By contrast with their colleagues whose data are—or were—obtained from living populations, palaeoepidemiologists must resort to those which are derived from the study of human remains, most usually skeletal remains. Palaeoepidemiologists encounter a number of problems in their work which do not beset conventional epidemiologists. The most obvious is that they are working with dead and not living populations, but they are also able only to carry out cross-sectional studies which almost always have a very long time base, one which is measured in decades and often in centuries. These and other problems associated with palaeoepidemiology are of considerable theoretical interest and are now being studied in some detail.1

One of the questions of great interest to palaeoepidemiologists is the degree to which the frequency of different diseases has changed over time. This issue can be studied without reference to modern data, but if comparisons between the prevalence of disease in past and contemporary populations are to be made, it is necessary to know the extent to which the data derived from a skeletal population accurately reflect those of the living population of which this was once a part, since if they do not, then comparisons with modern prevalence rates are invalid. On a priori grounds it does not seem likely that there would be much correspondence between data derived from two such apparently disparate groups. Mass deaths which result from sudden catastrophes, on the other hand, would seem in principle at least, to offer a much better prospect of providing data about disease and demography which are more akin to those obtained from a living population. On the assumption that the catastrophe struck indiscriminately, and affected a large enough sector of the population one might have, in effect, a reasonable—and possibly representative—cross-section of the population which was affected. In the past such catastrophes might include deaths from earthquakes or volcanic eruptions, or endemics such as the plague. There is no large population of victims of earthquakes or volcanoes in the UK, but a number of plague pits dating from the time of the Black Death are known to exist and the human remains recovered from one such pit in London are the subject of the present study.

The hypothesis under test was that the demography and the pattern of disease in the human remains for the plague pit would differ from those in the remains from a control 'conventional' cemetery dating to a similar period and would be more likely to resemble those to be found in a living population.
If the hypothesis were correct, then the study of the plague pit victims would be likely to provide more accurate information about the population of medieval London than the study of human remains from its other medieval cemeteries.

Materials and Methods

The plague victims were recovered from a Black Death (BD) cemetery on the site of the old Royal Mint to the north-east of the Tower of London. The cemetery was established in 1349 and was called the churchyard of the Holy Trinity. It consisted of mass burial trenches and 14 grave rows in two distinct areas from which 600 individual skeletons had been excavated and were available for study.

In 1350, the Abbey of St Mary Graces was founded on the site by Edward III and lasted until the dissolution in 1538. The church and chapels of the Abbey contained burials of monks and important lay people but, in addition, there was a large graveyard overlying the Black Death cemetery from which 236 individual skeletons were available for study. These skeletons formed the ‘conventional’ control group (CG).

Each skeleton was assessed using standard anthropological methods in order to assign an age and sex to each. It was not possible to do this blind to the status of the skeletons (BD or control) since each was stored in a box with a discrete context number which identified the site from which they came. Each skeleton was also examined for signs of pathology and any found were attributed to most probable cause.

An estimate of the age structure of the living population of medieval London was made using the data given by Oeppen for the life expectancy of the monks of Westminster Abbey and selecting a just below replacement age structure from level 4 of the Regional Life Tables.

Results

Demography

The age and sex distributions of both groups of skeletons are shown in Tables 1 and 2. From the Tables it can be seen that substantial numbers of adult skeletons could not be assigned an age and/or a sex because they were either too fragmentary or they lacked important diagnostic elements such as the pelvis or skull. It can also be seen that none of the sub-adults could be given a sex, as is almost always the case in skeletal studies.

The presence of so many skeletons of unknown age or sex seriously distorts the age/sex distributions and so it was decided to allocate the unknowns using the following assumptions:

- that the sex ratio of the sub-adults was the same as that of the adult skeletons in the assemblage; and
- that the adults of unknown age were evenly distributed among each of the age groups.

For the BD skeletons the male/female ratio was 1.25:1 and the infants (<5 years) and the juveniles (5–<15) were re-allocated by sex accordingly. The 48 males and 50 females of unknown age were re-allocated equally between the four adult age groups and the 27 adults of unknown sex were re-allocated between the sex and age groups by first applying the sex ‘correction factor’ and then adding equal numbers of the resultant males and females to each age group. The two skeletons which were of unknown age and unknown sex were eliminated from further analysis. A similar strategy was applied to the control skeletons although in this case the male/female ratio was 1.8:1 and this factor was used to make the adjustments.

Having made all the re-allocations, each age group (including infants and juveniles) was expressed as a percentage of the total for each sex and the proportional distributions were plotted; the resultant graphs are shown as Figures 1 and 2. In these Figures the estimate of the living age structure for medieval London is shown for comparison.

What is apparent from the figures is that the distribution of both sets of male skeletons (Figure 1) are broadly similar to each other although there is a significant deficit of BD males at age 15 compared with the controls ($P < 0.05$). Among females there is a significant excess of BD females (compared with the control group) at age 25 ($P < 0.05$) and a significant deficit at age 45 ($P < 0.01$).

The shape of the distribution curve of the males and females in the control group is reasonably consistent, but the distribution of the BD males and females differs from each other in that, whereas in the males, the proportions in the three oldest age groups are approximately equal, the female distribution peaks in the 25-year age group and declines thereafter.

In both males and females, the skeletal assemblages appear to overestimate the numbers in the younger age groups of the model population and considerably underestimate the numbers in the oldest age groups.

### Table 1 Sex and age distribution of Black Death burials from Royal Mint site

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Male</th>
<th>Female</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juvenile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–</td>
<td>21</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>25–</td>
<td>48</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>35–</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>45+</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td>50</td>
<td>48</td>
<td>27</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>210</td>
<td>167</td>
<td>223</td>
</tr>
</tbody>
</table>

Overall total = 600.

### Table 2 Sex and age distribution of control group burials from Royal Mint site

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Male</th>
<th>Female</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juvenile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15–</td>
<td>11</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>25–</td>
<td>15</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>35–</td>
<td>23</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>45+</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult</td>
<td>34</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>61</td>
<td>65</td>
</tr>
</tbody>
</table>

Overall total = 236.
The pattern of pathology was similar among both skeletal groups. Each condition was categorized into one of five broad groups and, as may be seen in Table 3, the great majority of conditions were included under the rubrics of degenerative disease (mostly osteoarthritis) and dental disease (caries, apical abscesses or ante-mortem tooth loss). There was only one substantial difference between the two groups; degenerative disease accounted for 42% and dental disease for 28% of all pathology in the BD skeletons whereas in the control group the proportions were 32.6% and 43.5%, respectively. These differences were not significant, however.

When considering how the distribution of osteoarthritis differed between the two groups (Table 4), it can be seen that three anatomical sites accounted for the majority of those affected, the facet joints of the spine, the acromio-clavicular joints and the hands. Although there were some differences in the rank ordering of the sites affected, none was significant.

### Discussion

The hypothesis which this study set out to test, that is, that the characteristics of a group of human remains from a mass disaster would differ from those from a conventional cemetery, and that the age distribution would be more like that of a living population, has not been corroborated by the data presented here. The two sets of male data obtained from the human remains, those from the plague pits and the overlying medieval cemetery, resemble each other closely; the distribution of the BD females, on the other hand, is somewhat different from that of the controls. Both skeletal assemblages overestimate the number in the younger age groups of the model population and considerably underestimate the numbers in the oldest age group; the control assemblage seems slightly closer to the model population than the BD group, perhaps because it is closer to it in time.

There are several factors which need to be considered when examining these results, the first relating to the ageing and sexing of the skeletons.

### The effects of ageing and sexing

The ageing and sexing of skeletons is one of the critical constraints under which palaeoepidemiologists have to work. Many methods have been described for assigning sex and age to...
a skeleton but their effectiveness depends upon both the amount of the skeleton present and the state of maturity. It is relatively straightforward to sex post-pubertal skeletons in which the pelvis and/or the skull are present, although there does seem to be a tendency to assign a male sex to a skeleton. When the pelvis or skull are missing, reliance has to be placed on other means—such as measurements of the maximum diameter of the femoral or humeral heads, or the gross morphology of the skeleton with dwindling confidence in the results. The state of preservation of most human remains inevitably means that a substantial number of skeletons will not be assigned a sex. In this case this applies to 10.8% of the mature BD skeletons and 5.8% of the controls. It is virtually impossible to sex pre-pubertal skeletons although recently it has been assessed using genomic DNA extracted from bone, but this is not a method which can be used routinely.

It is much easier to age juvenile than mature skeletons, either from a consideration of the state of the formation and eruption of the teeth, or from the state of epiphyseal fusion. Once the epiphyses have closed, however, recourse must be made to indicators such as tooth wear, the morphology of the symphysis pubis or the rib ends, or the fusion of the cranial sutures. Most anthropologists would not feel confidence in assigning an exact chronological age to an adult skeleton, preferring instead to indicate a broad band within which they felt the age most probably lay.

Since all the ageing and sexing of the skeletons studied for this project was carried out by a single observer, it is not likely that there was any systematic difference in the way in which this was done for the BD and control groups. That there were more skeletons unsexed among the BD group than the controls is a reflection of the differential state of preservation, not of any differences in the ability of the investigator when examining the two sets of skeletons. It may be thought that an explanation for the apparent deficit of BD males in the 15–24 year age group (Figure 1) is that they were assigned to the wrong age group. This seems unlikely to be the case, however, since skeletons in this age range are relatively easy to age.

One problem which arises from the inability to sex sub-adults and a relatively large proportion of adults is that plots of the age-sex distribution are distorted and cannot be used either for inter-study comparison, or for comparisons with data derived from modern populations. In an effort to overcome this problem, the skeletons of unknown sex or age were re-allocated according to the rules described above. There seems to be no reason to suppose that the skeletons of any one sex or any particular age group are less likely to preserve well than another. The processes which affect decomposition and preservation are principally governed by local features of the soil in which the body is buried—acidity, humidity, temperature and state of aeration—and these will be independent of the age or sex of the individual buried.

Allocating sex to the infants and juveniles according to the sex ratio of the adults is more questionable and probably resulted in the number of males being somewhat over-estimated. In modern populations the death rate for boys is greater than for girls so using the adult ratio of the skeletal groups at least tends in the right direction. In 1996 in England and Wales, the infant mortality rate was 7/10^3 for boys and 5/10^3 for girls; the death rate for children aged between 1 and 14 was 20/10^5 for boys and 15/10^5 for girls. Fifty years ago, the comparable figures were 39 and 30/10^3 for the infant mortality rates and 113 and 94/10^5 for deaths between 1 and 14. Thus, although the rates have fallen considerably in the past half century, the ratio of deaths has stayed relatively constant. It is likely that the infant and neonatal mortality rates in the middle ages were considerably greater than 50 years ago, but there is no reason to suppose that the sex ratio was substantially different and certainly not large enough in itself to invalidate the redistribution of the sub-adults to a sex.

The epidemiology of the plague

If the victims of a mass disaster are to represent the living population of which they were once a part, it is necessary that its effects should be random; if they are not, then the age and sex distribution of the victims may be subject to bias.

There is some evidence that the plague tends predominantly to affect the young, with about 60% of cases occurring in those aged under 20 years of age. It is also often noted that the death rate in males is greater than in females and Ell suggests that iron deficiency in the young and in females may explain these observations since the causative organism, *Yersinia pestis*, requires exogenous iron to flourish. What historical evidence is available relating to outbreaks of the plague in Europe during the 17th and 18th centuries suggests that in many cases, females tended to be more susceptible than males. In Marseilles, which was struck by plague in 1722, the numbers of male and female skeletons excavated from a plague pit were equal and no age group seemed especially affected. In England the evidence is somewhat contradictory. There are no data relating to the Black Death but later episodes of plague—those which occurred during the 16th and 17th centuries—have been studied from parish records. At Penrith in Cumberland, the plague was present in 1597 and 1598 and 606 individuals died. While there seemed to be no concentration of deaths at any particular age, females were affected more often than males in a ratio of 1.37:1. At Barton-on-Humber, on the other hand, where there was an outbreak of plague in 1593, of the 272 individuals who died that year (compared with a mean of 50 in the preceding 10 years), 141 were females and 131 males (Waldron, unpublished data). At St Botolph’s without Billingsgate the plague of 1603 killed more males than females but the mortality of the under 5s was greater than at any other age. At Eyam and Colyton, both struck by plague during the 17th century, the mortality among the sexes was approximately equal.

There were more males than females in the BD group but interestingly, the male/female ratio was lower (1.33:1) than in the overlying control group (1.88:1). This is not evidence to support the notion that men were necessarily more prone than women to the plague, nor do the data suggest that the young were particularly susceptible, indeed there is a relative dearth of both sexes in the 15–25-year-old group, which might have been expected to be substantially affected, to judge from modern experience.

The historical evidence relating to the epidemiology of the plague in England is thus by no means clear cut and the data from the Black Death plague pit give no support for the view than males were more often affected than females or that the young were more likely to die from it. The fact that the BD data
are very little different from those of the overlying medieval cemetery suggest that neither sex and no age group was more likely than another to succumb to this particular outbreak of the plague.

**The effect of later episodes of the plague**

Following the Black Death, there were many other outbreaks of plague in England, indeed, the Black Death is generally seen as the start of the second pandemic of plague in Europe. It is almost certain, therefore, that the control cemetery contains some individuals who had died from the plague. Their numbers would be relatively small, however, as the mortality rate of later episodes was thought not to be greater than 5–15% of the population. Nevertheless, their presence would tend to make the characteristics of the overlying control skeletons more like those of the BD group.

**How representative are the plague pit burials?**

The number who died in the Black Death cannot be known with certainty, but it has been suggested that between 30% and 40% of the population of England perished. Nevertheless, their presence would not represent the population of the city as a whole. We do not know from which area of the city those who were buried at the Royal Mint site came, nor whether their base population was affected in a manner similar to that elsewhere in the city. Nevertheless, these considerations are not germane to the present study since whether they are representative or not does not affect the hypothesis under test, i.e. that this plague pit assemblage provides better evidence for the demography and pathology of medieval London than the overlying control group. It may be one further reason why the hypothesis cannot be confirmed, however, and why—on the evidence of this study—the skeletons from plague pits are no more reliable an indicator of the true condition of the population of which they once formed a part, than other skeletal assemblages.

**References**


