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)

Casna, M.

CHAPTER 1

Introduction

Today, respiratory disease represents a substantial worldwide health burden: almost 545 million people presently live with a chronic respiratory condition, of which at least 4 million die annually (Soriano et al., 2020). These diseases, which primarily affect the lungs and airways, encompass a broad spectrum of conditions, from common ailments such as seasonal colds to life-threatening diseases (e.g., chronic obstructive pulmonary disease, lung cancer) that today represent the third leading cause of death worldwide (Figure 1.1) (WHO, 2023).

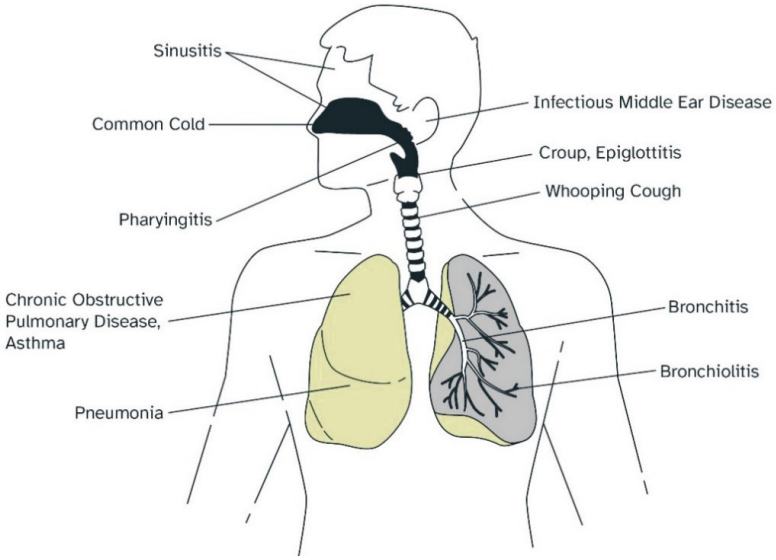

Figure 1.1. Diagram of the human respiratory system, highlighting a selection of associated respiratory conditions. Diagram adapted from storyset / Freepik.

While recent advancements in medical science have improved our understanding of respiratory disease, new challenges continue to emerge, reflecting the evolving nature of respiratory health threats in response to ever-transforming living and working environments (Eguiluz-Gracia et al., 2020; Soriano et al., 2020). In the past decade, the World Health Organization has striven to bring attention to the link between respiratory disease and poor air quality, as rising emissions associated with urbanization and industrialization have been proven to contribute significantly to the global prevalence and incidence of most respiratory conditions (Almetwally et al., 2020; Doiron et al., 2019; Tiotiu et al., 2020; WHO, 2016). However, while the correlation between air pollution and respiratory disease is today well-established, additional factors have clinically been recognized to play a significant role in the spread of these conditions, including socioeconomic inequalities, access to healthcare, and exposure to tobacco smoke (i.e., Badley et al., 1973; Kjaergaard et al., 1989; Soriano et al., 2020). These multifaceted etiologies underscore the complex responsiveness of respiratory disease to environmental factors, highlighting an intricate interplay between external conditions and the prevalence, severity, and spread of these health challenges.

1.1. Respiratory diseases in the past

Because of its link to air pollution, the high burden of respiratory disease is often considered to be a product of the modern world. However, chronic respiratory disorders have been historically documented since the emergence of the first medical science, suggesting these conditions were a recurring issue in the past as well (Brimblecombe, 1987; 2018). One of the earliest pieces of historical evidence of respiratory diseases in ancient populations can be traced back to Hippocrates in the 5th century BCE (Stefanakis et al., 2020). Hippocrates classified respiratory infections as either acute or chronic and emphasized the importance of medical intervention for patients with severe symptoms (Stefanakis et al., 2020). Five hundred years later, the Roman philosopher and statesman Lucius Annaeus Seneca observed a conspicuous connection between air pollution and respiratory health, highlighting the adverse impact of Rome's "infamous air"[1] on his own respiratory system (Brimblecombe, 1987). In the 13th century, a surge of grievances about pervasive smoke and its detrimental effects on residents' health led to the establishment of several commissions to investigate air pollution in London and in other European cities (Brimblecombe, 1987). However, despite efforts to regulate air quality, the rapid urbanization that swept across the European continent in the late- and post-medieval eras posed considerable challenges to any form of control, and air pollution remained an important issue throughout the 17th and 18th centuries (Brimblecombe, 2003; Fowler et al., 2020; Heidorn, 1978).

Contemporary historical data from diverse geographical and temporal contexts provide a comprehensive account of the concerns our ancestors held regarding air pollution (e.g., Brimblecombe, 1987; Fowler et al., 2020; Huisman, 2018; Pancino, 2015). However, while these documents offer valuable insights into historical health challenges, they often lack information on various aspects of respiratory disease, such as variation in occurrence patterns among populations, the impact of socioeconomic inequalities on health, as well as individual embodied experiences (Roberts, 2016). According to clinical research, the risk for respiratory disease can vary significantly based on one's living circumstances (e.g., sex, age, pre-existing conditions) or habits, suggesting that even individuals sharing the same environment may have experienced these conditions in remarkably different ways (Bush et al., 2024; DeBolt & Harris, 2021; WHO, 2010). Previous bioarchaeological research focusing on respiratory disease and its link to socioeconomic changes typically supports the results of clinical research, highlighting a higher historical prevalence of respiratory disease in heavily industrialized, impoverished populations compared to those from less industrialized, wealthier contexts (e.g., Bernofsky, 2010; Lewis, 2002; Lewis et al., 1995; Western & Bekvalac, 2019). However, while these studies have contributed to shaping the trope of how life dramatically worsened with urban development, it should be noted that they have only sporadically considered scenarios outside of England,

1 In the first century BCE, Rome residents referred to their city's smoke cloud as *infamis aer* ("infamous air"). The problem of air pollution in Ancient Rome was a recurring theme in the works of local poets and writers, who frequently highlighted its role in darkening the city's temples and monuments (Brimblecombe, 2018).

whose urban and industrial histories are among the most impactful in the European continent (Lee et al., 2024).

Recent, more diverse bioarchaeological analyses of diverse urban contexts across different time periods and regions suggest that the impacts of medieval and post-medieval developments on human health varied throughout Europe, likely reflecting the specific time, place, and population rather than responding to a uniform pattern (Betsinger & DeWitte, 2021). This is especially relevant when studying Dutch urbanization, as the Netherlands developed much more quickly than other European realities, but with considerable variation among cities (Blockmans, 2011). Due to the political and economic disconnection that persisted until the 19th century, Dutch towns experienced growth and decline asynchronously, achieving different levels of commercialization, specialization, and industrialization at different times (Blockmans, 2011; Brusse & Mijnhardt, 2011; de Vries, 1984). As a consequence, issues commonly associated with urbanization and industrialization, such as health risk factors and social inequalities, varied greatly from city to city, likely leading to significantly different life experiences and health challenges (Blockmans, 2011; Hoppenbrouwers, 2001).

Building on these unique historical perspectives, this study investigates the impact of changes through time and space of respiratory disease in historic Netherlands. Through the analysis of archaeological human skeletal remains, it examines how various demographic and socioeconomic factors influenced the occurrence of respiratory disease among 13 historical Dutch populations (ca. 470-1850 CE).

1.2. Research questions and objectives

The purpose of this study is to enhance current bioarchaeological knowledge on respiratory health by investigating the prevalence rates of different respiratory diseases (i.e., chronic maxillary sinusitis, infectious middle ear disease, and pleural inflammation) across the early, late, and post-medieval periods in the Netherlands. These conditions were specifically selected because they are commonly observed macroscopically in skeletal remains and have been widely studied in bioarchaeology as they provide valuable insights into the effects of respiratory infections and environmental stressors (e.g., Bernofsky, 2010; Boyd, 2020; Davies-Barrett et al., 2023; Krenz-Niedbała & Łukasik, 2020; Roberts, 2007). By examining these conditions, the present study aims to analyze how their prevalence varied in relation to risk factors commonly associated with urbanization, such as air pollution, overcrowding, tobacco smoke, and socioeconomic status.

To date, most bioarchaeological studies on respiratory disease have focused on differences in prevalence rates across various environments, often highlighting how, within a given time period, urban populations typically exhibit higher rates of respiratory conditions compared to their rural counterparts (e.g., Krenz-Niedbała & Łukasik, 2020; Lee et al., 2024). The present study aims to better frame results within a wider archaeological context, achieving a more complete understanding of the Netherlands' social past by not only taking into account different living

environments, but also including individuals from various different time periods. In doing so, the following research questions will be addressed:

> ***Research Question 1**: How did increasing urbanization in the Netherlands influence rates of respiratory diseases in different environments (e.g., rural, urban) in the time period under study?*

This question aims to examine how the progression of urbanization over time affected respiratory disease rates in various environments. By investigating diachronic differences in urbanization, I aim to understand how changes in urban development were reflected in the prevalence of respiratory diseases in both rural and urban settings.

> ***Research Question 2**: What are the differences in the prevalence, risk factors, and outcomes of respiratory diseases among urban populations of differing socioeconomic status?*

Socioeconomic status is widely acknowledged as a major risk factor for respiratory disease (e.g., Rocha et al., 2019). In the Dutch post-medieval period, lifestyles were significantly shaped by wealth and socioeconomic class (van der Vlis, 2001; Wintle, 2000). With this research question, I aim to test the hypothesis that individuals from the lower socioeconomic strata were more severely impacted by respiratory disease than their wealthier counterparts.

> ***Research Question 3**: To what extent did urbanization and socioeconomic developments affect the respiratory health of children in the Northern Low Countries?*

According to clinical research, children can be more susceptible to respiratory disease due to several physiological, behavioral, and cultural factors (Carraro et al., 2014). In addition, poor living conditions and exploitative working environments in the past are likely to have negatively influenced the (respiratory) health of younger populations (Hendrick, 2009; Kirby, 2013). However, until recently non-adults have been somewhat overlooked in bioarchaeological research on respiratory disease, resulting in a gap in our understanding of how these factors may have affected their health. By including this research question, I aim to obtain a comprehensive overview of the populations under study (i.e., both adults and non-adults) and to address demographic variations in susceptibility to respiratory disease.

> ***Research Question 4**: To what extent did tobacco consumption contribute to the burden of respiratory disease in past Dutch populations?*

Today, tobacco smoking is considered among the main risk factors for chronic respiratory disease (Salvi, 2014). In the Netherlands, tobacco was introduced in the 1600s and immediately became popular among all socioeconomic groups (Brongers, 1964). My aim is to investigate how

tobacco consumption specifically influenced respiratory disease rates in urban environments. By examining this relationship, my aim is to enhance our understanding of how tobacco consumption fits within the broader context of urbanization and socioeconomic changes, and how these factors collectively impacted past health.

1.3. Dissertation outline and structure

In this chapter, I have provided a comprehensive introduction to this dissertation, presenting the significance and objectives of this study, as well as the research questions it aims to answer. I laid the foundations for the subsequent chapters by discussing the prominent role that respiratory disease has had throughout human history, and how they have been addressed by (bio) archaeological research so far. **Chapter 2** provides a clinical overview of the respiratory diseases under investigation in this study (i.e., chronic maxillary sinusitis, infectious middle ear disease, and pleural inflammation). Additionally, it offers useful information on the various factors that trigger respiratory tract inflammation, and discusses how the human skeleton responds to such inflammation, ultimately leading to the development of lesions that are interpreted as indicators of respiratory disease in bioarchaeological research.

Chapters 3 to 8 present several published papers that address the sub-questions outlined earlier. Specifically, **Chapter 3** is a research article that examines the impact of urbanization and industrialization on respiratory diseases over time, offering a comprehensive diachronic overview of respiratory health in the Netherlands from the early Middle Ages to the post-medieval period. The findings presented in this chapter suggest that factors such as increased interaction between urban and rural areas, higher population densities, and the intensification of agricultural production significantly influenced the respiratory health of the studied populations in both rural and urban settings.

Chapter 4 examines socioeconomic disparities during the post-medieval period and their impact on the wellbeing of four populations with varying levels of wealth, focusing on patterns of respiratory health and non-specific stress markers. The results are surprising, revealing no consistent or significant variations in respiratory health or the prevalence rates of stress markers across the different socioeconomic groups. This suggests that, despite differences in wealth leading to varied life experiences, health challenges (especially those related to respiratory diseases) remained relatively consistent across all socioeconomic strata.

Chapter 5 presents data on differences in sinusitis and non-specific stress markers over time in a previously understudied setting (i.e., maritime cities). By analyzing prevalence rates in relation to the development of the sea industry associated with the Dutch West and East India Companies, we observed that de-urbanization and economic decline of maritime cities in the post-medieval period adversely affected the respiratory health of the populations under study, possibly influenced by factors such as working conditions and food availability.

While data presented up until Chapter 5 only consider adults, **Chapter 6** analyses how the aforementioned risk factors impacted respiratory health among non-adults. Similar to the results presented in Chapters 3 and 4, rates of sinusitis increased over time, suggesting that urbanization and industrialization impacted the respiratory wellbeing of both adults and non-adults alike.

Finally, **Chapter 7** and **Chapter 8** present data on tobacco consumption in four diachronic populations and examine its impact on their respiratory health. These chapters highlight the challenges of identifying specific risk factors within the osteoarchaeological record and suggest that tobacco's effects on respiratory health likely varied according to environmental conditions and differing levels of exposure to air pollution.

Chapter 9 concludes this dissertation offering a thorough discussion of the findings presented in the previous chapters. It reflects on how methodological and archaeological limitations have influenced the overall conclusions and identifies areas where further research is needed. This chapter also explores potential future directions for bioarchaeological research on respiratory diseases, offering recommendations to refine methodological approaches and to enhance our understanding of the historical impact of environmental and socioeconomic factors on human respiratory health.

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