Ecology and Infectious Disease in Britain from Prehistory to the Present: the Case of Respiratory Infections

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Summary: This paper considers the evidence for tuberculosis and some more rarely studied pathological lesions, as indicators of respiratory disease in British prehistoric and historic skeletal populations. As predicted, respiratory inflammation increases in frequency through time. Reasons suggested for this pattern are the development of urbanism, better insulated housing, increased population density and industrialisation, which contributed to both indoor and outdoor environmental pollution. Limitations of the data are discussed but the potential for further studies of respiratory disease is noted.
Key words: Ecology, infection, respiratory system, Britain, prehistory, history.

Introduction

The British Isles is a series of islands in north-west Europe. The mainland of Britain has been an island since 8,000 BC when rising sea levels severed the land connection between it and the rest of Europe. This connection was only re-established in 1994 with the construction of the Channel Tunnel. The British Isles is characterised by great diversity in climate, geology, geography and vegetation, and the climate and weather is much influenced by the sea. It is generally wetter and cooler in the upland terrain of the north and west, and drier and warmer with lowland terrain in the south and east. However, there are regional variations according to altitude and latitude, proximity to the sea and exposure to the wind. The British Isles have seen some major changes to the landscape as a result of management by human populations. For example, in the Neolithic period (4,000–2,500 BC) extensive forest clearances occurred during the transition to subsistence agriculture, and in the Later Medieval period (12^{th}–16^{th} centuries AD) urban environments were established with the growth of towns.

Britain has a long history of human occupation, stretching back to the Late Upper Palaeolithic (10,500–8,000 BC), and there has been a diversity of settlement patterns throughout prehistory and history. Population migration into the British Isles has also been a regular feature of Island development; for example, Anglo-Saxon populations migrated to the south and east of England in the 5^{th} century AD, and trade with the outside world occurred as early as the Bronze Age (2,600–800 BC). Britain has a wealth and variety of funerary ritual sites, ranging from the Neolithic earthen long barrows to the ordered cemeteries and crypts of the Medieval and Post-Medieval periods.

The study of skeletal remains from British archaeological sites also has a very long history. Biological anthropology has developed from the antiquarian interest of the 19th and earlier 20th centuries, to the more recent development of a biocultural approach to human population behaviour, which has characterised much of the research on British skeletal samples over the last ten years. The wealth of skeletal material that lies curated in museums, University departments of archaeology and anthropology, and other institutions, provides an invaluable resource base for palaeopathological research. Here, it is possible to test hypotheses and answer questions using the most up to date techniques of analysis, without the threat of repatriation and reburial that researchers in other countries of the world face.

While the evidence for health and disease has been studied for decades in human skeletal remains deriving from archaeological sites in Britain, and 'archaeological studies' of pollution have been undertaken (e.g. Camuffo et al. 2000), little attention has been paid to the effects of respiratory infection in the skeleton. Respiratory infections have been noted in mummified material (Zimmerman 2001, Pap et al. 1999) and perhaps this neglect in dry bone analysis is due to the fact that diseases of this area of the body usually only affect the soft tissues of the lungs (e.g. Munizaga et al. 1975, Pabst and Hofer 1998). However, the ribs surround the lungs and could be potentially affected by pulmonary disease, and the sinuses of the face comprise part of the upper respiratory tract. Today, respiratory infections are very common and are often initiated by general environmental (outdoor) and indoor pollution. In addition, specific organisms such as *M. tuberculosis* can be responsible for the occurrence of respiratory infection in human populations. As the world's population faces increasing respiratory health problems, it is rather surprising that this area is not a more common target for research in the past.

The aim of this paper is to consider the extant evidence for lesions related to infection of the respiratory system in skeletal samples, dating from prehistory to the Post-Medieval period, and to consider these data with reference to the wealth of information on the living environment of past populations in the British Isles. Aspects such as the development of agriculture, urbanism and industrialisation, and the impact these changes have had on living conditions, environmental pollution, diet and economy, trade and contact, and occupation, are some of the factors relevant to the appearance and maintenance of infectious disease.

Material and Methods

The data that form the basis of this paper were collated from a variety of sources (Boocock et al. 1995 – sinusitis data, Lewis et al. 1995 – sinusitis data, Roberts 1998 – rib data, Roberts et al. 1998 – sinusitis data, Lewis 1999 – all non-adult data, Roberts and Buikstra in review – tuberculosis data, Roberts and Cox in review – rib and sinusitis data), and comprise skeletal evidence related to respiratory disease of the upper (maxillary sinuses) and lower (ribs) systems of the body. All data, apart from that reported by Lewis (1999), are derived from adult skeletons. Biological sex of the adults was assessed according to the methods described in Buikstra and Ubelaker (1994), and age-at-death estimates were obtained for the non-adults (>17 years) using standards of dental development (Moorrees et al. 1963a, 1963b, tabulated by Smith 1991 and Lewis 1999). Where no teeth were present, diaphyseal lengths and skeletal maturation were used to assign an age (Ubelaker 1989, Buikstra and Ubelaker 1994). As the methods for age estimation for adult skeletons are problematic, age, as a variable in the interpretation of the evidence for respiratory disease in the adults was not considered. Much of the data was originally recorded in the form of the total number of individuals affected (hereafter referred to as crude prevalence rates, or CPR), apart from detailed site specific studies. This obviously precludes providing absolute prevalence rates for disease i.e. number of bone elements affected, compared to elements available to be observed. However, this is a reflection of the limited nature of the data collected in Britain (Roberts and Cox in review).

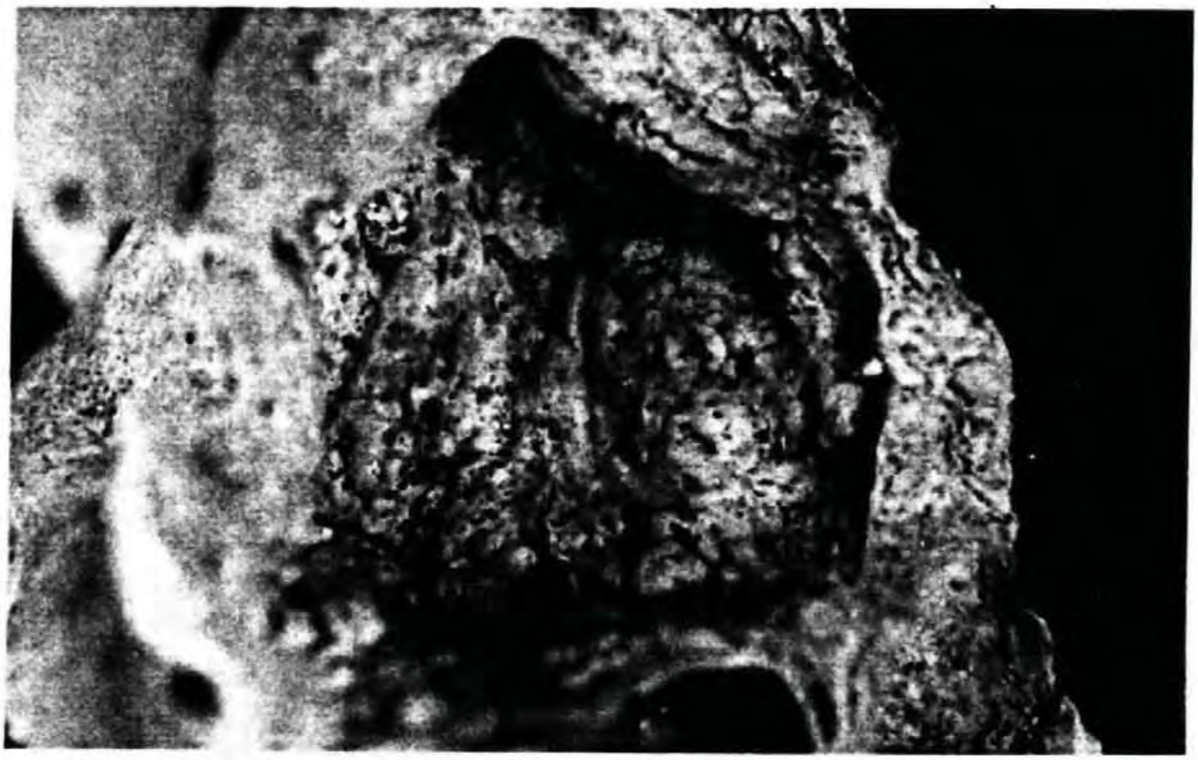

Figure 1: Maxillary sinusitis from St. James and St Mary Magdalene, Chichester (C94) with evidence of extensive lamellar bone formation (lateral sinus wall).

For the detailed site-specific studies, chronic maxillary sinusitis (Figure 1) was recorded according to the classification system described by Boocock et al. (1995: 486–490) with the exception of 'pits' which are believed to represent normal sinus development (Lewis et al. 1995). For this reason, sinusitis was only recorded in the non-adult individuals from 2.6 years onwards, when sinus development is advanced enough to allow more effective visualisation of the cavities (Maresh 1940). In some cases, an endoscope was employed to visualise the interior of intact sinuses. Dental disease was also recorded in order to differentiate between dental disease induced sinusitis from another, perhaps respiratory, aetiology. New bone formation on visceral surfaces of ribs (Figure 2) was recorded in terms of its presence, location on the rib and rib cage (where possible) and whether the bone formed was woven or lamellar in nature (see Roberts et al. 1994). Finally tuberculosis was recorded where obvious Pott's disease of the spine was noted (Aufderheide and Rodríguez Martin 1998 and Figure 3).

Roberts and Cox (in review) document other evidence for infection on the ribs and sinuses reported in published and unpublished skeletal reports. Data derived from all sources date from the Neolithic to the Post-Medieval period and span several thousand years of British history.

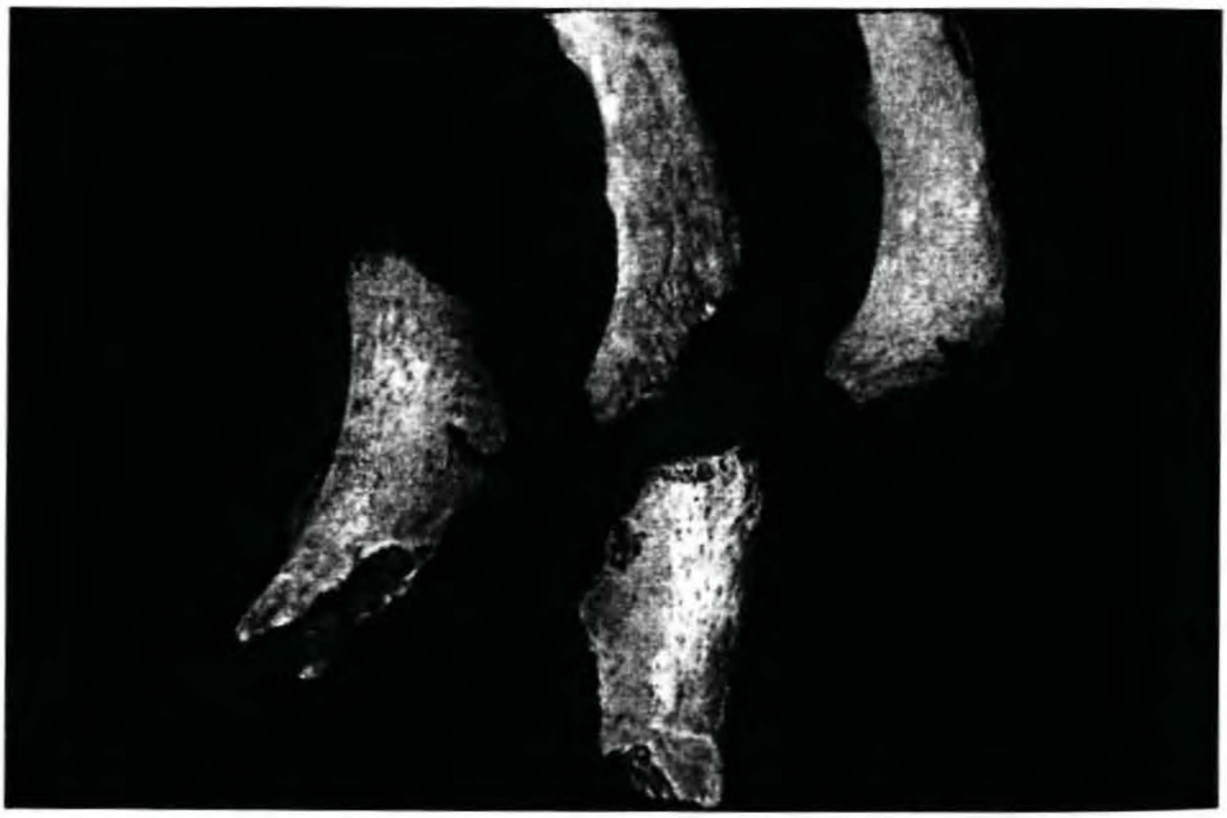

Figure 2: New bone formation on ribs from the Romano-British site of Cirencester, Gloucestershire (189).

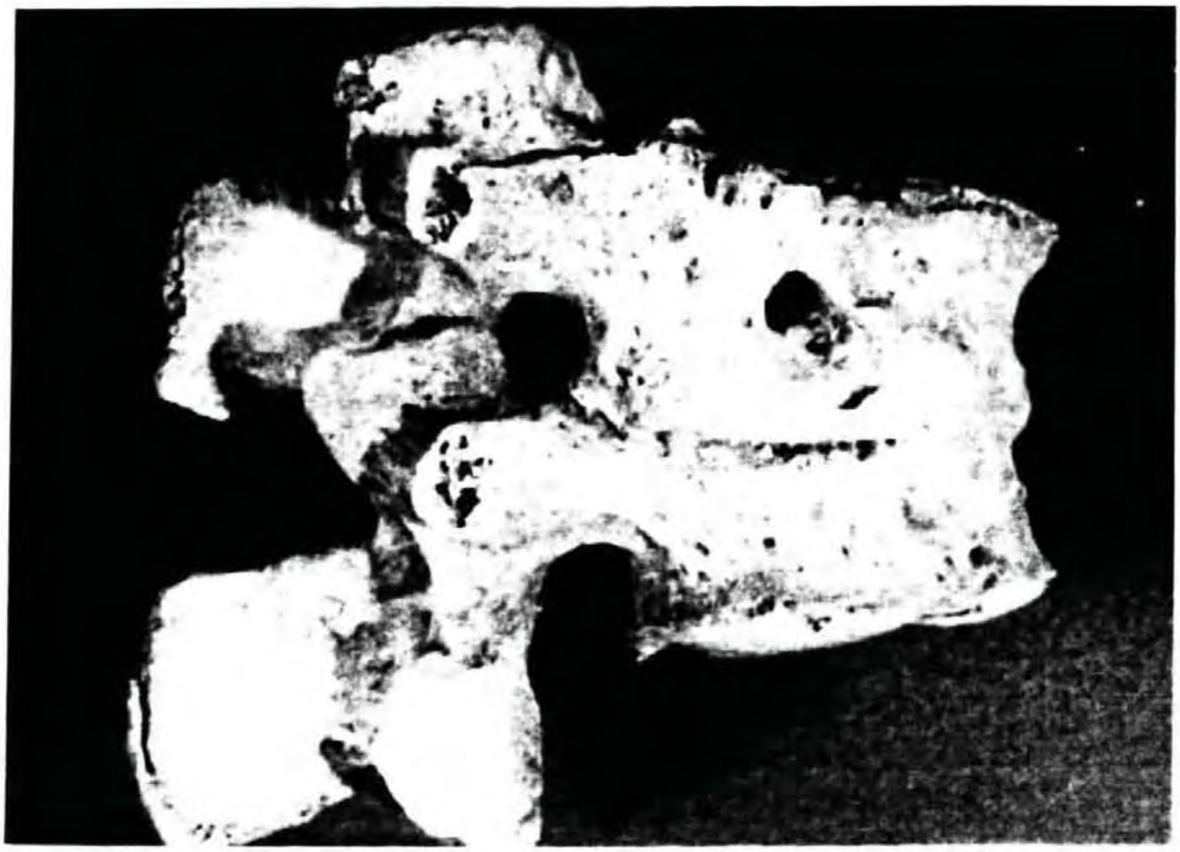

Figure 3: Lumbar vertebrae from the Roman-British site at Cirencester, Gloucestershire (S) with fusion of the vertebrae, compression of the inferior element, and a long standing sinus.

Results

Data on health and disease in general was considered from as early as the Late Upper Palaeolithic period (Roberts and Cox in review). However, maxillary sinusitis was not noted until the Neolithic period, when only one individual out of 772 from 24 sites was recorded with the lesion. During the Bronze Age (2,600–800 BC) this condition was recorded in a further two individuals (CPR 0.7%) from a total of 45 sites and 291 skeletons. However, it is in the Roman period (AD 43–410) that evidence for maxillary sinusitis begins to increase. A crude prevalence rate of 1.7% (35 of 2013 individuals) was recorded in a total of nine sites. Table 1 summarises the data for sinusitis in the Roman to Post-Medieval periods.

One of the major limitations of this study resulted from the fact that many authors did not state whether sinusitis had or had not been recorded, which means that many of the prevalence rates here could be higher. Therefore, presence or absence of data did not exist for 3703 Roman skeletons from 42 sites, 5130 individuals from 59 sites in the Early Medieval period, 16,051 individuals from 59 sites in the Later Medieval Period and for 2715 individuals from 11 sites in the Post-Medieval period.

Table 2 summarises the results of chronic maxillary sinusitis in specific sites from the Early, Late and Post-Medieval periods from rural, urban and industrial environments. Table 3 provides data for sinusitis in those populations where dental disease was considered a possible aetiology.

Table 1: Crude prevalence rates for maxillary sinusitis in adults: Roman to post-Medieval periods.

Period	Total individuals for all sites	Total affected (number examined)	CPR (%)
Roman	5716	35 (2013)	0.6
Early Medieval	7122	93 (1992)	1.3
Late Medieval	16,327	276 (2076)	1.7
Post-Medieval	3790	74 (1075)	2.0

Table 2: Numbers of individuals affected by sinusitis by site.

Site	Total number of adults	*Total affected	*Males	*Females	*Non-adults
Raunds Furnells Rural, early medieval	109	55 (51%)	36/68 (53%)	19/41 (46%)	2/20 (10%)
St Helen Urban, late medieval	114	82 (72%)	37/49 (76%)	45/65 (69%)	6/35 (17%)
Wharram Percy Rural, late medieval	169	86 (51%)	43/97 (44%)	43/72 (60%)	8/88 (9%)
Chichester Hospital, late medieval	131	72 (55%)	46/84 (55%)	26/47 (55%)	No data
Spitalfields Industrial, post-medieval	394	71 (18%)	34/202 (12%)	37/192 (19%)	1/33 (3%)

*Number and % of total

Table 3: Evidence for dental disease induced sinusitis by site.

Site	Adults with dental disease	Adults without dental disease	Non-adults with dental disease	Non-adults without dental disease
Raunds Furnells Rural, early medieval	19/55 (34.5%)	36/55 (65%)	1/2 (50%)	1/2 (50%)
St Helen Urban, Late medieval	7/82 (9%)	75/82 (91%)	3/6 (50%)	3/6 (50%)
Wharram Percy Rural, late medieval	23/86 (27%)	63/86 (73%)	2/8 (20%)	6/8 (80%)
Chichester Hospital, late medieval	5/72 (7%)	67/72 (93%)	No data	No data
Spitalfields Industrial, post-medieval	62/71 (87%)	9/71 (13%)	1/1 (100%)	0/1 (0%)

Data on rib periostitis revealed, again, that this condition did not appear until the Neolithic period (two individuals), is present in one person from the Bronze Age and three from the Iron Age, but does not appear in higher frequencies until the Roman period. Forty-five individuals from 15 sites (2075 total) were affected, and from the early Medieval period 28 people from eight sites (1278 total) showed evidence of infection. Data from the Late and Post-Medieval sites show 97 and 40 people affected, respectively. Detailed data from Raunds Furnells revealed only five individuals with rib lesions and 38 individuals at Chichester, while at Spitalfields there were 31 cases from 394 individuals, or 9.4% (19 or 202 males or 9.4%, and 12 of 192 females or 6.3%). Rib lesions were evident in four non-adults at Raunds Furnells and Wharram Percy, and in only one child at St Helen-on-the-Walls and Spitalfields. However, as for sinusitis, it was not always clear whether new bone formation on ribs was specifically observed and recorded.

Tuberculosis was first identified in the Roman period and the results are summarised in Table 4. Once again, many of the skeletal reports failed to indicate whether lesions indicative of tuberculosis were or were not present.

Table 4: Crude prevalence rates for tuberculosis (adults and non-adults combined).*

Period	Total burials For all sites	Affected (number examined)	CPR (%)
Roman	5716	13 (549)	0.2
Early Medieval	7122	17 (1542)	0.2
Late Medieval	16,327	63 (8133)	0.4
Post-Medieval	3790	8 (1711)	0.2

* data from Roberts and Buikstra (in review)

Note: there were only two non-adult individuals affected and both derive from the post-Medieval period

Data from specific sites from the Medieval periods showed low prevalence rates for the disease, with a slightly higher prevalence being recorded at the hospital site of Sts. James and Mary Magdalene at Chichester (5 of 306 or 1.6%). At Raunds Furnells one (of 356 or 0.3%) person was affected, with five of 1042 at St Helen-on-the-Walls (0.5%), seven of 687 at Wharram Percy (1.0%), and two of 968 at Spitalfields (0.2%).

Discussion

Disease of both the upper and lower respiratory tracts can be caused by a number of factors including the weather and climate (Howe 1997:31), exposure to dust associated with processing crops (McCurdy et al. 1996), environmental pollution, indoor pollution from dust mites, smoke from cigarettes and open wood (Honicky et al. 1985) and coal burning fires, animal hair, insects, mould growth and fungi (Harrison 2000). Using unprocessed biomass fuels for cooking and heating in poorly ventilated structures, for example animal dung, is also a hazard for rural areas of the developing world (Albalak 1997, Ozbay et al. 2001, Ezzati and Kammen, 2001, Behera et al. 2001, Riojas-Rodriguez et al. 2001). In the Highlands of New Guinea pulmonary disease was the most important cause of morbidity and mortality (Master 1974), and in Nepal the use of straw and wood as fuels for cooking and heating in houses with no chimneys, in an environment free of industrial pollution, led to chronic bronchitis in 516 people (of 2826 or 18.3%), with 17.6% of males and 18.9% of females affected (Rajpandey 1984). In addition, maxillary sinusitis, while a feature of indoor and outdoor pollution, is also associated with the complications of dental disease such as a dental abscess spreading into the sinus (Lundberg 1980). Congenital abnormalities and infectious diseases including tuberculosis and leprosy (Rachelefsky et al. 1984, Wald et al. 1981, Wright 1979) have also been implicated in chronic maxillary sinusitis. Clement et al. (1989) diagnosed nasal and sinus infections in 64% of children under the age of nine and Horiuchi et al. (1981) found the condition to be more prevalent in children living in areas with high levels of air pollution. Clearly, in developing countries, poorly ventilated polluted houses contribute much to the burden of respiratory disease purely from burning basic fuels, but also from more specific factors such as the keeping of animals. Data on pollution related to health derived from these populations may be considered analogous to past populations, although they are distanced in space and time.

Data from British prehistoric and historic periods suggest that fuels such as wood, animal dung, and coal in later periods would have been used for cooking and heating. From the Neolithic period onwards domesticated animals were also utilised for their meat and milk, but also for traction and other purposes; it is also suggested that people lived in close contact with their animals and, certainly for the Later Medieval period, in the same structures. Archaeological data for the prehistoric period suggests that people in the Neolithic, Bronze and Iron Ages lived in rectangular, round, or oval "huts" constructed of posts, with wattle and daub or plank walling, completed with a thatched roof. These structures, depending on the period being considered, may have been multiple and enclosed by a ditch or palisade (Whittle 1999, Parker Pearson 1993, Haselgrove 1999). A central hearth for warmth and cooking purposes may have created some problems for ventilation, but experimental archaeology indicates that the interiors of these structures only accumulated smoke in the roof space and then the smoke dissipated through the thatch. Poorly insulated and draughty structures in this period may have been beneficial for health in some respects. Thus, indoor pollution may not have been a problem for these prehistoric populations to contend with, and the data on respiratory disease bears this out. Although tuberculosis as a respiratory infection is not present in prehistoric Britain, domesticated animals are evident from the Neolithic period onwards (providing the opportunity for a gastrointestinal form of this infection with consumed meat and milk). However, high population density is not apparent which would have limited the opportunity for the droplet infection mode of transmission from human to human to operate.

During the Roman period similar housing to previous periods served the poor, while villas in rural areas and "town houses" were built by and for the rich (Ellis 2000). A hearth was a feature of all housing, but in stone walled town houses (and the country's villas) tiled and slated roofs, along with the stone walls, may have trapped smoke and caused respiratory problems. Indeed, the evidence for respiratory disease does become more frequent. In addition, industries such as metalworking, tanning, textile manufacture, quarrying and mining would have created local and general environmental pollution and respiratory irritation. Although these industries were apparent in the Bronze and Iron Ages, their intensification was not seen until later. Tuberculosis also appears for the first time in Britain but not in large numbers and we do not know whether it was a human or non-human transmission.

During the early Medieval period, housing becomes more basic and comprises posts in a sunken sub-rectangular pattern (*grubenhauser*), with wattle and daub walls and a gabled thatched roof (Arnold 1997); a central hearth is still present. Larger halls also dominated settlements and often provided shelter for both humans and their animals. While maxillary sinusitis increases (crude prevalence rate) from the Roman period onwards and into the early Medieval period, so does tuberculosis. Again, it is not possible to comment on the origin of the tuberculosis. As early Medieval society was predominantly rural, and of low population density, it is likely a gastrointestinal route of infection and not a respiratory mode.

In the Later Medieval period timber framed buildings with wattle and daub walls, without effective chimney stacks, housed animals and humans, often in high densities (Dyer 1989). The burning of sea coal and wood for warmth and cooking purposes created pollution both indoors and out. Brimblecombe (1975:388) notes that in 13th century Britain air pollution problems 'were serious enough to warrant local body government investigations as early as 1285'. The intensification of industries such as metalworking, and lime ('cement') burning for building purposes, in this period created further problems of pollution, with pottery and tile manufacture, glassworking, brewing and tanning also contributing to the repertoire of urban work for the population. The pollutants from these industries and the fuel used may have led to the apparent rise in evidence for respiratory infection on the basis of crude prevalence rates; the frequency rates, however, may have fluctuated through the year-cycle. Perceptions of air quality as a result of the use of coal as a fuel in the 13th century were also apparent, especially from the higher social classes and visitors to towns and cities from rural areas (Brimblecombe 1976:942). People were particularly concerned about their health.

Later in the Post-Medieval period, timber framed buildings are replaced by stone walled housing, and wattle and daub walls by brickwork (George 1965). Chimneys and staircases were also installed which, certainly for the rich, helped ventilation indoors. However, for the poor, single unventilated rooms were more the norm. Again, intensification of industry as a result of steam power, and coal fires contributed, for some, to a potentially damaging environment for the population. The complete switch to coal as the major fuel was devastating (Brimblecombe 1978). Crude prevalence rates for both maxillary sinusitis and tuberculosis increase during the Later Medieval periods, and in the Post-Medieval period maxillary sinusitis also increases. However, focussing on the evidence from post-Medieval Christchurch, Spitalfields indicates that maxillary sinusitis rates were considerably lower than in previous periods. This is surprising, but perhaps the high status and lifestyle of these individuals, gleaned from historical data, protected them from, what we believe to have been at the time in London, a polluting outdoor environment (Brimblecombe 1977). However, studies of rural and urban frequencies in respiratory disease in some countries do not necessarily indicate a higher disease load in urban communities (e.g. see Venners et al. 2001). Additionally, although high pollen levels may be expected in rural areas to produce respiratory problems, some studies suggest that urban groups of people may suffer more from pollen-induced respiratory allergies than their rural contemporaries, for example (D'Amato et al. 2001); this suggests that in both environments there may be equally harmful factors with respect to respiratory problems. Tuberculosis also increases throughout the Later and Post-Medieval periods but the reason for this is probably because of increased population density, urbanism and industrialisation, and a respiratory route of infection.

There are few population studies of maxillary sinusitis with which to compare data, apart from that by Merrett and Pfeiffer (2000) where 50% of 207 individuals from a 15th century Southern Ontario Iroquian ossuary (Uxbridge, Canada) had sinusitis (rib lesions and tuberculosis were not considered here). They attributed the frequency to poor indoor air quality and high airborne pathogen levels in the living environment of the population. The frequency rates are similar to all the sites in Table 2 apart from the urban site of St Helen-on-the-Walls (72%), and the Post-Medieval site of Spitalfields, London (18%). Wells (1977) also studied sinusitis in different period British populations and found more evidence in the early medieval period, and suggested that indoor pollution was the cause; his data however were not directly comparable to that cited here. Despite finding a higher prevalence of maxillary sinusitis in the adults from St. Helen-on-the-Walls (urban), compared to those at Wharram Percy and Raunds Furnells (rural) during the early and late medieval periods, no significant differences were evident in the non-adults (Lewis 1999). However, once evidence for dental disease was accounted for, Wharram Percy had the highest rate of sinusitis resulting from other factors. Evidence for pulmonary infections (on the visceral surface of the ribs) were also higher at Wharram Percy and Raunds Furnells compared to the Later Medieval sites of St. Helen-on-the-Walls and Post-Medieval Spitalfields. This result reflects the evidence of Williams and Galley (1995) who found respiratory diseases to be twice as common in rural than urban areas, even during the industrial period. Allergic reactions brought about by close contact with animals and exposure to irritants in the soil may be responsible. The increased prevalence of dental disease in the adults and children from Post-Medieval Spitalfields may be disguising maxillary sinusitis caused by other respiratory factors.

Clearly more studies of both maxillary sinuses and ribs in skeletal populations generally are needed to appreciate the effects of indoor and outdoor pollution in the past. However, the multifactorial nature of the aetiology of rib and sinus lesions should always be considered. While sinusitis represents irritation of the sinus mucous membrane lining as a response to particulate environmental pollution (unless caused by dental disease), rib lesions may be the result of lung disease not related to "pollution" *per se*, e.g. chronic bronchitis.

Although an increase in health problems associated with the respiratory system through time in Britain has been identified through this study, problems with the data presented focus on a number of areas. The recording of maxillary sinusitis and rib periostitis has not been an area of study until more recent years as researchers have realised their potential for highlighting the impact of "pollution" on respiratory health in the past. This may explain the lack of evidence from the prehistoric period. In addition, maxillary sinuses are not always well preserved enough for examination, and they may also be inaccessible for examination if preserved intact. Much of the data presented, apart from those for specific sites, is also based on the total numbers of individuals available for study and not the total number of sinuses, ribs or spines (tuberculosis) present for observation. This is a problem generally in published data for disease in archaeologically derived populations from Britain, in that most frequency data is generated as a percentage of the total individuals available for study and not on the basis of the total numbers of bone or tooth elements examined. Thus, frequencies for respiratory infections in the skeletal material considered may be a gross underestimate of the real frequencies for the periods considered. However, as Wood et al. (1992) have suggested that there are a number of factors that can compromise our understanding of health and disease in the past. These include: a lack of knowledge of how representative the study sample of skeletons is of the living population, that people die before bone changes occur, the fact that only a few percentage of people with disease will develop bone changes (and many will contract disease that only affects the soft tissue), and that there is a lack of knowledge of individual frailty and its impact on disease.

Conclusions

Most people today have suffered the effects of environmental "pollution" on their health, but there is much more of an awareness of the detrimental damage particles in the environment can do to the air that we breathe into our respiratory system. For prehistory it is only possible to guess whether populations were concerned about environmental pollution. However, by the Late Medieval period in Britain concern over the effects of pollutants in the air are expressed via historical documents. Our evidence for what we interpret to be respiratory disease is also more apparent in later periods. Whether people were differentially affected according to status (and their perception of polluted environments affecting health) cannot, for the present, be discussed. One exception can be seen in the results of maxillary sinusitis rates for the high status site of Spitalfields; here, frequencies were lower than for other (earlier dated) sites and may reflect protection of the rich from a polluted environment. This study has shown that the evidence for respiratory infection increases through time in Britain and appears to be related to the development of complex societies. However, much of the data being considered is limited in its interpretation. There is a need to undertake more studies of this nature at a population level in different geographic regions of the world and time periods in order to gain a better understanding of our ancestors' exposure to indoor and outdoor pollution.

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