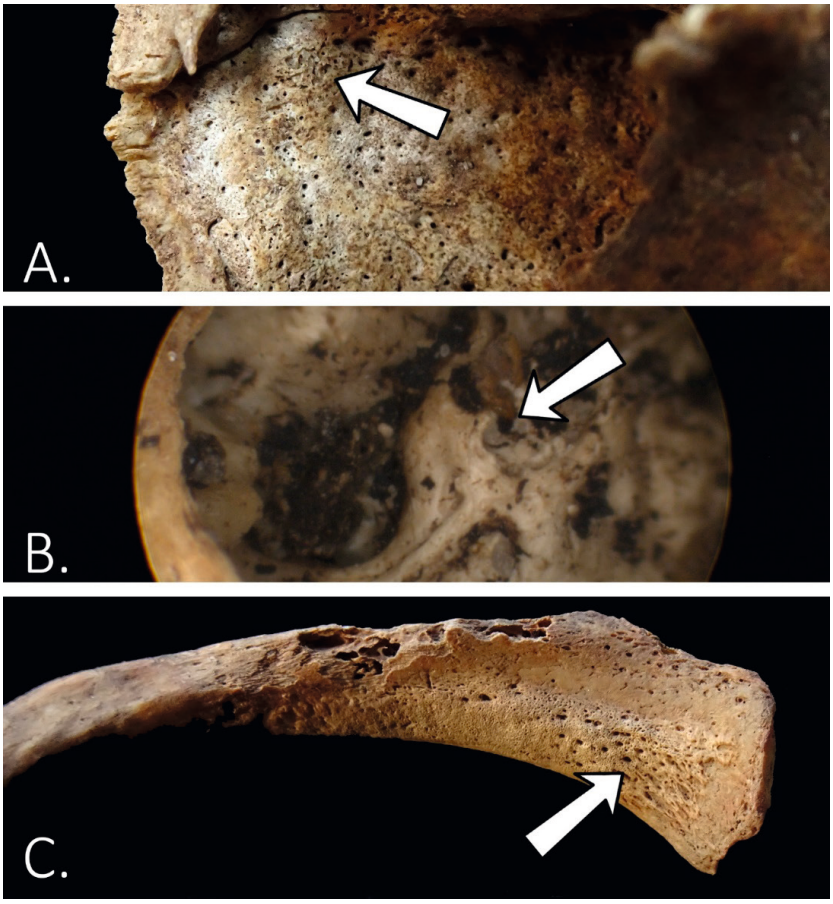


Figure 8.2. Examples of lesions observed in this research: A: chronic maxillary sinusitis in the form of new bone formation on the sinus wall; B: infectious middle ear disease in the form of erosion of the bony promontory of the middle ear; and C: pulmonary inflammation in the form of periosteal bone formation on the visceral surface of a rib. Lesions are indicated by the white arrows. Photographs by M. Casna.

Finally, the presence/absence of IPR was scored for every rib whose shaft was at least 50% complete. To avoid mistakes in seriations, ribs were categorized into four groups based on their most likely position within the rib cage: 'upper' (ribs #1-3), 'upper-middle' (ribs #4-6), 'lower-middle' (ribs #7-9), or 'lower' (ribs #10-12). IPR was considered present in groups where at least one rib showed evidence of bone growth, forming a distinct layer atop the original cortical surface (Figure 8.2, C) (Davies-Barrett et al., 2019). If only one rib in a group was present and showed no signs of IPR, the group was deemed unobservable. For IPR to be considered 'present' within an individual, it needed to be observed in at least one of the rib groups mentioned above, either on the right or left side of the rib cage.

8.3.1. Statistical analysis

Statistical analysis was performed using SPSS version 29.0 for Windows. We used binary logistic regression to consider various confounding factors (i.e., time period, skeletal sex, and age-at-death) alongside tobacco consumption, and to gain a more comprehensive understanding of how these variables interacted and influenced the risk of respiratory diseases. In binary logistic regression, if the upper limit of the 95% confidence interval is below 1, it indicates that the group is significantly less likely to be associated with the disease compared to the reference group. Conversely, if the lower limit of the 95% confidence interval is above 1, it signifies that the group is significantly more likely to be associated with the disease than the reference group (Harris, 2021). In all statistical analyses, an initial *p*-value of ≤0.05 was considered as statistically significant.

8.4. Results

Our final sample consisted of 235 adult individuals (61 tobacco consumers and 174 non-consumers) for which the presence of respiratory disease (considered here to be the presence of at least one condition among CMS, IMED, and/or IPR) could be determined (Table 8.2). Figure 8.3 displays the demographic composition of the final sample. See Supplementary Table 2 for the complete demographic profile.

Table 8.2. Composition of the sample included in this study.

	Arnhem			Vlissingen		
	1330-1650 CE	1650-1829 CE	Total	Oude Markt, 1300-1590 CE	Scheldekwartier, 1600-1800 CE	Total
	(%)	(%)	(%)	(%)	(%)	(%)
Tobacco consumers	5 (6.5)	28 (45.2)	33 (23.7)	5 (15.6)	23 (35.9)	28 (29.2)
Tobacco non-consumers	72 (93.5)	34 (54.8)	106 (76.3)	27 (84.4)	41 (64.1)	68 (70.8)
Total	77 (100)	62 (100)	139 (100)	32 (100)	64 (100)	96 (100)

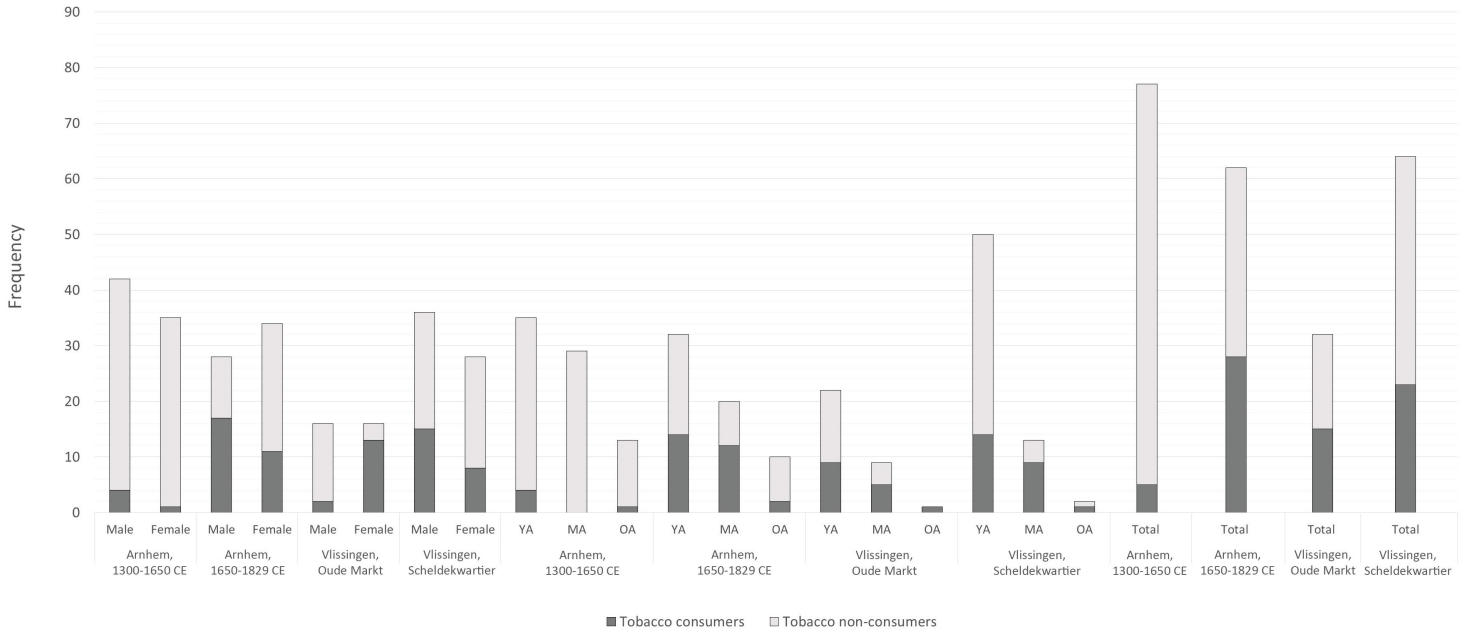


Figure 8.3. Demographic composition of the sample. YA=Young Adult (20-34 years), MA=Middle Adult (35-49 years), OA=Old Adult (50+ years).

Overall, the presence of respiratory disease was observed in 136 (57.9%) individuals (Figure 8.4). Among all populations under study, lesions associated with CMS emerged as the most prevalent, presenting in 50.2% of the total sample. IMED was observed in 23.2% of the sample, while IPR was the least frequent lesion, occurring in only 14.1% of the cases. Surprisingly, in the total sample all three respiratory diseases were more prevalent among non-consumers compared to tobacco consumers (Table 8.3). When analyzing the prevalence of each condition in relation to tobacco consumption across different populations, we observed that tobacco consumers were more affected by CMS in Vlissingen, Scheldekwartier (70% of consumers vs. 41.7% of non-consumers) (Figure 8.5). Additionally, IPR was more prevalent among tobacco consumers in both Vlissingen, Oude Markt (66.7% of consumers vs. 8.3% of non-consumers) and Vlissingen, Scheldekwartier (36.8% of consumers vs. 26.7% of non-consumers). In all other cases, non-consumers showed higher prevalence rates of respiratory diseases (Supplementary Table 3).

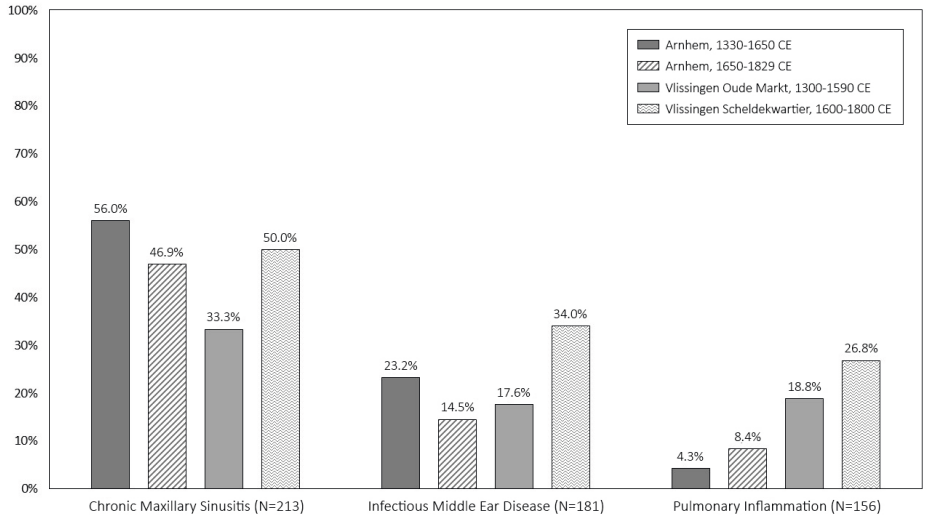


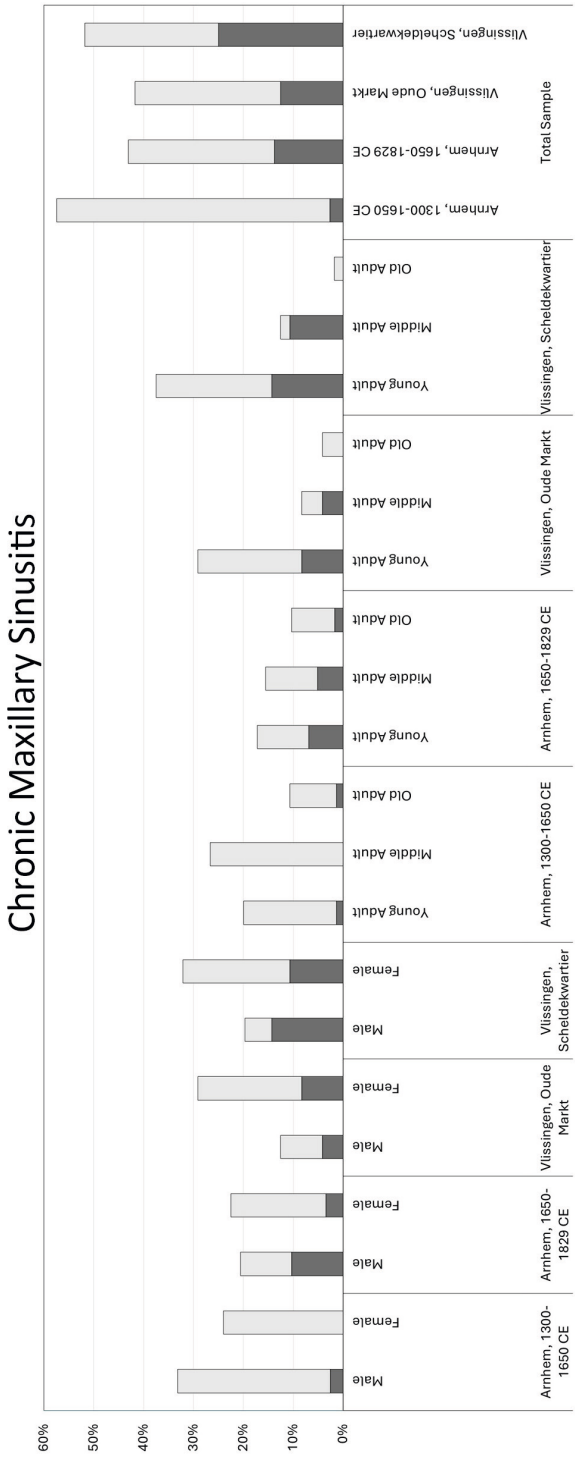
Figure 8.4. Prevalence of evidence of chronic maxillary sinusitis, infectious middle ear disease, and pulmonary inflammation for all samples under study.

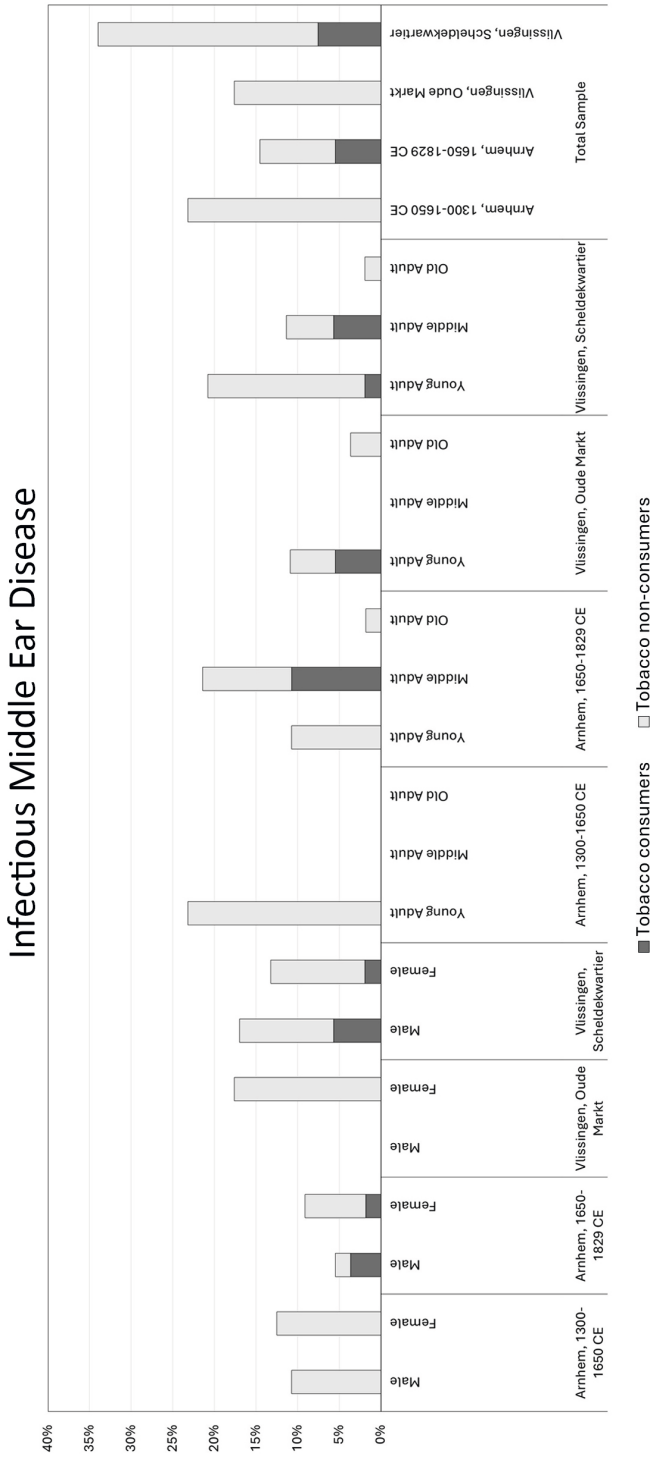
Table 8.3. Prevalence of respiratory diseases observed within the total sample of this study.

	Tobacco Consumers (%)	Tobacco Non-consumers (%)	Total (%)
Chronic Maxillary Sinusitis	27 (25.2)	80 (74.8)	107 (50.2)
Infectious Middle Ear Disease	7 (16.7)	35 (83.3)	42 (23.2)
Pulmonary Inflammation	9 (40.9)	13 (59.1)	22 (14.1)

Interestingly, the binary logistic regression analysis of the Arnhem population indicated that tobacco consumers were less likely than non-consumers to exhibit evidence of both CMS and IMED (Table 8.4). However, as this finding was not statistically significant, it should be interpreted with caution. Although *p*-value was again non-significant, individuals from Arnhem dating to 1650-1829 CE (i.e., when tobacco was historically widespread across most Dutch societies) were 4.040 times more likely to show evidence of IPR compared to those from 1330-1650 CE. Additionally, males from Arnhem were also more likely to show evidence of IPR than females. Finally, middle and old adults in Arnhem were respectively 2.150 and 2.696 times more likely to present with CMS compared to young adults, this outcome being statistically significant only in middle adults (p=0.015).

In Vlissingen, tobacco consumers were found to be five times more likely to present evidence of CMS than non-consumers (p=0.012) (Table 8.5). Over time, individuals from Vlissingen appeared to be at increased risk for all three studied respiratory conditions, though these observations were not statistically significant. Interestingly, females from Vlissingen were 7.24 times more likely to exhibit CMS than males (p<0.01). Age-at-death did not significantly impact the results, except for IMED, which was more prevalent in middle and old adults compared to young adults, though this finding was again not statistically significant.


Chronic Maxillary Sinusitis
60%
50%
40%
30%
20%
10%
0%
Male
Female
Male
Female
Male
Female
Male
Female
Female
Male
Young Adult
Middle Adult
Old Adult
Young Adult
Middle Adult
Old Adult
Young Adult
Middle Adult
Old Adult
Young Adult
Middle Adult
Old Adult
Arnhem, 1300-1650 CE
Arnhem, 1650-1829 CE
Vlissingen, Oude Markt
Vlissingen, Scheldekwartier
Arnhem, 1300-1650 CE
Arnhem, 1650-1829 CE
Vlissingen, Oude Markt
Vlissingen, Scheldekwartier
Total Sample
Vlissingen, Scheldekwartier
Vlissingen, Oude Markt
Arnhem, 1650-1829 CE
Arnhem, 1300-1650 CE
Tobacco consumers
Tobacco non-consumers


Infectious Middle Ear Disease
40%
35%
30%
25%
20%
15%
10%
5%
0%
Tobacco consumers
Tobacco non-consumers
Male
Female
Male
Female
Male
Female
Male
Female
Young Adult
Middle Adult
Old Adult
Young Adult
Middle Adult
Old Adult
Young Adult
Middle Adult
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Arnhem, 1300-1650 CE
Arnhem, 1650-1829 CE
Vlissingen, Oude Markt
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Arnhem, 1300-1650 CE
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Vlissingen, Oude Markt
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Total Sample

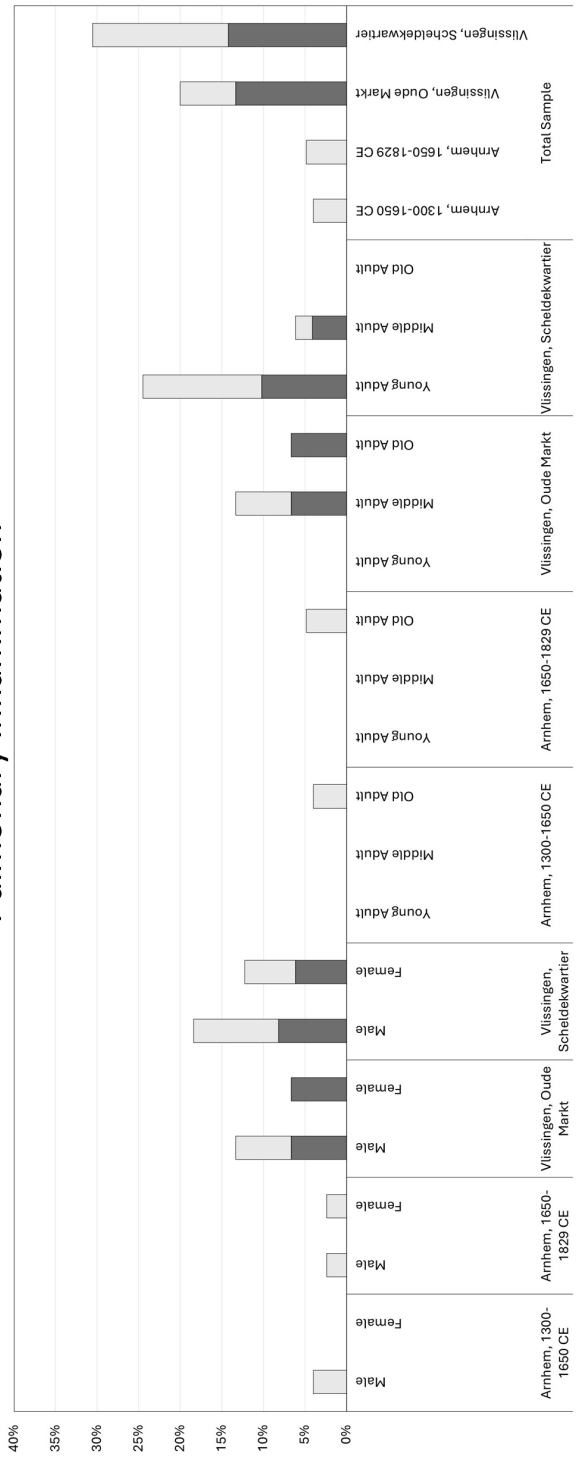

Figure 8.5. Prevalence rates of chronic maxillary sinusitis, infectious middle ear disease, and pulmonary inflammation among tobacco consumers and non-consumers in the populations under study.

Table 8.4. Outcomes of binary logistic regression in the Arnhem population.
Constants: Tobacco consumption status = non-tobacco consumers; Time = Arnhem, 1330-1650 CE; Skeletal sex = males; Age-at-death = young adult. OR = Odds ratio; CI = Confidence Intervals; * = indicates *p*-value ≤0.05.

		Chronic Maxillary Sinusitis				Infectious Middle Ear Disease				Pulmonary Inflammation			
		OR	CI for OR		*p*-value	OR	CI for OR		*p*-value	OR	CI for OR		*p*-value
			Lower	Upper			Lower	Upper			Lower	Upper	
Tobacco consumption status		0.418	0.154	1.134	0.087	0.449	0.231	2.029	0.285	n/a	n/a	n/a	n/a
Time		0.786	0.350	1.764	0.559	0.685	0.231	2.029	0.495	4.040	0.384	42.532	0.245
Skeletal sex		0.788	0.374	1.1661	0.532	1.127	0.400	3.177	0.821	0.240	0.018	3.178	0.279
Age-at-death					*0.040				0.592				n/a
	Middle adult	2.696	1.208	6.016	*0.015	0.609	0.200	1.851	0.382	n/a	n/a	n/a	n/a
	Old adult	2.150	0.785	5.890	0.137	0.566	0.131	2.447	0.446	n/a	n/a	n/a	n/a

Table 8.5. Outcomes of binary logistic regression in the Vlissingen population.
Constants: Tobacco consumption status = non-tobacco consumers; Time = Vlissingen, Oude Markt; Skeletal sex = males; Age-at-death = young adult. OR = Odds ratio; CI = Confidence Intervals; * = indicates *p*-value ≤0.05.

		Chronic Maxillary Sinusitis				Infectious Middle Ear Disease				Pulmonary Inflammation			
		OR	CI for OR		*p*-value	OR	CI for OR		*p*-value	OR	CI for OR		*p*-value
			Lower	Upper			Lower	Upper			Lower	Upper	
Tobacco consumption status		4.995	1.421	17.560	*0.012	0.289	0.071	1.185	0.085	2.703	0.799	9.141	0.110
Time		1.335	0.425	4.196	0.621	3.273	0.744	14.396	0.117	1.581	0.373	6.701	0.534
Skeletal sex		7.245	2.451	21.416	*<0.001	1.021	0.343	3.039	0.970	0.899	0.283	2.857	0.856
Age-at-death					0.974				0.139				n/a
	Middle adult	1.084	0.270	4.355	0.910	3.982	0.965	16.437	0.056	n/a	n/a	n/a	n/a
	Old adult	1.311	0.108	15.918	0.832	3.441	0.167	70.720	0.423	n/a	n/a	n/a	n/a

8.5. Discussion

Because of the great clinical impact that tobacco has on human respiratory wellbeing today, the aim of this study was to investigate whether individuals showing evidence of tobacco consumption would also show evidence of respiratory diseases (i.e., CMS, IMED, and/or IPR).

Unexpectedly, despite the prevalence of respiratory diseases in both populations studied, no clear pattern was observed between tobacco consumption and respiratory health. The only statistically significant association found was between tobacco consumption and CMS in individuals from Vlissingen, where smokers were five times more likely to develop sinusitis than nonsmokers. At first, these findings may seem surprising: however, we argue that when interpreting results it is important to consider the complex and multifaceted etiologies of respiratory diseases, which are often polygenic in nature (Huertas & Palange, 2011; Pokorski, 2017; van den Bergh et al., 2012). As demonstrated by the clinical practice, these conditions often arise from intricate interactions among diverse elements, such as genetic predisposition, environmental influences (e.g., air pollution, tobacco smoke, allergens), lifestyle preferences (e.g., alcohol consumption, dietary patterns), pre-existing conditions (e.g., dental diseases, autoimmune diseases, cardiovascular diseases), and occupational risks (Hoover et al., 1997; Mannino & Buist, 2007; Slavin et al., 2005; Zanobetti et al., 2000). Past urban contexts such as Arnhem and Vlissingen likely offered a wide range of health hazard for the respiratory system (e.g., pollution, overcrowding, hazardous working conditions, limited access to healthcare and to food/drinking water) which co-existed with tobacco consumption (e.g., Boyd, 2020; Casna et al., 2023; Goossens et al., 2021; Kopadze & Jikurashvili, 2023; Krenz-Niedbała & Łukasik, 2020). Individuals from Arnhem were likely employed in the industrial sector, where they were frequently exposed to dust and chemicals (Kuiper & Lengkeek, 1994; van Braam, 1978; Wintle, 2000). Their living arrangements were also reportedly hazardous to their respiratory health: according to historical sources, most factory workers at the time lived in dark, humid, and unventilated residential barracks that often hosted more people than what they could accommodate (van Braam, 1978; van Laar, 1966; Wintle, 2000). Living and working in polluted, overcrowded, and unhygienic indoor spaces (with potential increased exposure to second-hand smoke) likely worsened the spread of infectious diseases in Arnhem, which may have contributed to tobacco consumers and non-consumers showing similar risk for respiratory disease in our analysis. In Vlissingen, it is likely that people had access to cleaner air due to their primary involvement in the naval or fishing industries, which required substantial time spent outdoors (de Ridder, 2004). However, their frequent exposure to harsh and cold weather conditions may have heightened their susceptibility to (respiratory) infectious diseases, hence confounding our observations (Casna & Schrader, 2024). We argue that our results stem from the interplay of various risk factors affecting the populations under study, rather than being solely indicative of tobacco's impact on human health. This interpretation is further supported by the absence of significance regarding time as a risk factor for any of the conditions under study. It might have been expected that the passage of time (here indicative of the transition from a period when tobacco was just introduced to the Netherlands to the time when it had become one of the most consumed commodities) would have played a significant

role in our analysis. However, although a slight increase in respiratory disease is seen over time, our findings align with previous diachronic research on respiratory disease in Dutch populations, which concluded that differences in living and working conditions between the late-medieval and the post-medieval periods were not substantial enough to cause significant variations in respiratory disease rates (Casna et al., 2023; Casna & Schrader, 2024).

Another crucial and potentially confounding factor in our analysis, which could contribute to the absence of a significant impact of tobacco consumption on respiratory disease, is that dental evidence alone cannot identify individuals who were exposed to second-hand smoke. As already mentioned, chronic exposure to second-hand tobacco smoke increases the risk of respiratory disease to a level comparable to that of active consumers (Bhat et al., 2018; Vozoris & Lougheed, 2008). In contexts such as Arnhem, where people lived and worked in crowded spaces with little to no room for privacy, inhalation of tobacco smoke was likely very common. In these circumstances, it is likely that tobacco did indeed influence respiratory health, but its impact extended beyond those who directly consumed it. Conversely, in Vlissingen, working outdoors may have limited exposure to second-hand smoke. This may explain why, in Vlissingen, tobacco consumption was found to significantly put individuals at risk for CMS. This interpretation is further supported by our data when considering our results on skeletal sex and respiratory disease. In Vlissingen, females were more than seven times more likely to present evidence of CMS, a pattern not observed in Arnhem. Historically, Arnhem saw men and women engaged in different tasks but within similar (if not the same) industrial environments where tobacco consumers and non-consumers shared small and unventilated indoor spaces (van Laar, 1966; Wintle, 2000). In contrast, in most Dutch maritime communities men and women were still equally employed, yet their work environments varied significantly (Stuurman, 2023). Men typically worked on ships, spending most of their time (and likely multiple days) at sea, while women often stayed indoors, engaging in tasks such as making fish nets and ropes for market sale (Stuurman, 2023). This likely resulted in both a higher exposure to indoor air pollution for women and potentially to increased exposure to second-hand smoke. This hypothesis is further supported by our findings; while in Vlissingen, Scheldekwartier it was primarily tobacco consumers who presented evidence of CMS among males, among females CMS was prevalent in both tobacco consumers and non-consumers (see Supplementary Table 3).

Alongside the complicated etiologies of respiratory diseases and the role of second-hand tobacco smoke, it is likely that other factors presented as major limitations in our study. Firstly, while the data on tobacco consumers collected by Casna and colleagues (2024) was gathered following established macroscopical methods for detecting tobacco consumers in osteological samples, it should be acknowledged that the observations were confined to individuals exhibiting complete dentition, and that only instances in which tobacco was consumed orally (e.g., smoking or chewing) could be detected. This may have led to an underestimation of the number of tobacco consumers, as: 1) edentulous individuals were excluded from analysis despite the fact that tobacco negatively impacts tooth loss (Holm, 1994); and 2) those who did consume tobacco orally or simply long enough to develop dental evidence were scored as non-consumers.

Biomolecular techniques such as metabolomics offer promising solutions to this limitation, as they are not dependent on the way tobacco was consumed nor by the presence of specific observable skeletal features (Badillo-Sanchez et al., 2023). In the future, the incorporation of biomolecular techniques into paleopathological studies of tobacco consumption may lead to new insights, potentially highlighting distinct correlations between tobacco use and respiratory diseases. Moreover, biomolecular approaches may also help to address the limitation posed by the intrinsic heterogeneous frailty of osteological samples. For example, according to clinical research, tobacco consumers have a significantly shorter life expectancy compared to non-consumers (Preston et al., 2011; Rogers & Powell-Griner, 1991). In our total sample, CMS, IMED, and IPR were often more commonly observed among non-consumers than among individuals showing evidence of tobacco consumption. Additionally, as evidenced in Figure 8.3, most evidence of tobacco consumption was observed in younger individuals. This may suggest that tobacco consumers were less likely to live to old age. However, this was difficult to investigate in the samples under study, as most older adults were often either too highly fragmented or did not present enough preserved dentition to be included in the sample. The role of age was partly addressed in our binary logistic regression as we considered it among the variables that may have put individuals more at risk of respiratory disease. Even if, in most cases, age-at-death did not significantly impact any of the respiratory conditions examined in either of the populations under study, we observed that middle adults from Arnhem were 2.7 times more likely to present evidence of CMS than young adults. This trend may indicate a transition from child to adult labor within factory settings, where tasks evolved from relatively minor duties, such as button making, to more physically demanding roles, such as load lifting (Wintle, 2000). However, it is challenging to confirm this hypothesis based solely on the current dataset. In addition, it is important to note that osteoarchaeological methods for accurately estimating age-at-death in adults are inherently dependent on developmental processes, which are influenced by a variety of factors such as genetics, lifestyle, access to resources, and disease (Milner & Boldsen, 2011). In the past, these factors likely had a significant impact on individuals' bodies, leading to potential inaccuracies and inconsistencies in the aging of skeletons. Although these issues were partially addressed through statistical analysis and the application of diverse methods to estimate age-at-death (Casna, Davies-Barrett, et al., 2024), it is still possible that inaccuracies in age estimation may have impacted the results to some extent.

Finally, while further research on the impact of the popularization of tobacco on historical human health is underway, it should be considered that respiratory disease represents just one of the several outcomes associated with tobacco consumption. Countless other life-impacting conditions stemming from tobacco (e.g., cancer, chronic tissue inflammation, diabetes) were not considered here as they fell beyond the scope of our analysis. However, since tobacco represents such a pivotal cultural feature in Dutch (and global) history, it is imperative for future research to expand beyond respiratory diseases into the other aspects of human wellbeing. This broader approach will yield a more comprehensive understanding of tobacco's historical impact on health, potentially revealing new insights into its effects on mortality and longevity over the past 500 years.

8.6. Conclusions

This study explored the historical impact of tobacco consumption on the respiratory health of two Dutch populations dating to 1300-1829 CE and yielded nuanced insights into the complex interplay of various factors influencing human respiratory wellbeing. Alongside tobacco consumption, factors such as exposure to indoor pollution, overcrowding, adverse weather conditions, and occupational hazards emerged as significant contributors to respiratory disease prevalence rates, highlighting the multifaced etiologies of respiratory infections.

While exposure to second-hand tobacco smoke and the overall harsh living conditions in past urban Dutch communities undoubtedly posed a challenge to the interpretation of our results, we argue that methodological constraints also severely limited our understanding of the impact tobacco had on people's respiratory wellbeing. Future research should: 1) consider employing biomolecular techniques to address the limitations that come with macroscopical analysis; and 2) expand beyond respiratory diseases to understand broader health impacts of tobacco consumption. We argue that interdisciplinary approaches are vital to unravel the complex interactions between tobacco consumption and human health across different historical contexts. As we continue to explore the historical legacy of tobacco, it is imperative to consider its multifaceted impact on various aspects of human wellbeing.

Supporting information

Supplementary materials for this paper are available on the publisher's website: https://doi.org/10.1080/00438243.2024.2425814

Data availability statement

The datasets generated and analyzed during the current study are available at Casna, Maia, 2024, "Data for Exploring the Impact of Tobacco Consumption on the Respiratory Health of two Dutch Skeletal Populations (1300-1829 CE)", https://doi.org/10.17026/AR/B01AUM, DANS Data Station Archaeology.

References cited

Badillo-Sanchez, D., Ruber, M. S., Davies-Barrett, A. M., Sandhu, J. K., Jones, D. J. L., Hansen, M., & Inskip, S. A. (2023). Examination of human osteoarchaeological remains as a feasible source of polar and apolar metabolites to study past conditions. *Scientific Reports*, *13*(1), 696. https://doi.org/10.1038/s41598-023-27401-0

Bartholdy, B. P., Hasselstrøm, J. B., Sørensen, L. K., Casna, M., Hoogland, M., Beemster, H. G., & Henry, A. G. (2024). Multiproxy analysis exploring patterns of diet and disease in dental calculus and skeletal remains from a 19th century Dutch population. *Peer Community Journal*, *4*, e46. https://doi.org/10.24072/PCJOURNAL.414

Bates, M. N., Khalakdina, A., Pai, M., Chang, L., Lessa, F., & Smith, K. R. (2007). Risk of Tuberculosis From Exposure to Tobacco Smoke: A Systematic Review and Meta-analysis. *Archives of Internal Medicine*, *167*(4), 335–342. https://doi.org/10.1001/ARCHINTE.167.4.335

Bhat, T. A., Kalathil, S. G., Bogner, P. N., Miller, A., Lehmann, P. V., Thatcher, T. H., Phipps, R. P., Sime, P. J., & Thanavala, Y. (2018). Secondhand Smoke Induces Inflammation and Impairs Immunity to Respiratory Infections. *The Journal of Immunology*, *200*(8), 2927–2940. https://doi.org/10.4049/JIMMUNOL.1701417

Bonnie, R. J., Stratton, K., Kwan, L. Y., Products, C. on the P. H. I. of R. the M. A. for P. T., Practice, B. on P. H. and P. H., & Medicine, I. of. (2015). *The Effects of Tobacco Use on Health*. National Academies Press (US).

Boocock, P., Roberts, C. A., & Manchester, K. (1995). Maxillary sinusitis in Medieval Chichester, England. *American Journal of Physical Anthropology*, *98*(4), 483–495. https://doi.org/10.1002/ajpa.1330980408

Boyd, D. A. (2020). Respiratory Stress at the Periphery of Industrial-Era London: Insight from Parishes Within and Outside the City. In T. K. Betsinger & S. N. DeWitte (Eds.), *The Bioarchaeology of Urbanization. The Biological, Demographic, and Social Consequences of Living in Cities* (pp. 379–402). Springer. https://doi.org/10.1007/978-3-030-53417-2_15

Brongers, G. A. (1964a). *Nicotiana Tabacum. The history of tobacco and tobacco smoking in The Netherlands*. Theodorus Niemeyer N.V.

Brongers, G. A. (1964b). *Pijpen en tabak*. Uitgeverij C. A. J. Van Dishoeck.

Casna, M., Burrell, C. L., Schats, R., Hoogland, M. L. P., & Schrader, S. A. (2021). Urbanization and respiratory stress in the Northern Low Countries: A comparative study of chronic maxillary sinusitis in two early modern sites from the Netherlands (AD 1626–1866). *International Journal of Osteoarchaeology*, *31*(5), 891–901. https://doi.org/10.1002/oa.3006

Casna, M., Davies-Barrett, A. M., & Schrader, S. A. (2024). Smoking histories: A bioarchaeological approach to tobacco consumption in two skeletal populations from the Netherlands (1300-1829 CE). *Post-Medieval Archaeology*, *58*(1), 1–13. https://doi.org/10.1080/00794236.2024.2355461

Casna, M., Schats, R., Hoogland, M. L. P., & Schrader, S. A. (2023). A distant city: assessing the impact of Dutch socioeconomic developments on urban and rural health using respiratory disease as a proxy. *International Journal of Paleopathology*, *42*, 34–45. https://doi.org/10.1016/j.ijpp.2023.07.003

Casna, M., & Schrader, S. A. (2024). The urban sea: Cribra orbitalia, porotic hyperostosis, linear enamel hypoplasia, and sinusitis in three diachronic urban sites from the Dutch province of Zeeland (1030–1800 CE). *International Journal of Osteoarchaeology*, e3302. https://doi.org/10.1002/OA.3302

CDC/Centers for Disease Control and Prevention, N. C. for C. D. P. and H. P. O. on S. and H. (2010). *How Tobacco Smoke Causes Disease: The Biology and Behavioral Basis for Smoking-Attributable Disease: A Report of the Surgeon General*. Centers for Disease Control and Prevention (US).

Charlton, A. (2005). Tobacco or health 1602: an Elizabethan doctor speaks. *Health Education Research*, *20*(1), 101–111. https://doi.org/10.1093/her/cyg097

Claeys, J., Jaspers, N. L., & Ostkamp, S. (2010). *Vier eeuwen leven en sterven aan de Dokkershaven in Vlissingen*. ADC ArcheoProjecten.

Corey, J. P., Houser, S. M., & Ng, B. A. (2000). Nasal Congestion: A Review of its Etiology, Evaluation, and Treatment. *Ear, Nose, & Throat Journal*, *79*(9), 690–704. https://doi.org/10.1177/014556130007900908

Davies-Barrett, A. M., Antoine, D., & Roberts, C. A. (2019). Inflammatory periosteal reaction on ribs associated with lower respiratory tract disease: A method for recording prevalence from sites with differing preservation. *American Journal of Physical Anthropology*, *168*(3), 530–542. https://doi.org/10.1002/ajpa.23769

Davies-Barrett, A. M., & Inskip, S. (2024). Who smokes anymore? Documentary, archaeological and osteological evidence for tobacco consumption and its relationship to social identity in industrial England (AD 1700-1850). In L. Craig-Atkins & K. Harvey (Eds.), *The Material Body: Embodiment, History and Archaeology in Industrializing England, 1700-1880* (pp. 133–169). Manchester University Press.

De Ridder, J. (2004). *De geschiedenis van Vlissingen en haar ambachtsgilden*. Werkgroep Ambachtsgilden.

Duco, D. H. (1987). *De Nederlandse kleipijp, handboek voor dateren en determineren*. Pijpenkabinet.

Dunbar, A., Gotsis, W., & Frishman, W. (2013). Second-hand tobacco smoke and cardiovascular disease risk: An epidemiological review. *Cardiology in Review*, *21*(2), 94–100. https://doi.org/10.1097/CRD.0B013E31827362E4

Floreanova, K., Gilat, E., Koren, I., & May, H. (2020). Ear infection prevalence in prehistoric and historic populations of the southern Levant: A new diagnostic method. *International Journal of Osteoarchaeology*, *30*(4), 449–457. https://doi.org/10.1002/oa.2873

Fraga, S. (2010). Tabaco Panaceia no Século XVI e Patologia no Século XX. *Acta Medica Portugesa*, 23, 243–246.

Goodman, J. (2005). *Tobacco in History: The Cultures of Dependence*. Taylor & Francis.

Goossens, J., Jonckheere, A. C., Dupont, L. J., & Bullens, D. M. A. (2021). Air Pollution and the Airways: Lessons from a Century of Human Urbanization. *Atmosphere 2021, Vol. 12, Page 898*, *12*(7), 898. https://doi.org/10.3390/ATMOS12070898

Harris, J. K. (2021). Primer on binary logistic regression. *Family Medicine and Community Health*, *9*(Suppl 1), e001290. https://doi.org/10.1136/FMCH-2021-001290

Holm, G. (1994). Smoking as an Additional Risk for Tooth Loss. *Journal of Periodontology*, *65*(11), 996–1001. https://doi.org/10.1902/JOP.1994.65.11.996

Hoover, G. E., Newman, L. J., Platts-Mills, T. A. E., Phillips, C. D., Gross, C. W., & Wheatley, L. M. (1997). Chronic sinusitis: Risk factors for extensive disease. *Journal of Allergy and Clinical Immunology*, *100*(2), 185–191. https://doi.org/10.1016/S0091-6749(97)70223-9

Huertas, A., & Palange, P. (2011). COPD: a multifactorial systemic disease. *Therapeutic Advances in Respiratory Disease*, *5*(3), 217–224. https://doi.org/10.1177/1753465811400490

Inskip, S., Zachary, L., Serrano Ruber, M., & Hoogland, M. (2023). Pipe smoking and oral health in males from The Netherlands during the 18th–19th century. *Post-Medieval Archaeology*, *57*(1), 94–107. https://doi.org/10.1080/00794236.2022.2156834

Jayes, L., Haslam, P. L., Gratziou, C. G., Powell, P., Britton, J., Vardavas, C., Jimenez-Ruiz, C., Leonardi-Bee, J., Dautzenberg, B., Lundbäck, B., Fletcher, M., Turnbull, A., Katsaounou, P., Heederik, D., Smyth, D., Ravara, S., Sculier, J. P., Martin, F., & De Grada Orive, J. I. (2016). SmokeHaz: Systematic Reviews and Meta-analyses of the Effects of Smoking on Respiratory Health. *Chest*, *150*(1), 164–179. https://doi.org/10.1016/J.CHEST.2016.03.060

Jetton, J. A., Ding, K., Kim, Y., & Stone, D. U. (2014). Effects of tobacco smoking on human corneal wound healing. *Cornea*, *33*(5), 453–456. https://doi.org/10.1097/ICO.0000000000000100

Jiang, C., Chen, Q., & Xie, M. (2020). Smoking increases the risk of infectious diseases: A narrative review. *Tobacco Induced Diseases*, *18*. https://doi.org/10.18332/TID/123845

Kim, C. H., Lee, Y. C. A., Hung, R. J., McNallan, S. R., Cote, M. L., Lim, W. Y., Chang, S. C., Kim, J. H., Ugolini, D., Chen, Y., Liloglou, T., Andrew, A. S., Onega, T., Duell, E. J., Field, J. K., Lazarus, P., Le Marchand, L., Neri, M., Vineis, P., … Zhang, Z. F. (2014). Exposure to secondhand tobacco smoke and lung cancer by histological type: A pooled analysis of the International Lung Cancer Consortium (ILCCO). *International Journal of Cancer*, *135*(8), 1918–1930. https://doi.org/10.1002/IJC.28835

Koning, M. W. A., & Wattenberghe, J. (2007). *Archeologisch onderzoek Oude Markt te Vlissingen*. RAAP Archeologisch Adviesbureau B.V.

Kopadze, T., & Jikurashvili, M. (2023). Urbanization and its impact on population health. *Junior Researchers*, *1*(1), 52–57. https://doi.org/10.52340/2023.01.01.07

Krenz-Niedbała, M., & Łukasik, S. (2020). Urban-Rural Differences in Respiratory Tract Infections in Medieval and Early Modern Polish Subadult Samples. In T. K. Betsinger & S. N. DeWitte (Eds.), *The Bioarchaeology of Urbanization. The Biological, Demographic, and Social Consequences of Living in Cities* (pp. 245–274). Springer. https://doi.org/10.1007/978-3-030-53417-2_10

Kuiper, H. L., & Lengkeek, A. A. (1994). *Boeren, Burgers en Rijkelui - Een geschiedenis van Arnhem*. Prodesse Conamur.

Lieu, J. E. C., & Feinstein, A. R. (2000). Confirmations and Surprises in the Association of Tobacco Use With Sinusitis. *Archives of Otolaryngology–Head & Neck Surgery*, *126*(8), 940–946. https://doi.org/10.1001/ARCHOTOL.126.8.940

Ligthart, S., Steenaard, R. V., Peters, M. J., van Meurs, J. B. J., Sijbrands, E. J. G., Uitterlinden, A. G., Bonder, M. J., Hofman, A., Franco, O. H., Dehghan, A., Heijmans, B. T., 't Hoen, P. A. C., Isaacs, A., Jansen, R., Franke, L., Boomsma, D. I., Pool, R., van Dongen, J., Hottenga, J. J., … van Zwet, E. W. (2016). Tobacco smoking is associated with DNA methylation of diabetes susceptibility genes. *Diabetologia*, *59*(5), 998–1006. https://doi.org/10.1007/S00125-016-3872-0/TABLES/3

Manfredsdottir, V. F., Vikingsdottir, T., Jonsson, T., Geirsson, A. J., Kjartansson, O., Heimisdottir, M., Sigurdardottir, S. L., Valdimarsson, H., & Vikingsson, A. (2006). The effects of tobacco smoking and rheumatoid factor seropositivity on disease activity and joint damage in early rheumatoid arthritis. *Rheumatology*, *45*(6), 734–740. https://doi.org/10.1093/RHEUMATOLOGY/KEI240

Mannino, D. M., & Buist, A. S. (2007). Global burden of COPD: risk factors, prevalence, and future trends. *Lancet*, *370*(9589), 765–773. https://doi.org/10.1016/S0140-6736(07)61380-4

Milner, G. R., & Boldsen, J. L. (2011). Estimating Age and Sex from the Skeleton, a Paleopathological Perspective. In A. L. Grauer (Ed.), *A Companion to Paleopathology* (pp. 268–284). Blackwell Publishing Ltd.

Pelkonen, M. K., Laatikainen, T. K., & Jousilahti, P. (2019). The relation of environmental tobacco smoke (ETS) to chronic bronchitis and mortality over two decades. *Respiratory Medicine*, *154*, 34–39. https://doi.org/10.1016/J.RMED.2019.06.006

Pokorski, M. (2017). *Respiratory System Diseases*. Springer. https://doi.org/10.1007/978-3-319-59498-9

Prasetyo, A., Sadhana, U., & Budiman, J. (2021). Nasal Mucociliary Clearance in Smokers: A Systematic Review. *International Archives of Otorhinolaryngology*, *25*(1), e160. https://doi.org/10.1055/S-0040-1702965

Preston, S. H., Glei, D. A., Wilmoth, J. R., & Crimmins, E. M. (2011). Contribution of smoking to international differences in life expectancy. *International Differences in Mortality at Older Ages: Dimensions and Sources*, 105–131.

Ramasamy, J., & Sivapathasundharam, B. (2021). A study on oral mucosal changes among tobacco users. *Journal of Oral and Maxillofacial Pathology*, *25*(3), 470. https://doi.org/10.4103/JOMFP.JOMFP_105_21

Reh, D. D., Higgins, T. S., & Smith, T. L. (2012). Impact of tobacco smoke on chronic rhinosinusitis: a review of the literature. *International Forum of Allergy & Rhinology*, *2*(5), 362–369. https://doi.org/10.1002/ALR.21054

Roessingh, H. K. (1976). *Inlandse tabak: expansie en contractie van een handelsgewas in de 17e en 18e eeuw in Nederland*. Wageningen University & Research.

Roessingh, H. K. (1979). Tobacco growing in Holland in the seventeenth and eighteenth centuries: A case study of the innovative spirit of Dutch peasants. In *The Low Countries history yearbook 1978: Acta Historiae Neerlandicae XI* (pp. 18–54). Springer.

Rogers, R. G., & Powell-Griner, E. (1991). Life expectancies of cigarette smokers and nonsmokers in the United States. *Social Science & Medicine*, *32*(10), 1151–1159.

Slavin, R. G., Spector, S. L., Bernstein, I. L., Kaliner, M. A., Kennedy, D. W., Virant, F. S., Wald, E. R., Khan, D. A., Blessing-Moore, J., Lang, D. M., Nicklas, R. A., Oppenheimer, J. J., Portnoy, J. M., Schuller, D. E., Tilles, S. A., Borish, L., Nathan, R. A., Smart, B. A., & Vandewalker, M. L. (2005). The diagnosis and management of sinusitis: a practice parameter update. *The Journal of Allergy and Clinical Immunology*, *116*(6), S13–S47. https://doi.org/10.1016/J.JACI.2005.09.048

Snelders, S. (2021). Normalisation and Ambivalence: Tobacco in the Seventeenth-Century Dutch Republic. *The Journal of the Social History Society*, *20*, 11–26. https://doi.org/10.1080/14780038.2021.1976701

Stallones, R. A. (2015). The association between tobacco smoking and coronary heart disease. *International Journal of Epidemiology*, *44*(3), 735–743. https://doi.org/10.1093/IJE/DYV124

Strachan, D. P., & Cook, D. G. (1998). Health effects of passive smoking. 4. Parental smoking, middle ear disease and adenotonsillectomy in children. *Thorax*, *53*(1), 50–56. https://doi.org/10.1136/THX.53.1.50

Stuurman, S. (2023). *Vrouwen op Scheveningen. Van nettenboetster tot redersweduwe*. Amsterdam University Press.

Su, Z., Xie, Y., Huang, Z., Cheng, A., Zhou, X., Li, J., Qin, R., Liu, Y., Xia, X., & Song, Q. (2023). *Second hand smoke prevalence and attributable disease burden in 204 countries and territories, 1990–2019: a systematic analysis from the global burden of disease study 2019*. http://dx.doi.org/10.2139/ssrn.4517320

van Braam, A. (1978). *Westzaandam in de tijd van de Republiek*. Gemeentearchief van Zaanstad.

van Cruyningen, P. (2012). Economie. In P. Brusse & W. Mijnhardt (Eds.), *Geschiedenis van Zeeland deel 2: 1550-1700* (pp. 51–75). Uitgeverij Wbooks.

van den Bergh, M. R., Biesbroek, G., Rossen, J. W. A., de Steenhuijsen Piters, W. A. A., Bosch, A. A. T. M., van Gils, E. J. M., Wang, X., Boonacker, C. W. B., Veenhoven, R. H., Bruin, J. P., Bogaert, D., & Sanders, E. A. M. (2012). Associations between Pathogens in the Upper Respiratory Tract of Young Children: Interplay between Viruses and Bacteria. *PLOS ONE*, *7*(10), e47711. https://doi.org/10.1371/JOURNAL.PONE.0047711

van der Lingen, B., & Korpershoek, E. (2024). *Harlingen, pijpenmakers en bodemvondsten*. PKN/Stitching voor onderzoek historische tabakspijpen.

van der Rijst, N., & Garfield, J. L. (2023). Adverse Effects of Tobacco Products (Cigarettes, E-Cigarettes, Hookah, Smokeless Tobacco) Use on Health. In H. Eakin Michelle N. and Kathuria (Ed.), *Tobacco Dependence: A Comprehensive Guide to Prevention and Treatment* (pp. 23–43). Springer. https://doi.org/10.1007/978-3-031-24914-3_2

van Laar, E. (1966). *Hoop op gerechtigheid: De arbeiders en hun organisaties in Arnhem gedurende de tweede helft van de negentiende eeuw*. Gemeentearchief van Arnhem.

Vineis, P., Alavanja, M., Buffler, P., Fontham, E., Franceschi, S., Gao, Y. T., Gupta, P. C., Hackshaw, A., Matos, E., Samet, J., Sitas, F., Smith, J., Stayner, L., Straif, K., Thun, M. J., Wichmann, H. E., Wu, A. H., Zaridze, D., Peto, R., & Doll, R. (2004). Tobacco and Cancer: Recent Epidemiological Evidence. *Journal of the National Cancer Institute*, *96*(2), 99–106. https://doi.org/10.1093/JNCI/DJH014

Vozoris, N., & Lougheed, M. D. (2008). Second-hand smoke exposure in Canada: Prevalence, risk factors, and association with respiratory and cardiovascular diseases. *Canadian Respiratory Journal*, *15*(5), 263–269. https://doi.org/10.1155/2008/912354

Walker, D., & Henderson, M. (2010). Smoking and health in London's East End in the first half of the 19th century. *Post-Medieval Archaeology*, *44*(1), 209–222. https://doi.org/10.1179/174581310X12662382629373

WHO/World Health Organization. (2021). *WHO report on the global tobacco epidemic 2021: addressing new and emerging products*. World Health Organization.

Wintle, M. (2000). *An Economic and Social History of the Netherlands, 1800–1920*. Cambridge University Press. https://doi.org/10.1017/cbo9780511496974

Zanobetti, A., Schwartz, J., & Dockery, D. W. (2000). Airborne particles are a risk factor for hospital admissions for heart and lung disease. *Environmental Health Perspectives*, *108*(11), 1071–1077. https://doi.org/10.1289/EHP.001081071

Zielman, G., & Baetsen, W. A. (2020). *Wat de nieuwe Sint Jansbeek boven water bracht: dood en leven in het Arnhemse verleden: archeologisch onderzoek Sint Jansbeek te Arnhem*. RAAP Archeologisch Adviesbureau B.V.