Detecting social change: an examination of the role of the Industrial Revolution on osteoporosis in London, United Kingdom

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DETECTING SOCIAL CHANGE

AN EXAMINATION OF THE ROLE OF THE INDUSTRIAL REVOLUTION ON OSTEOPOROSIS IN LONDON, UNITED KINGDOM

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Abstract

The period of the Industrial Revolution brought major changes in nutrition, lifestyle, and living conditions in London. These changes are conducive to the development of osteoporosis in the population. Osteoporosis is a metabolic bone disease, which is characterised by increased bone porosity, and may result in more fragile bones and fractures. The World Health Organisation has identified osteoporosis as one of the most prevalent diseases in the modern world, however archaeological sources remain mainly silent on the subject.

Data from London provided by the Museum of Archaeology London (MOLA) is compared to observe whether there is a change in prevalence of osteoporosis between the Medieval and post-Medieval period. This research shows that if advanced techniques, such as radiography, are incorporated within the osteological analysis more osteoporosis cases are found within the archaeological record. Structural incorporation of modern techniques will provide new insights in past populations.

Keywords

Paleopathology, Metabolic bone disease, Medieval period, Post-Medieval period, Osteoarchaeology

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Introduction

According to the World Health Organisation, osteoporosis is one of the most prevalent chronic diseases in the modern Western World (Kanis 2007, 6). For instance, in the United Kingdom (UK) 53.2% of women and 20.7% of men aged 50 years and over will have an osteoporotic fracture in their remaining lifetime (van Staa et al. 2001, 519-520). Since it is such a prevalent disease today, it is remarkable that documentary sources on archaeological human remains remain generally silent about osteoporosis in the past (Mays 2010, 206).

Osteoporosis is a skeletal disorder characterised by increased porosity of bone. In elderly females, it is especially associated with the menopause and the drop in oestrogen levels. This results in an increase in bone remodelling and bone resorption (Brickley and Ives 2008, 153). The balance between bone resorption and formation is thus disturbed and results in a reduced bone density (fig. 1). Affected bones are more fragile and prone to fracture (White et al. 2011, 447). There are different types of osteoporosis and it can be caused by multiple factors. Although the development of osteoporosis is known to be age and sex related, other influential factors include; genetics, ethnicity, physical activity, calcium intake, vitamin D deficiency, smoking, alcohol and caffeine intake (Agarwal 2008, 391; Karlsson et al. 2006, 620-624). The known relationship between these

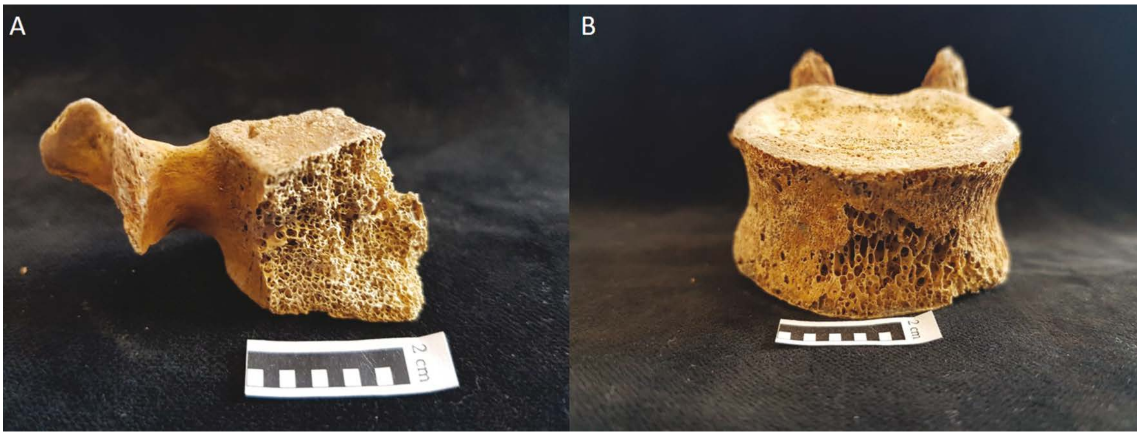

Figure 1. On the left (1a) is a section of a normal vertebrae visible and on the right (1b) a vertebrae affected by osteoporosis. The difference can be seen in both the external (cortical) and internal (trabecular) bone. The cortical bone in the right vertebrae is thinner and void spaces emerge in the matrix of the trabecular bone. Due to the thinner outer layer and larger gaps in the internal structure is the bone less dense and therefore more prone to fractures (photographs by S.A. Inskip, 2017).

factors and osteoporosis make it relevant to study this disease in past populations since its prevalence can reflect socioeconomic and environmental conditions in the past (Brickley et al. 2006, 136).

During the Industrial Revolution in Britain there was a change in nutrition, lifestyle and living conditions. London's population more than doubled in size during the eighteenth and nineteenth century, which had a dramatic influence on living conditions, especially for the poorer population (Schwarz 1992, 126). The urban expansion of narrow streets and industrial growth resulted in smog formation and blocked sunlight (Bucholz and Ward 2012, 333; Henderson et al. 2013, 256). Sunlight provides vitamin D, which is an important substance in the protection against osteoporosis. However, less sunlight would have affected the whole population of London.

These recorded changes in nutrition, lifestyle and living conditions during the Industrial Revolution are largely conducive to the presence of osteoporosis in a population. This leads to the expectation that a greater prevalence of osteoporosis would be expected in the post-Medieval period than in the preceding period. However, earlier research by Roberts and Cox (2003), using a crude prevalence rate (CPR) demonstrated a decrease in prevalence between the Medieval and post-Medieval period in Great Britain (2.62% Medieval and 1.20% post-Medieval period). Although, CPR is a sufficient method to examine a change, the authors admit that the percentage value for their post-Medieval sample is only based on two cemeteries in London. Roberts and Cox (2003) recognise their limitations and therefore the rate based on the two sites could be a bias. This raises the question whether or not the crude prevalence rates presented for the Medieval and post-Medieval period are representative for the whole period and the whole of Britain. This is especially important since recent archaeological studies on osteoporosis in the UK compare their rates with the presented results from the study by Roberts and Cox (e.g. Miles et al. 2008, 155).

This study therefore aims to assess this trend by researching multiple sites from London. It will examine whether there is an increase or decrease in prevalence of osteoporosis during the time of industrialisation by comparing osteoporosis rates between analysed individuals from Medieval cemeteries and post-Medieval cemeteries in London.

Materials and methods

The data used in this research is derived from information provided by the Museum of London Archaeology (MOLA). The osteological material has been analysed by the Centre of Human Bioarchaeology (CHB) and has been published by MOLA in monographs or in the Wellcome Osteological Research Database (WORD). Using data generated by MOLA and CHB has the advantage that it all follows the same methods and analysis strategy. Biased comparisons between data derived from different institutions are thereby excluded.

Site	Date	Type of Cemetery	Status	Total*	Adults	F	F (OP)	M	M (OP)	I and U	I and U (OP)	Reference
Dominican Friary Carter Lane (PIC87)	13th c. - 1538 AD	Monastic	N/A	57	48	12	1	16	–	20	–	WORD database, 2015a
East Smithfield Black Death Cemetery (MIN86)	1348 - 1350 AD	Epidemic	N/A	636	420	104	1	189	–	127	–	WORD database, 2015a
Guildhall Yard (GYE92)	1050 - 1150 AD	Parish	N/A	68	47	15	–	18	–	14	1	WORD database, 2015a
Merton Priory (MPY86)	1117 - 1538 AD	Monastic	N/A	676	643	53	–	485	–	105	–	WORD database, 2015a
Saint Saviour Monastery Cemetery, Bermondsey Abbey (BA84)	1089 - 1538 AD	Monastic	N/A	201	200	–	–	147	–	53	–	WORD database, 2015a
Spital Square (NRT85)	circa 1200 - 1500 AD	Hospital	N/A	54	35	8	1	20	–	7	–	WORD database, 2015a
St Benet Sherehog (ONE94)	1280 - 1666 AD	Parish	N/A	39	24	4	–	8	–	12	–	WORD database, 2015a
St Mary Graces (MIN86)	1350 - 1540 AD	Monastic	N/A	389	283	68	–	136	1	79	–	WORD database, 2015a
St Mary Spital (SRP98)	circa 1120 - 1539 AD	Hospital	N/A	5387	4360	1883	2	2237	2	240	–	Connell et al. 2012
Total Individuals				7507	6060	2147		3256		657		
Total with Osteoporosis					9		5		3		1	

*Table 1a. Synopsis of the Medieval cemeteries (Connell et al. 2012; WORD database, 2015a). Abbreviations: F=female, M=male, I=intermediate, U=unknown, and OP=osteoporosis. *Total is this respect means total individuals analysed.*

The data for nine Medieval cemeteries was collected for this research. The cemeteries date between 1050 and 1538 AD, with one exception: the Medieval burials from St Benet Sherehog (ONE94) which date to 1666 AD (tab. 1a). Data was also collected for a total of sixteen post-Medieval cemeteries, which date between circa 1540 and 1853 AD (tab. 1b). The distribution of the sites in Greater London can be found in figure 2a and 2b.

The prevalence of osteoporosis at the cemeteries calculated as the CPR will be compared with the results of Roberts and Cox (2003). The ratio visualises the percentage of affected individuals with osteoporosis in relation to the entire excavated population. This approach has its limitations since the outcome of the CPR is applied to the overall population over a certain period of time, which also includes non-analysed adults and subadults. Type 3 of primary osteoporosis, which only occurs to subadults, is rare and secondary osteoporosis accounts for less than 5% of all modern clinical osteoporosis cases (Schultz 2003, 175, 177). Therefore, the statistical analysis will be based on adults only. Research also demonstrates that osteoporosis is related to sex and age and therefore

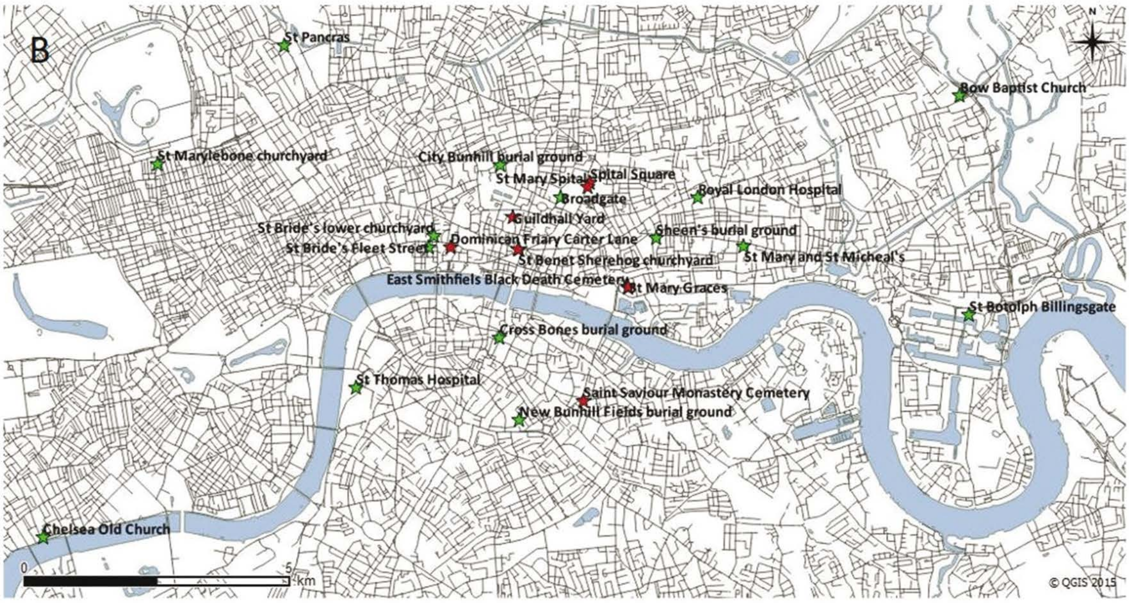

Figure 2a. Distribution of the Medieval and post-Medieval cemeteries with their corresponding site codes in Greater London. Red stars represent the Medieval cemeteries and the green stars the post-Medieval cemeteries (WORD database, 2015a and b). The outlined area has been enlarged in figure 2b.

Figure 2b. Enlargement of the outlined area of figure 2a. Distribution of the burial grounds in central London (WORD database, 2015a and b).

the prevalence data will be analysed separately per category to examine whether these factors influence the data. The CPR calculation will be followed by a statistical analysis of the collected data.

The large sample size of this study allowed the data to be statistically analysed with the Chi-squared (χ^2) method with Yates' correction. The latter provides a conservative statistical outcome for large data. This method is suitable to determine the correlation

Site	Date	Type of Cemetery	Status	Total*	Adults	F	F (OP)	M	M (OP)	I and U	I and U (OP)	Reference
Bow Baptist Church (PAY05)	Circa 1816 - 1853 AD	Urban - Baptist		416	214	115	3	86	–	13	–	Henderson et al. 2013
Broad gate (LSS85)	1569 - 1714 AD	Urban - Municipal	Low	150	76	33	–	20	–	23	–	WORD database, 2015b
Chelsea Old Church (OCU00)	1695 - 1842 AD	Urban	High	198	165	74	8	78	1	13	2	Cowie et al. 2008; WORD database, 2015b
City Bunhill Burial Ground (GDA06)	1833 - 1853 AD	Urban - Dissenters	Low	239	117	58	2	55	–	4	–	Connell and Miles 2010
Cross Bones Burial Ground (REW92)	1729 - 1853 AD	Urban	Low	147	44	27	1	12	–	5	–	WORD database, 2015b
New Bunhill Fields Burial Ground (DVL05)	1821 - 1853 AD	Urban - Private	Low	514	157	72	–	85	–	–	–	Miles and Connell 2012
Royal London Hospital (RLP05)	1825 - 1841 AD	Hospital	N/A	640	607	57	1	152	1	398	–	Bekvalac, pers. comm. 2015
Sheen's Burial Ground (CXL06)	1763 - 1853 AD	Urban - Private	Low	254	166	78	–	51	–	37	–	Henderson et al. 2013
St Benet Sherehog (ONE94)	circa 1670 - 1853 AD	Urban - Parish	Mixed	231	167	46	5	81	2	40	–	WORD database, 2015b
St Botolph Billingsgate (BIG82)	1540 - 1666 AD	Urban - Parish	Unknown	23	18	4	–	13	–	1	–	WORD database, 2015b
St Bride's Church Fleet Street (SB79)	1676 - 1853 AD	Urban - Parish	High	227	213	103	8	109	1	1	–	Bekvalac, pers. comm. 2015
St Brides Lower Cemetery (FAO90)	1750 - 1849 AD	Urban - Parish	Low	544	369	125	19	194	9	50	3	WORD database, 2015b
St Mary and St Michael's Burial Ground (LUK04)	1843 - 1854 AD	Urban - Catholic	Low	705	268	105	2	143	–	20	–	Henderson et al. 2013
St Marylebone (MAL92/MBH04)	circa 1740 - 1840	Urban - Parish	High	301	223	86	2	105	–	32	–	Miles et al. 2008
St Pancras (YKW01)	Late 18th c. - 1853 AD	Urban - Parish	High	715	532	224	6	231	–	77	–	Emery and Woolridge 2011
St Thomas' Hospital (NLB91)	1540 - 1714 AD	Hospital	Low	193	160	33	–	58	–	69	–	WORD database, 2015b
Total Individuals				5497	3496	1240		1473		783		
Total with Osteoporosis					76		57		14		5	

*Table 1b. Synopsis of the post-Medieval cemeteries (Bekvalac, pers. comm. 2015; Connell and Miles 2010; Cowie et al. 2008; Emery and Wooldridge 2011; Henderson et al. 2013; Miles and Connell 2012; Miles et al. 2008a; WORD database, 2015b). Abbreviations: F=female, M=male, I=intermediate, U=unknown, and OP=osteoporosis. *Total is this respect means total individuals analysed.*

between two variables within categorical data. It demonstrates an association between variables and whether the outcome is statistically significant (Fletcher and Lock 2005, 125). When the outcome of the Chi-squared method is close to zero then there is no evidence of association (Fletcher and Lock 2005, 131). There is a significant relation between evidence when the result is equal to or larger than $\chi^2 = 3.84$ (Fletcher and Lock 2005, 202). Results were determined to be statistically significant when the P-value was equal or below the 0.05 level.

Results

In total, the data from 9556 individuals analysed by MOLA were available for this research. From the nine Medieval cemeteries included in the WORD database and monographs, 6060 adults were analysed of which nine individuals showed skeletal changes conforming osteoporosis. Of the sixteen post-Medieval cemeteries evaluated, which contained 3496 adults, 76 individuals show skeletal changes diagnosed as (possible) osteoporosis. The distribution per site of males and females of different ages affected with osteoporosis can be found in the previous mentioned overview tables: 1a and 1b.

The CPR calculated for the Medieval period is 0.07%. Three of the sites contained zero individuals with osteoporosis and five cemeteries had one individual in their excavated population with osteoporosis. The calculated CPR for the post-Medieval period is higher with 1.08%. Five cemeteries contained no individuals with osteoporosis. However, four post-Medieval cemeteries exceed this average post-Medieval CPR with large numbers. These cemeteries are: St Benet Sherehog (post-Medieval graves) with 2.55%, Chelsea Old Church with 3.79%, St Bride's Church Fleet Street with 3.96% and St Brides Lower Cemetery with 5.16%. Overall, the result of the Chi-squared test demonstrated a strong statistically significant difference in the prevalence of osteoporosis between the samples from the two periods (P-value = < 0.0001, χ^2 = 100.879, 1df). These results demonstrate that here is more osteoporosis in the post-Medieval period.

Since osteoporosis can be linked to sex, it is useful to look at statistical differences between males and females with osteoporosis in the Medieval and post-Medieval period. However, the number of affected adults in the Medieval period is too small to make any meaningful comparisons. The result for the post-Medieval period (tab. 2a) shows an extremely significant result for the relationship between sex and osteoporosis (P-value = < 0.0001, χ^2 = 33.707, 1df). This indicates that females are more affected with osteoporosis than males in this period.

	OP	No OP	Total
post-Medieval Males	14	1459	1473
post-Medieval Females	57	1183	1240
Total	71	2642	2713

Table 2a. Contingency table for analysed males and females from the post-Medieval period.

	OP	No OP	Total
Medieval Males	3	3253	3256
post-Medieval Males	14	1459	1473
Total	17	4712	4729

Table 2b. Contingency table for analysed males with osteoporosis between periods.

	OP	No OP	Total
Medieval Females	5	2142	2147
post-Medieval Females	57	1183	1240
Total	62	3325	3387

Table 2c. Contingency table for analysed females with osteoporosis between periods.

To assess if one or both sexes were more or less affected, prevalence rates were calculated for each sex. To assess whether osteoporosis prevalence rates differed between Medieval and post-Medieval males, their prevalence rates were compared (tab. 2b). The difference is again highly significant (P-value = < 0.0001, χ^2 = 18.531, 1df). The relationship for females with osteoporosis (tab. 2c) between the Medieval and post-Medieval period is extremely significant (P-value = < 0.0001, χ^2 = 80.887, 1df). This suggests that both sexes are more affected with osteoporosis in the post-Medieval period.

	OP	No OP	Total
post-Medieval 36-45 Years	6	650	656
post-Medieval ≥46 Years	59	683	742
Total	65	1333	1398

Table 2d. Contingency table for individuals with osteoporosis in two different age categories for the post-Medieval period.

Discussion

It is known that osteoporosis correlates with an increasing age. Therefore, the two affected age categories, 36-45 years and the ≥46 years and older, have been studied for both periods. Unfortunately, the data does not provide enough results for the Medieval period to calculate the expected frequency for the Chi-squared method. The relationship between these two categories for the post-Medieval period (tab. 2d) shows a significant correlation (P-value = < 0.0001, $\chi^2 = 37.318$, 1df). Effectively, this means that with the increase of age there is an increasing chance to develop osteoporosis as well.

At the end of the Medieval period, significant advances in science and technology resulted in the Industrial Revolution. The changes brought about by this had a dramatic effect on environment, lifestyle, and diet. As many of these changes would favour the development of osteoporosis, this study aimed to see whether there was a general increase in the prevalence of osteoporosis from the Medieval to the post-Medieval period. The results demonstrate that the crude prevalence rate of individuals affected by osteoporosis increases from 0.07% for the Medieval period to 1.08% for the post-Medieval period, a statistically significant outcome. Analysis of sex specific changes show that the increase of affected females with osteoporosis was a significant factor in the rise of the overall percentage.

It is known from clinical research that elderly females are systematically more affected by osteoporosis than males and younger individuals. This expectation is confirmed in this research with the statistical results for females and older adults that suffer from osteoporosis. In addition, the expected factors that could have influenced the prevalence of osteoporosis during the Industrial Revolution are reflected in again significant results for the post-Medieval period with the increase of individuals with the disease in general. However, the problem with the older adult category is that this is a very large category wherein no distinction can be made between individuals in their forties or nineties. It might be possible that more individuals reached this age during the post-Medieval period or became older in general, which could have led to an increase in osteoporosis during this period.

It is questionable whether the osteoporosis CPR composed by Roberts and Cox (2003) for the post-Medieval period in Great Britain is representative for other cemeteries. This current study presents more results from multiple sites in London and shows the opposite trend. Nevertheless, care should still be taken when comparing these results to cemetaries from elsewhere in Britain, since the industrialisation was far more extensive in London than it was in smaller cities or rural areas.

While this paper tries to limit the impact of inter-observer error by using data collected by the same institution, it is of course possible that some differences may still be a product of different data collectors or by when they were researched. The Medieval cemeteries discussed in this research were excavated between 1984 and 1998, while more than half of the post-Medieval ones were excavated in the 21st century (Van Heekeren 2015, 60). The WHO determined the definition of osteoporosis in 1994. It is likely that the increase in osteoporosis cases in archaeology was influenced by the introduction of this definition and the development of methods to detect osteoporosis in archaeological human remains (Waldron 2009, 120). An example of improved detection of osteoporosis in archaeological human remains are the results from the St Brides Lower Cemetery. This site was used for composing the CPR found in Roberts and Cox (2003) and eight individuals were affected with osteoporosis in the original study from Molleson and Cox in 1993 (Roberts and Cox 2003, 355). The population of this cemetery has been re-examined by Brickley (1997) using modern techniques and this resulted in 31 individuals with skeletal changes conforming to osteoporosis (WORD database, 2015b). The advances of science and the use of medical technology, which is recently also more frequently used in osteoarchaeology, allow for better detection of osteoporosis and will most likely result in an increased detection of affected individuals in the future.

Despite the availability of improved detection techniques, osteoarchaeologists still struggle with the definition of osteoporosis and how to determine when an individual was affected by this disease or not. This is also visible within the MOLA database where osteoporosis sometimes was recorded as a pathology, although based on different characteristics. The diagnosis could be based on the bones feeling lightweight and the age and sex of the individual, while on other occasions an individual should at least have one osteoporotic fracture (WORD database, 2015). Waldron (2009) argues that the true prevalence of osteoporosis will be underestimated in past populations when researchers only count the individuals with an osteoporotic fracture. However, counting osteoporotic fractures is the only way to make the results repeatable and comparable for future research (Waldron 2009, 121). It is a sincere problem that there are no standards at the moment for investigating osteoporosis in past populations. This research shows that there is certainly potential for future research to study osteoporosis in past populations, nevertheless a clear defined definition and systematic method for diagnosis should be developed.

Conclusion

The aim of this paper was to reveal whether there is a change in prevalence of osteoporosis from the Medieval to the post-Medieval period in London. Earlier research pointed to a decrease, while the change in nutrition, lifestyle and living conditions would suggest an increase in osteoporosis. With the presented results in this paper, it becomes clear that during the industrialisation period in London there is an increase in prevalence of individuals affected by osteoporosis. This increase is shown by both the crude prevalence rate and the statistical analysis using the Chi-squared method. Although there is a trend visible in this data, it is unclear whether this is a specific result of the Industrial Revolution or the increase in advanced research methods. Future research should incorporate advanced methods in osteological analysis to examine more closely the influence of the Industrial Revolution on health, disease, and the development of osteoporosis.

It is a limitation that there are currently no standards for investigating osteoporosis in past populations. This is especially problematic when researchers would like to make their results repeatable and use them to measure trends. It is recommended for future research to produce a standard for the examination of osteoporosis in archaeological human remains. Even though research could be improved, the findings from this study contribute to the current literature. This is the first study that demonstrates an increase in osteoporosis during the Industrial Revolution in London based on a larger dataset than mentioned in previous studies. It therefore provides new crude prevalence rates for osteoporosis and statistical results for sex and age categories in the Medieval and post-Medieval period in London. When the recommendations for further research will be incorporated in the future it will provide new insights on osteoporosis and therefore on lifestyle and living conditions in the past.

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