Chapter 4: Human Skeletal Remains

INTRODUCTION

A total of 107 skeletons were osteologically analysed. These comprised 104 skeletons excavated from Areas 1 and 2, one from the electrical substation trench and two from Trench 15. The high level of completeness and good overall bone preservation make this a particularly valuable assemblage. It is remarkable for the high prevalence of a wide range of pathologies, which clearly reflect the prevailing social depravation of their working class upbringing, the hardships and dangers aboard ship, and the advanced age of the group. The results of the osteological analysis for each skeleton are presented in the skeletal catalogue (Appendix 3).

Unlike many skeletal assemblages, the Greenwich assemblage dates to a known and restricted time period (AD 1749- 1856). It is unusually homogenous in terms of age and sex, and most individuals are of known occupation. Such specialist populations are extremely rare, and offer a unique opportunity to investigate aspects of osteological methodologies and pathology, whilst controlling for age and sex that otherwise may bias interpretation.

It must be stressed that this osteological report covers only the basic demography and pathology observed during fairly rapid analysis of the bones. The assemblage has considerable potential for further research, particularly in the areas of ancestry, activity-related changes, 18th-century naval surgery, and a range of palaeopathologies. A number of post-graduate dissertations addressing aspects of the osteology not covered by the standard client report have been undertaken already using the Greenwich material. A list of these studies is presented in Appendix 11.

Osteological methodology

The following methods were employed during osteological analysis.

Preservation and completeness

Bone preservation may vary considerably between burials as a result of differences within the immediate micro-environment surrounding each skeleton. These include a wide range of environmental factors such as the pH of the surrounding soil, the coffin material and substances and objects placed within the coffin. These factors may interact, creating a unique niche environment for each skeleton (Henderson 1987, 43). Principal factors that affected preservation within the present assemblage were the soil type, the wood of the coffins, the possible use of absorbent material such as sawdust and bran within the coffin - a common practice in this period - all of which may accelerate diagenesis. Pathological conditions such as osteoporosis may also influence bone survival.

Bone preservation was scored on a four point scale - destroyed, poor, good and excellent - on the following basis:

- *Destroyed* - bone severely leached and fragmented with most elements of the skeleton completely destroyed, trabecular bone not surviving, making it impossible to undertake most osteological examinations.
- *Poor* - cortical bone was soft, leached, flaking or eroded particularly relating to trabecular bone; it was not possible to identify most pathologies.
- *Good* - there was some damage to cortical bone, but large areas sufficiently well preserved to identify pathology and non-metric traits and to undertake metrical analysis; trabecular bone preservation was good with most epiphyses and joint surfaces intact, and good representation of ribs, vertebrae and pelvii.
- *Excellent* - cortical and trabecular bone was pristine, not having undergone the above taphonomic changes, making it possible to undertake full osteological analysis.

Completeness was also scored on a four point scale, based on the percentage of the total skeleton present. The four categories were 5–25%; 26–50%; 51–75%, and 76%-near complete. Completeness was affected by bone preservation and to some extent by the intercutting of graves (particularly in the southern part of Area 1) and truncation by later features. Where charnel within one grave could be clearly identified as originating from an earlier truncated grave, these elements were re-united with their skeleton. Where this was not possible, the charnel was analysed separately. This osteological analysis was kindly undertaken by Dr Peter Hacking, and forms part of the site archive but has not been included in this report.

Skeletal inventory

An inventory of each skeleton was created by shading in the skeletal elements that were present on a pictorial representation. In addition, the presence or absence of skeletal elements was recorded in tabular form and entered into an Access database. This recording formed the basis of the calculated true prevalence of pathological lesions described below.

Dental inventories were made following the Zsigmondy system (as cited in Hillson 1996, 8–9). Dental notations were recorded by using universally accepted recording standards and terminology (after Brothwell 1981).

Sex determination

Sexually dimorphic traits emerge after the onset of puberty, and hence, can only be ascribed with any degree of certainty to skeletons aged greater than 16–18 years. The pelvis is the most sexually dimorphic element, exhibiting features that directly relate to functional evolutionary differences between the sexes (Meindl, Lovejoy, Mensforth, *et al*. 1985; Mays 1998; Mays and Cox 2000), most significantly childbirth in females. Blind studies of individuals of known sex reveal that ascribing sex using this element alone had a reported accuracy as high as 96% (Mays 1998; Sutherland and Suchey 1991).

The skull is the next most sexually dimorphic element, from which it is claimed that sex may be correctly inferred in up to 92% of cases (Mays 1998, 38). It has been claimed that sex estimation from the cranium alone has an accuracy of 88% (St Hoyme and Iscan 1989, 69) whilst 90% accuracy is achieved when the mandible is also present (Krogman and Iscan 1986, 112). This observed sexual dimorphism arises as the result of the action of testicular hormones on the bones of the male skull (ibid., 38), which cause a general increase in robusticity and enlargement of muscle attachment sites. Blind studies undertaken on the named assemblage of Christ Church, Spitalfields, revealed that in skeletons where both complete skulls and pelvii were present, sex determination had an accuracy as high as 98% (Molleson and Cox 1993).

Six cranial features and a maximum of ten pelvic features were used for sexing adults. On the cranium, the features used were selected from Ferembach *et al* (1980) and Buikstra and Ubelaker (1994). Sexually diagnostic features of the pelvis included the greater sciatic notch and preauricular sulcus (Ferembach *et al* 1980), as well as several features of the pubic bone described by Phenice (1969).

Metrics used in the assignment of sex are based on the generalisation that males (under the influence of male hormones) tend to be taller and more robust than their female counterparts. Metrics used were the diameters of the femoral, humeral and radial heads, the clavicular length, and the width of the glenoid fossa (Chamberlain 1994). This method is limited by the fact of considerable interpersonal and inter-population variation. A substantial zone of intermediate values exists between the sexes, rendering sexing using metrical analysis alone very unhelpful in most cases. In the Greenwich assemblage, sex was thus determined principally by cranial and pelvic morphology.

Sex may be ascribed to skeletons with differing levels of certainty, depending on the extent of sexual dimorphism present and the number of sexually dimorphic sites available for study. Sex categories used in this study reflect this uncertainty. Probable male (= '? Male') or probable female (= '? Female') is used where the sex could be ascribed but where some uncertainty exists, and 'male' or 'female' is used where there is considerable certainty of the sex of an individual.

Age estimation

Macroscopic estimation of age establishes the biological age of the skeleton and not the individual's chronological age. Disparity between the two may develop as a result of factors such as nutrition and lifestyle, which may impact on skeletal growth and degeneration (Schwartz 1995, 185). Limitation in ageing methods, particularly in older individuals, was particularly significant in this ageing population, and was probably most responsible for the great disparity between biological age and the age at death range known from historical records.

In order to increase the accuracy of age estimations, multiple methods were employed. Age estimation of the two sub adults was based on the sequence and timing of epiphyseal fusion (Ferembach *et al*. 1980; Schwartz 1995) and on dental development of permanent dentition (Moorees *et al*. 1963). Adults were aged from the extent of degeneration of the ilial auricular surface (Lovejoy, Meindl, Pryzbeck, *et al*. 1985) and the pubic symphysis (Todd 1921a and 1921b; Brooks and Suchey 1990). Age estimation based on the timing of ectocranial suture closure (Meindl and Lovejoy 1985) was also used but was not as rigorously applied as the aforementioned, as the accuracy and precision of this method is believed not to be high (Cox 2000). Dental attrition models (such as Miles 1962) were not used as considerable discrepancies between this method and other ageing methods have been identified. In general, the Greenwich pensioners' dentition showed greater overall wear than that found in contemporary skeletal populations. Nonetheless considerable under-ageing using dental attrition methods (eg. Miles 1962) was still present. This probably reflects the more refined diet and milling techniques in this time period compared with earlier agricultural societies on which such ageing methods were based. Table 2 presents the age categories employed in this analysis.

Stature estimation

Adult stature was calculated from the maximum length of the left femur by applying the regression formulae for white males and females devised by Trotter and Gleser (1952) and revised by Trotter (1970). Skeletons of ambiguous sex and those displaying marked pathology of the femur were excluded.

Table 2 Age-at-death categories used in osteological analysis.

Skeletal age at death
Adolescent : 13–18 yrs
Young Adult : 19–25 yrs
Middle Adult : 26–35 yrs
Mature Adult: 36–45 yrs
Older Adult: 45+ years
Adult: age undetermined

Comparative assemblages used in the analysis

The results of the osteological analysis of the Greenwich pensioner sample were compared to seven broadly contemporary English skeletal assemblages of differing socio-economic backgrounds. This facilitated comparisons between different social classes with regards to their patterns of health and disease. These assemblages were from the Newcastle Infirmary, Newcastle-upon-Tyne (Boulter *et al*. 1997), the Cross Bones burial ground, London (Brickley *et al*. 1999), St Martin's, Birmingham (Brickley *et al*. 2006); Christ Church, Spitalfields, London (Cox 1996; Molleson *et al*. 1993), St Luke's church, Islington (Boyle *et al*. 2005), St George's crypt, Bloomsbury (Boston *et al*. 2006; Boston *et al.* forthcoming) and from an archaeological evaluation at the Royal Hospital Haslar, Gosport, Hampshire (Boston 2005).

Burials from the Newcastle Infirmary dated to between 1745 and 1845, and were those of patients who died in the hospital. Medical treatment in public hospitals was reserved for the poor, as the more affluent classes were treated privately at home. Hence, the burial assemblage comprised the poor of the city, who were eligible for medical care under the Poor Law (Nolan 1997). The assemblage is particularly interesting as it included a number of merchant seamen, perhaps accounting for 35% of the assemblage (ibid).

The Cross Bones burial ground was in use from the middle of the 19th century. The inhumations comprising the sample were interred within a 10 to 30 year time span. Around 18% of those buried there were from the workhouse. Overall, the dead were the poorest members of the underprivileged community of Southwark, London (Brickley *et al*. 1999, 48).

The skeletal assemblage from St Martin's churchyard, Birmingham, dated to the post-medieval period, with the bulk of the burial population being interred during the period from the later 18th century to the 1860s. The bulk of the population comprised the working classes of the parish, with some middle class elements.

The named sample from Christ Church, Spitalfields, was buried within the church crypt between 1729 and 1852. Trade directories and burial records indicate that most individuals were artisans and master craftsmen (Cox 1996, 69), many of whom had achieved considerable affluence in the silk trade, but remained resolutely middle class. Very few were professionals or independently wealthy. Still fewer were indigent.

The named assemblage from the crypt of St George's church, Bloomsbury, London, comprised 72 skeletons retrieved from open wood and lead coffins (Boston *et al*. 2006; Boston *et al.* forthcoming). The assemblage contained few sub adults, and many individuals fell within the mature to older adult age categories. The assemblage was principally upper middle class, with professions such the Law, medicine, politics, the military and the Church being well represented. Paleodemographics and disease profiles were consistent with an affluent population. Burials dated from 1812 to 1856.

An evaluation in the grounds of Haslar Hospital, Gosport, Hants., one of the three Royal Navy hospitals devoted to treating the sick and hurt on active service revealed 167 graves of seamen and soldiers who died at the hospital (Boston 2005). The remains of 19 servicemen were examined *in situ*, but not lifted. All were male, and most were young to prime age adults. Relatively little pathology was noted on the skeletons, suggesting that many had died of acute diseases or injuries that left little evidence on the bone. The burials dated from 1753 to 1826.

PRESERVATION AND COMPLETENESS
(Tables 3–4)

The integrity of the majority of Greenwich skeletons had been largely maintained, with 71.96% of the skeletons being more than 75% complete; and 93.46% being more than 50% complete (Table 3). Only one skeleton was represented by less than 25% of its elements. Although many grave cuts contained more than one skeleton, the burials had been neatly stacked one above the other, such that the integrity of each skeleton was easily maintained during excavation. It is probable that some mixing of smaller bones (such as phalanges) did occur, although the excavators were certain that this was limited in extent. In some cases, where a burial had been truncated by a later grave - more common in Area 1 than Area 2 - the disturbed elements of the earlier skeleton were often included in the backfill of the new grave. It was with a high degree of confidence that this charnel was reunited with the skeleton of which it had originally been part. Otherwise, the bones were assigned as charnel and excluded from the analysis below.

Overall, bone preservation was good (63.55% of assemblage) to excellent (14.02%). In 22.43% of skeletons, however, it was rated as poor (Table 4). With more than three-quarters of the assemblage so well preserved, there was considerable potential for identification of pathological and non-pathological bone modification, and for the presence of non-metric traits. Fragmentation was also relatively minor, allowing a large proportion of crania and long bone measurements to be taken.

Table 3 Skeletal completeness (N = 107).

Completeness	N (skeletons)	%
76–100%	77	71.96
51–75%	23	21.50
26–50%	6	5.61
0–25%	1	0.93
Total	**107**	

Table 4 Bone preservation (N = 107).

Bone condition	N (skeletons)	%
Excellent	15	14.02
Good	68	63.55
Poor	24	22.43
Destroyed	0	0
Total	**107**	**100**

PALAEODEMOGRAPHY

Age and sex distribution (Table 5)

The assemblage comprised 107 skeletons, of which 105 were adult and two (skeletons 3132 and 3249) were sub adult (Fig. 13). The sub adult skeleton 3132 was aged between 12 and 14 years, and skeleton 3249 between 16 and 18 years. Skull and pelvic morphology did suggest that skeleton 3249 was male, but due to its sub adult classification, it was categorised as sex unidentified. It is possible that these two adolescents were the offspring of pensioners living in the hospital. Skeleton 3249, however, showed degenerative changes of the vertebral bodies consistent with one who had undertaken prolonged strenuous physical activities, particularly the carrying of heavy weights. It is possible therefore that this individual was a young recruit - boys as young as 12 years were recruited - who had been debilitated in active service at an early age, and was pensioned to Greenwich. However, this interpretation does not accord with historical records, and furthermore there was no evidence of traumatic injury to the skeleton.

One older adult skeleton (6019) could not be sexed. There were five females in the adult assemblage (4.76%; n = 105) and two possible females (3223 and 6027). Three female skeletons were mature adults: skeleton 3245 aged 35–45 years; 3072 aged 40+ years, and 6132 aged 40–50 years. Two skeletons (2005 and 3174) were of older adults aged 50+ years. One possible female skeleton (3223) was aged 40+ years and the other possible female (6027) was aged as 50+ years. It is probable that these were the wives or widows of in-pensioners. Historical documents reveal that such women were often employed within the hospital as domestic servants or nurses (see Chapter 2 above).

Unsurprisingly, given the nature of the assemblage, the vast majority of the adult population (n = 105) was sexed as male (83.8%; n = 88) or possibly male (8.57%; n = 9). In the following analysis possible males and females were treated as definitely male and female.

Most males and possible males were mature or older adults. The exceptions were 4 adult males skeletons (3061, 3108, 3164 and 3261) and a possible male (3274) of 30–40 years, and 10 skeletons aged at 35–40/45 years. It was possible to identify 34 male individuals from Greenwich as being aged over 40 years, 12 as over 45 years, and 35 as greater than 50 years and one greater than 60 years.

Most older individuals could not be more precisely aged due to the limitations of osteological methodologies that are most accurate in skeletons aged 30 years or less at death, but become increasingly imprecise with advancing age (Mays 1998). Unfortunately, the sternal rib end ageing method devised by Iscan *et al*. (1984), that Loth (1995), and Witkin and Boston (2005; 2006) demonstrated to be so useful in ageing older post-medieval skeletons beyond 50 years of age and up to the age of 78 years, could not be employed on the Greenwich material due to the poor preservation of the fourth sternal rib end.

Ageing methods used in this analysis (such as degeneration of the ilial auricular surface and the pubic symphysis) do not allow for the identification of individuals older than 50 to 60 years, as variation in the rate of degeneration of these joints becomes increasingly varied with advancing age (Cox 2000). Historical data collated from a sample of 100 individuals listed in the Ayshford Trafalgar Rolls (Appendix 1) indicated that the mean age of death of pensioners dying at the hospital was 70.1 years, with the age range tightly clustered about the mean (see below). Due to the limitations in osteological ageing methods, it was impossible to precisely determine biological age at death, or for this age distribution to accurately reflect the chronological age distribution known from historical data, other than to concur that this was an aged population.

Table 5 Summary of age and sex distribution in the total sample (N = 107).

Age categories	Unknown sex	Male	? Male	% male & ? male	Female	? female	% females & ? females	Total	% population
Adolescent	2	0	0	0.00	0	0	0	2	1.87
Young adult	0	0	0	0.00	0	0	0	0	0
Prime adult	0	1	0	1.03	0	0	0	1	0.93
Mature adult	0	13	5	18.56	1	0	14.29	19	17.76
Older adult	1	73	5	80.41	5	1	85.71	85	79.43
Total	**3**	**87**	**10**	**100.00**	**6**	**1**	**100.00**	**107**	**100.00**

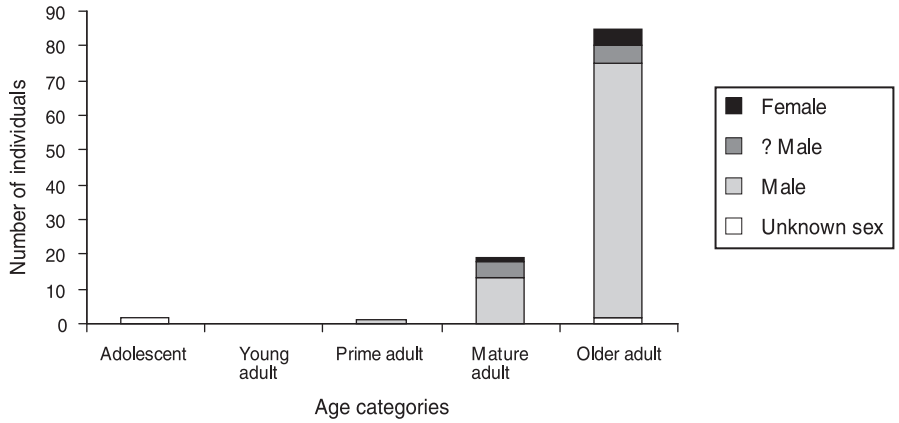

Figure 13 Age and sex distribution in the Greenwich assemblage (N = 107).

Ancestry

Given the wide geographical catchment for recruitment for the Royal Navy (see Chapter 2 above), it is not altogether surprising that the craniometry and morphology of some individuals was indicative of non-Caucasian ancestry. No systematic osteological analysis of ancestry using methodologies employed by forensic anthropologists (e.g. Byers 2005) was undertaken on this assemblage. During the course of the analysis, however, two individuals (skeletons 3061 and 3164) were tentatively ascribed negroid ancestry on the basis of cranial (Gill and Rhine 1990) and femoral morphology (Gilbert 1976). Limited craniometrics (Giles and Elliot 1962) were undertaken, which substantiated the morphological findings. Computer programmes using discriminate function analysis, such as FORDISC (Ousley and Jantz 2005) and CRANID (Wright 2005), were not utilised in this initial analysis. A more systematic and detailed analysis of ancestry is warranted, but unfortunately lay beyond the scope of this report.

Interestingly, both negroid males were aged between 30 and 40 years, and hence were amongst the younger age categories. Skeleton 3061 had undergone a below knee amputation, whilst skeleton 3264 had suffered a comminuted fracture of the left tibia. Both injuries were well healed at the time of death. Skeleton 3061 was the subject of a National Geographic documentary in 2003. As part of the programme, strontium, oxygen and lead isotope analysis was undertaken on the dentine and enamel of a tooth from the skeleton in order to investigate his place of origin (Evans and Chenery 2004). Interestingly, the results indicated that he was not of Caribbean or African origin as expected, but had isotope signatures consistent with a British origin, particularly Eastern Britain.

The presence of significant numbers of blacks in Georgian Britain, particularly in the large cities, has only been acknowledged recently by historians, and because systematic osteological analysis of ancestry is seldom undertaken on post-medieval skeletal populations in Britain, identification of these individuals may be often overlooked. One exception was an adult male of negroid ancestry identified in the assemblage of St Luke's church, Islington, London (Boyle *et al*. 2005). The true number of blacks in Georgian England is difficult to quantify, but in 1764, the *Gentleman's Magazine* estimated the number in London to be as high as 20,000. Other authors (for example Fryer 1984) estimate that the black population was much higher with at least 70,000 black people living in Britain. Most were male and most worked in menial occupations, such as domestic servants or labourers, whilst others were professional boxers and sailors. The possible presence of a black Briton amongst the Greenwich pensioners should thus not come as a great surprise.

STATURE ESTIMATION

Stature is determined by the interplay of inherited and environmental factors. Whilst we all have a maximum genetic potential to attain a certain adult stature, physical and emotional stressors during childhood and adolescence may prevent us achieving this potential (Lewis 2007, 66–68). If such stressors (eg. malnutrition, infection or chronic illness) are too severe or prolonged for the growing body to 'catch-up' growth later, the individual will become permanently stunted. Chronically deprived adolescents may prolong their growth well into their twenties and sometimes even thirties through the delayed fusion of the epiphyses of the long bones, thereby maximising their final adult stature.

Stature has been used as a rough yardstick to indicate the overall health of individuals during the growing years. When analysed in conjunction with indicators of childhood stress, such as dental enamel hypoplasia and cribra orbitalia, adult stature may be a useful indicator of health in individuals and in assemblages as a whole, commonly reflecting the socio-economic nature of that population. As discussed in

Table 6 Distribution of male statures in the Greenwich sample (N = 88).

Stature (m)	N (skeletons)	%
1.50–1.54	1	1.1
1.55–1.59	5	5.6
1.60–1.64	21	23.8
1.65–1.69	32	36.3
1.70–1.74	22	25.0
1.75–1.79	6	6.8
1.80–1.84	1	1.1
1.85+	0	0
Total	**88**	**100%**

Chapter 2, the vast majority of ratings in the Royal Navy were drawn from the working classes, among whom poor nutrition and disease was widespread. It is thus interesting to compare the stature of this assemblage with other recently analysed skeletal assemblages of this period (see Table 7).

It was possible to estimate the stature of 88 adult males and 5 females in the Greenwich assemblage. Female stature ranged from 1.563 to 1.617 m (5ft 1in – 5ft 3in), with a mean stature of 1.595 m (5ft 2in), [sd 1 of 2.19]. Male stature showed a much wider distribution, ranged from 1.542 m - 1.83 m (5ft – 6ft), with a mean of 1.679 m (5ft 5in) [sd 1 of 5.57] (Table 6; Fig. 14).

Although the stature of seamen was not systematically recorded in naval records, one private study undertaken by a Captain Rotheram is held in the National Maritime Museum at Greenwich. Rotheram measured the heights of seamen aboard his ship, and calculated their mean stature as 5ft 5ins (Adkins and Adkins pers. comm.) - a figure that neatly concurs with osteological stature estimates of the Greenwich pensioners.

The mean stature of the Greenwich assemblage was compared with that of seven other contemporary English skeletal populations (Table 7). Although all estimations were undertaken using the equations of Trotter (1970), there are differences in long bones which were used in the analysis. Inevitably, this will introduce subtle differences in stature estimation. In addition, the long bone lengths of 19 male skeletons from the Haslar Hospital were measured whilst the skeletons were *in situ*, undoubtedly introducing a greater margin of error than in laboratory analysed specimens. Notwithstanding these caveats, it is interesting to compare the stature of the two contemporary Royal Naval assemblages, with one another and with contemporary civilian populations.

Table 7 shows that the mean stature of the five females of Greenwich was comparable with the stature of the working class assemblage of the Newcastle Infirmary and the upper middle class assemblage of St George's, Bloomsbury, and was 10 mm greater than that of St Martin's, Birmingham. However, inadvertent bias may have been introduced by the small sample size of the Greenwich females.

Unlike female stature, the pensioners' mean male stature was noticeably less than even that of the pauper assemblage of the Cross Bones, Southwark (by 10 mm), 30 mm less than the mean stature of the other working class assemblage of the Newcastle Infirmary (which included many merchant seamen), and 40 mm less than St Martin's, Birmingham. Interestingly the mean stature of the seamen and soldiers from the Haslar Hospital, Gosport, was the lowest of all the assemblages. It must be acknowledged, however, that the statures of the Greenwich pensioners were not adjusted in accordance with their advanced age (as recommended by Trotter 1970).

The short stature of the ratings appears to reflect their deprived working class origins, where growth stunting during childhood and adolescence had resulted in permanently reduced adult stature (Fig. 15). Marine musters taken on enlistment record many physical characteristics, including stature. Although useful, we cannot know how accurately their heights were taken. Ayshford and Ayshford (2004) collated stature measurements from all musters kept during the Napoleonic Wars, presenting them as distribution graphs (the raw data was not presented). This has been reproduced below as Figure 16. Their pop-

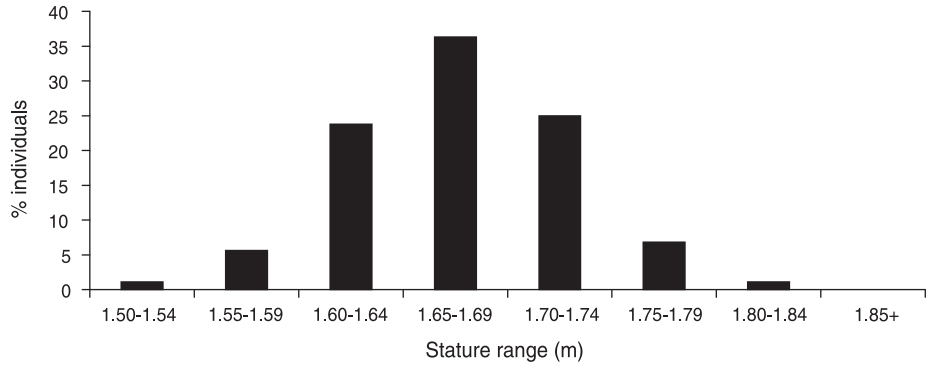

Figure 14 Distribution of male stature by percentage of males with measurable left femora, N = 88.

Table 7 Stature estimates from seven contemporary assemblages in England.

Assemblage	Male (Mean)	Male (Range)	Female (Mean)	Female (Range)
Royal Hospital, Greenwich	1.68 m	1.54–1.83 m	1.60 m	1.56–1.62 m
Haslar Hospital, Gosport	1.64 m	1.54–1.68 m	-	-
St Martin's Church, Birmingham	1.72 m	1.56–1.85 m	1.59 m	1.39–1.71 m
St George's Church, Bloomsbury	1.72 m	1.52 m–1.85 m	1.60 m	1.49 m–1.72 m
St Luke's Church, Islington	1.70 m	1.55 m–1.93 m	1.58 m	1.49 m–1.72 m
Newcastle Infirmary, Newcastle-upon-Tyne	1.71 m	1.60 m–1.83 m	1.60 m	1.50 m–1.76 m
Christ Church, Spitalfields	-	1.68 m–1.70 m	-	1.54 m–1.59 m
Cross Bones, Southwark	1.69 m	1.53 m–1.80 m	1.58 m	1.42 m–1.72 m

ulation included boy recruits who would not have reached their full adult height, and may account for some of the very low statures (some less than 4ft 6in) recorded in the musters. The majority of marines had statures between 5ft 2in and 5ft 8in, and peaked at 5ft 4in. The distribution about the mode is broadly symmetrical. Unfortunately, the stature of seamen was not similarly recorded in the Naval records and it is not known if it differed significantly from marines with whom they sailed.

In the years following Napoleon's defeat at Waterloo, large numbers of servicemen were discharged from the Army and Navy. Marine discharge papers of that time reveal that being 'undersized' was a criterion for the exclusion of privates. In practice this meant that marines shorter than 5ft 4in were discharged. Being 'undersized' did not appear to have been an impediment when the Navy was desperately recruiting men during the French and Napoleonic Wars. In implementing this rule, the Navy effectively excluded between a quarter to a third of the marine force.

Interestingly, the peak stature of marines recorded in the musters broadly concurs with the mean stature (5ft 5in) of the skeletal assemblage from Greenwich Hospital calculated from femoral length. It must be remembered that many marines enlisted in their late teens and early twenties, when they may still have been growing (given the probable delayed fusion of epiphyses), which may in part account for the one inch discrepancy. Methodological limitations also are probably responsible for the differences between historical and osteological stature.

SKELETAL PATHOLOGY

Introduction

The skeletal assemblage from the Royal Hospital burial ground was remarkable for the high prevalence

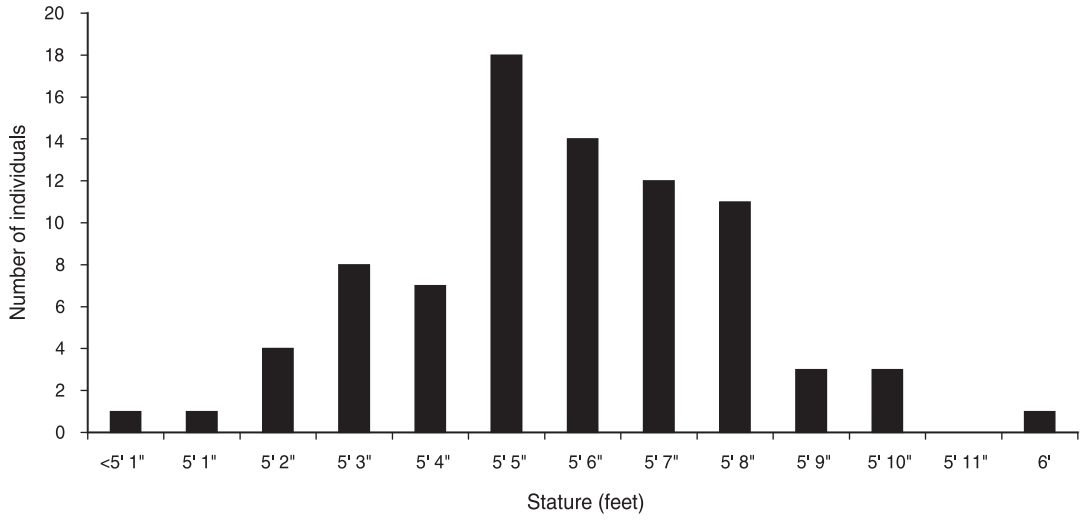

Figure 15 Stature distribution of the Greenwich pensioners, from left femoral lengths (in feet).

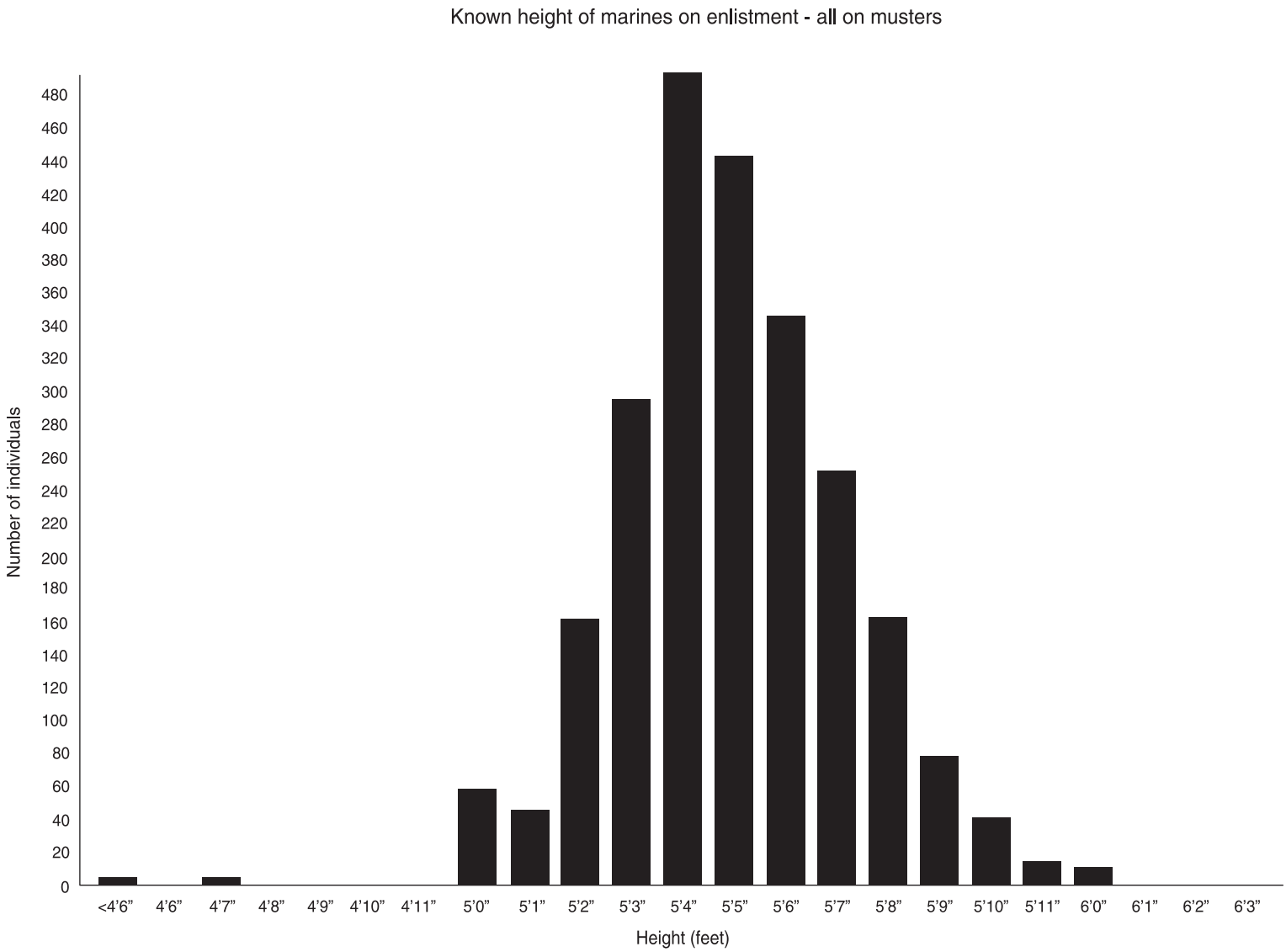

Figure 16 Stature distribution of marines collated from Marine Description Books, in feet (taken from Ayshford and Ayshford 2004).

and wide range of pathologies displayed on the skeletons. Disease and trauma patterns vividly reinforce what is known historically about the origins, on board conditions and dangers faced by the seamen and marines comprising Nelson's Navy. Degenerative joint diseases, such as osteoarthritis, are both reflective of the advanced age group of this assemblage and their physically rigorous lives.

Although it must be acknowledged as an oversimplification of the complex and multiple aetiologies of many of the injuries and diseases, pathologies were classified into seven major categories: trauma, infection, joint disease, metabolic disorders, neoplasms, congenital anomalies and 'other pathologies' that did not fall into any of the above groups. Medical interventions (amputations and craniotomies) and dental pathology are discussed separately below.

Skeletal pathology prevalences were calculated as crude prevalences per skeleton (CPR) and as true prevalences per skeletal element present (TPR). Table 8 summarises the CPR of major categories of disease and trauma noted on the adult skeletons of the assemblage. TPR by skeletal element is presented for the most common pathologies, namely fractures (Table 9) and non-specific bone infection (Table 10).

It should be stressed that the osteological analysis and pathology identification was tightly constrained by time, and that it is the opinion of the examining osteologist, Annsofie Witkin, that some of more subtle bony modifications were missed during analysis. It is therefore probable that the prevalences presented below may slightly under-represent the true picture.

Trauma

The Greenwich assemblage is remarkable for its high rates of trauma, particularly fractures. More of these injuries were probably sustained during everyday life aboard ship than during enemy action, although injury due to the latter could be considerable. As Lewis

Table 8 Crude prevalences (CPR) of pathology in the adult assemblage (N = 105).

Pathology categories	Male (n = 97) N (%)	Female (n = 7) N (%)	Indeterminable sex (n =1) N (%)	Total Adults (n= 105) N (%)
Joint disease				
Osteoarthritis	62 (63.9)	2 (28.57)	0 (0)	64 (60.65)
Rheumatoid arthritis	1 (1)	0 (0)	0 (0)	1 (0.95)
Seronegative spondyloarthropathy	16 (16.4)	0 (0)	0 (0)	16 (61.3)
DISH	3 (3)	0 (0)	0 (0)	3 (2.86)
Osteophytosis (all joints excluding vertebrae)	92 (94.8)	6 (85.7)	0 (0)	98 (93.33)
Schmorl's nodes	67 (69)	2 (28.57)	1 (100)	70 (66.67)
Spinal Degenerative Joint Disease	94 (96.9)	5 (71.43)	1 (100)	100 (95.23)
Spondylolysis	5 (5.1)	0 (0)	0 (0)	5 (47.62)
Other spine conditions	14 (14.4)	0 (0)	0 (0)	14 (13.33)
Other joint diseases	7 (7.2)	2 (28.57)	1 (100)	10 (9.52)
Trauma				
Ante-mortem fracture	82 (84.5)	2 (28.57)	1 (100)	85 (80.95)
Skull wound/injury	52 (53.6)	0 (0)	0 (0)	52 (49.52)
Ligament trauma	6 (6.1)	0 (0)	0 (0)	6 (5.71)
Osteochondritis dissecans	6 (6.1)	0 (0)	1 (100)	7 (66.67)
Cortical defects	1 (1)	0 (0)	0 (0)	1 (0.95)
Other trauma	12 (12.3)	0 (0)	0 (0)	12 (11.43)
Infection				
Maxillary sinusitis	5 (5.1)	1 (14.29)	0 (0)	6 (5.71)
Periostitis	61 (62.8)	2 (28.57)	0 (0)	63 (60.0)
Osteomyelitis	3 (3)	0 (0)	0 (0)	3 (2.86)
Infective arthropathies	1 (1)	0 (0)	0 (0)	1 (0.95)
Tuberculosis	2 (2)	0 (0)	0 (0)	2 (1.90)
Treponemal disease	3 (3)	0 (0)	0 (0)	3 (2.86)
Other infectious diseases	3 (3)	0 (0)	0 (0)	3 (2.86)
Metabolic disorders				
Cribra orbitalia	34 (35)	1 (14.29)	0 (0)	35 (33.33)
Scurvy	12 (12.37)	0 (0)	0 (0)	12 (11.43)
Rickets	10 (10.3)	0 (0)	0 (0)	10 (9.53)
Osteoporosis	2 (2)	0 (0)	0 (0)	2 (1.90)
Other metabolic conditions	1 (1)	0 (0)	0 (0)	1 (0.95)
Neoplastic disease				
Neoplastic disease	9 (9.2)	0 (0)	0 (0)	9 (85.71)
Congenital disorders				
Congenital anomalies	9 (9.2)	1 (14.29)	1 (100)	11 (10.483)
Medical interventions				
Amputations	5 (5.16)	0 (0)	0 (0)	5 (4.76%)
Craniotomies	3 (3.09%)	0 (0)	0 (0)	3 (2.86)

(1960, 361) phrased it battle casualties 'were small compared with those inflicted by causes other than the hand or wit of man'. Falling from the rigging, injuries from swinging booms, and crush injuries during violent storms were probably responsible for a great many injuries. Seamen were aloft in the rigging at all times of day or night and in all weathers, often performing feats that could only be expected of an acrobat or steeplejack. A fall from the rigging onto the deck some 100 feet below was often fatal, and there was also the distinct possibility of killing or injuring another seaman on the crowded decks below (Lewis 1960, 392). Able seaman George Gamsby (Trafalgar veteran and Greenwich pensioner) was one seaman who suffered major disability by falling from the hatchway into the cockpit during the Battle of Trafalgar. His injuries left him with impaired use of both legs and constant back and leg pain (Ayshford and Ayshford 2004).

Skeleton 3241 of the Greenwich assemblage was remarkable for the sheer number of fractures he had sustained. The majority was to the right side of his body and involved the left parietal, the clavicle, four ribs, the humerus, distal radius, pisiform, neck of femur, fibula and distal tibia. All were well healed, although many showed considerable malalignment and overlapping of the broken elements. The most probable explanation for this suite of injuries was a fall onto the deck from a great height. In spite of this multiple trauma, he survived to a ripe old age of 50+ years.

On deck or below deck, landmen and ordinary seamen spent much of their days raising or lowering sails, hauling or pushing out heavy, awkward or dangerous loads, often within confined spaces. Guns that broke loose during firing (either in practice or during enemy action) or during violent storms were responsible for many crush injuries, sometimes fatal (hence the term 'a loose cannon'). On deck, falling or being flung against the ship's sides or contents during bad weather and heavy seas was also a significant cause of injuries. Loose cables and lifeboats and falling rigging also presented a risk of crushing (Lewis 1960, 391–96; Fremont-Barnes 2005).

Injuries sustained during enemy action were often severe, leaving many individuals with permanent disfigurement or disability. Direct hits from small arms fire and cannon balls were a major source of injury during bombardment by the enemy, but flying wooden splinters from enemy cannon balls smashed into the sides of the vessel were an even greater source of injury and subsequent infection (Fremont-Barnes 2005). In the sample of 100 Trafalgar veterans who died at Greenwich Hospital (Appendix 3), trauma suffered at Trafalgar included major injuries from splinters and musket fire; rupture; loss of sight and hearing (probably during the cannonade); fractured arms and skulls, and the loss of limbs. For example, Thomas Chapman, a Royal Marine who died in Greenwich Hospital in 1851 aged 72 years, received a musket ball through the head during the battle. Wounds to both cheeks left him with a rigid lower jaw, which subsequently caused considerable difficulties in eating and speaking. He was one of the lucky ones, however. Memoirs of both seaman 'Jack Nastyface' (Robinson 2002) and ship's surgeon James Lowry (2006) describe balls completely taking off the heads or bodies of seamen that they stood alongside during a bombardment.

Fractures

At least one fracture was observed on 85 adult skeletons: 84.5% (n = 97) of the males, 28.57 % (n = 7) of the females, and in the one of unknown sex. Many male skeletons had sustained multiple fractures, all of which were well healed. Due to the advanced age and prolonged retirement of most of the pensioners, it is reasonable to assume that the majority of these injuries were sustained during active service. Some injuries may well have been of more recent date, however. Interpersonal violence between inpensioners in the Hospital was not unknown. An entry in the Trafalgar Rolls (Ayshford and Ayshford 2005) records that one James Bagley (retired private in the Royal Marines and former stocking maker) was discharged from the Hospital in 1856 for '*being drunk and striking Boatswain Morris'*. He was 71 years old at the time of this misdemeanour.

Table 9 summarises the location of fractures on the male skeletons. These data are presented in Figure 17. The skull (including calvarium, face and mandible) was the most common part of the skeleton to display fractures (TPR 57.1%). In her study of more than 6,000 archaeological skeletons from Britain, Roberts (1991) also found that the skull was most commonly affected. In the Greenwich assemblage, injuries included nasal bone fractures (TPR 61.8%), depression fractures of the cranial vault (frontal bone, n = 4; parietal bones, n = 4) and fractures of the face (zygomas, n = 4; maxillae, n = 12) and mandible (n = 1). In a study of 2280 individuals from Siberia, Spain, the United Kingdom and the U.S.A. undertaken by Walker (1997), it was found that nasal bones were the most commonly fractured bone (7.0%), followed by the frontal (4.6%) and parietal bones (3.9%). Nasal fractures were also the most common fracture location on the skull in the Greenwich pensioner assemblage, but this type of injury and injuries to the face were considerably more common than in Walker's study. Cranial vault fracture prevalence does not appear to differ considerably from Walker's assemblage.

Further analysis on a sample of 43 adult male skulls from Greenwich undertaken by Turnbull (2004) revealed an average of 1.92 fractures per skull, of which the vast majority were radiating fractures (79.26%). Ten depressed fractures of the cranial vault and one of the right zygoma (13.12% of skull fractures) were also identified. Both were attributed to blunt force trauma.

One example of sharp force trauma was identified on the right ascending ramus of the mandible of skeleton 3032, the blow had entirely removed the

Table 9 True prevalence of fractures by element (n = 105).

Elements	Males	Females	Total Adults (including one unsexed skeleton)
Total skull	57.1% (52/91)	0% (0/5)	53.6 % (52/97)
Nasal fractures	61.8 % (47/76)	0% (0/5)	57.3 % (47/82)
Vertebra	1.1 % (21/1880)	0% (0/90)	1.0 % (21/1994)
Ribs	5.1 % (74/1425)	0% (0/64)	4.8 % (74/1513)
Clavicles	4.0 % (7/174)	0% (0/9)	3.7 % (7/185)
Scapulae	1.1 % (2/180)	0% (0/13)	1.0 % (2/195)
Humeri	0.5 % (1/187)	7.6% (1/13)	0.9 % (2/202)
Radii	4.2 % (8/188)	0% (0/13)	3.9 % (8/203)
Ulnae	2.1% (4/189)	0% (0/15)	1.9 % (4/206)
Carpals	0.5 % (4/799)	0% (0/53)	0.4 % (4/863)
Metacarpals	2.6 % (20/763)	0% (0/51)	2.4 % (20/822)
Phalanges	0.3 % (4/1216)	0% (0/84)	0.3 % (4/1307)
Femora	3.7 % (7/185)	0% (0/17)	3.4 % (7/204)
Patella	1.4 % (2/142)	0% (0/10)	1.2 % (2/154)
Tibiae	8.8 % (16/180)	0% (0/12)	8.2 % (16/194)
Fibulae	11.1 % (20/180)	0% (0/12)	10.3 % (20/194)
Tarsals	1.7 % (17/988)	0% (0/69)	1.6 % (18/1071)
Metatarsals	1.2 % (10/772)	0% (0/54)	1.1 % (10/836)
Phalanges	0.9 % (7/705)	0% (0/59)	0.8 % (7/778)

mandibular angle at a 30° to 40° angle to the ramus. Soft tissue damage and resulting loss of function had lead to considerable atrophy of the mandible on that side. This low prevalence is somewhat surprising given that cutlasses and knives were issued to both the French and English before boarding an enemy vessel (Fremont-Barnes 2005), and may well suggest that hand-to-hand combat was less common than has been previously believed. There were no examples of projectile trauma in the assemblage.

In modern western populations, nasal fractures are most commonly caused by blunt trauma in the form of automobile accidents, interpersonal violence and falls, and are the third most frequently broken bone in the body (Vipul *et al*. 2006). Many skeletons displayed fractures of more than one facial bone. For example, skeleton 3103 had fractured both nasal bones, both maxillae and the right zygoma (Plate 16). Considerable deviation of the nose to the right is apparent.

Falls and interpersonal violence were highly probable causes of fractures amongst the ratings. As described above, falls were a common feature of everyday life aboard ship, whilst the social life below decks was anything but decorous, particularly where alcohol was involved.

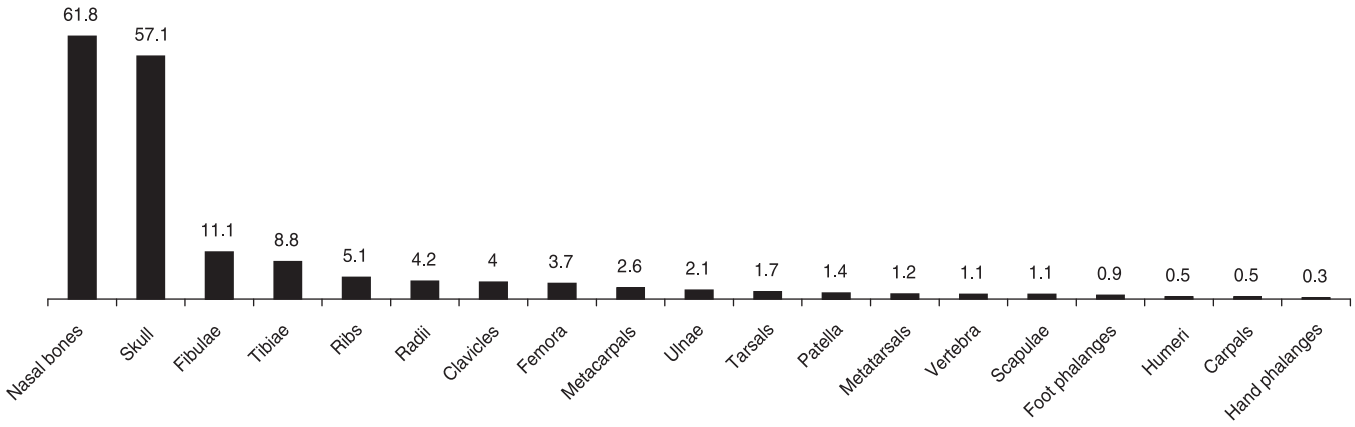

Figure 17 Location of fractures in male skeletons by element (N = 97).

Drunkenness was a perennial problem amongst seamen, but given the conditions and monotony of the service it is hardly surprising that seamen chose this method of escapism (Fremont-Barnes 2005, 27; Lewis 1960, 398–401). According to Leech (cited in Fremont-Barnes 2005, 27)

> to be drunk is considered by almost every sailor as the acme of sensual bliss; whilst many fancy that swearing and drinking are necessary accomplishments in a genuine man-of-war's man.

Lord Keith of the Admiralty, writing in 1812 lamented that

> almost every crime except theft originates in drunkenness, and that a large proportion of men who are maimed or disabled are reduced to that situation by accidents that happen from the same abominable vice (cited in Rodger 2004, 495).

Whilst this may well be somewhat of an overstatement, drunkenness was certainly perceived as being extremely threatening to the ordered regulation of life aboard ship, and the wellbeing of the crew, and officers made considerable efforts to curtail excesses. The extremely generous daily Navy issue of one gallon of beer or half a pint of spirits (most commonly rum or grog) was carefully regulated, and drunkenness was treated as a serious and punishable offence (Fremont-Barnes 2005, 27–8). It was occasionally tolerated, however, and a general free-for-all was often permitted at Christmas and when ships were in home ports. Due to the ever-present risk of desertion, seamen were seldom allowed to celebrate on land. Instead, swarms of bumboats that plied the major seaports brought food, drink, and women to the ships. Plate 11 shows such a scene of revelry in the lower deck. In the foreground is a boxing contest between two seamen (note the cords around their waists limiting their movement), whilst other seamen dance or consort with the prostitutes who have been allowed on board. The scene underlies the potential for both organised and spontaneous brawling. It is highly probable, that the very high prevalence of nasal and facial fractures may well be attributed to interpersonal violence on such occasions. The high prevalence of first metacarpal fractures may be explained in the same way (discussed below).

The prevalence of nasal bone fractures (TPR 61.8%; CPR 35.51% of total population) is particularly startling when compared to the contemporary predominantly working class population of St Martin's, Birmingham. Brickley *et al* (2006) report a CPR of 1.98% for the whole population. However, there was a significance difference between groups within the churchyard, with 11.1% of adult males from vaults displaying nasal fractures compared to 2.11% from earthcut graves. This was interpreted as culturally induced interpersonal violence (Brickley *et al*. 2006).

In the Greenwich assemblage rib fractures were also very common (TPR 5.1%), and was observed in 26 males (CPR 28.87%). This is considerably higher than the CPR of 2.3% identified at St Martin's, Birmingham (Brickley *et al*. 2006). In the Greenwich assemblage, rib fractures per capita varied between 1 and 11. Like nasal fractures, the most common aetiology in modern populations is falling or interpersonal violence.

Injury to the hands, particularly the metacarpals featured frequently (metacarpals, TPR 2.6%), with six fractures to the first metacarpal; three to the second; seven to the third; three to the fourth, and two to the fifth. Sidedness of the injury was apparent in the third metacarpal (two on the left and five on the right), suggesting a greater prevalence of injury to the dominant hand. The distribution of injuries does not reflect the clear preference for the first metacarpal (Bennet's fractures) noted at St Martin's, Birmingham (Brickley and Smith 2006). Bennet's fractures have been associated with the style of boxing popular in the earlier 19th century before the introduction of the Queensbury Rules in 1867, and the wearing of gloves. Styles of professional boxing were copied by the masses, who often undertook bare knuckle fist fighting as a socially acceptable way of settling disputes (ibid.). This boxing style is illustrated by the two pugilist sailors in Plate 11. Interpersonal violence may well be the cause of many first metacarpal fractures. However, Brickley and Smith (2006) also noted that the most common modern cause of Bennet's fracture is falling onto an outstretched hand - undoubtedly a likely hazard aboard ship.

In the Greenwich assemblage fractures to the third metacarpal (CPR 7.2%; n = 7) showed a preference for the right side (although admittedly the sample was small). The cause of these fractures is unclear but injury whilst grasping and pulling on heavy ropes may well have precipitated this damage.

Fractures of the appendicular skeleton occurred with equal frequency on the left and right in the Greenwich assemblage (Galer 2002). The lower leg bones were the most commonly affected (fibulae TPR 11.1%; tibiae TPR 8.8%), and humeri the least affected (TPR 0.5%). In archaeological populations, femoral shafts are infrequently fractured due to the large force required to break this dense bone, but in 3.7% of males this bone had been broken. One example was skeleton 3229, which had suffered bilateral fractures of the femoral shafts with extensive overlapping of the fractured parts, resulting in considerable foreshortening of both bones (Plates 18 and 19). Radiography revealed extensive callus formation and associated osteomyelitis. Clearly this had been an open fracture that had become infected. Neither bone had been set competently, possibly suggesting the lack of effective medical care or that associated soft tissue injury made reduction and fixation unfeasible or problematic soon after the injury was sustained. This is also suggested by the fractured tibial shaft of skeleton 3164 (Plate 17), although no infection was associated with the latter.

Fractures to the vertebrae largely involved crush or wedge fractures of the vertebral bodies (TPR 1.1%).

Systematic analysis of the location of these fractures in the spinal column was not undertaken, but overall, the thoracic and lumbar regions appeared most affected. Compression fractures often occur as a result of weakening of the bone by osteoporosis, causing collapse of the body, and hence, are particularly prevalent in older individuals. Vertebral collapse may involve the whole body or may be restricted to one aspect (most commonly anterior or lateral), resulting in a wedge fracture (Roberts and Manchester 1995, 69–70). Wedge fractures often cause malalignment of the spine, most commonly kyphosis (hunchback) (Aufderheide and Rodríguez- Martín 1998, 24), but rarely produce a neurological deficit (Browner *et al*. 2003, 886). Unequal weight-bearing often precipitates secondary osteoarthritis, and fusion of the affected bodies. Other causes of compression fractures include trauma (usually when the force is applied vertically downwards, or due to hyperflexion), and as secondary to other pathological disorders, such as tuberculosis of the spine (discussed below) and metastatic carcinoma. The advanced age of the Greenwich pensioners make it probable that osteoporosis played a significant role. Macroscopic diagnosis of osteoporosis is particularly problematic in archaeological skeletons (Roberts and Manchester 1995, 179), and hence, this must remain just a hypothesis. Trauma may also have been significant.

Although all long bone fractures had knitted together, many were poorly aligned and often considerable overlap of the broken elements was present. Radiography of some of the long bones was undertaken by Galer (2002) but a more comprehensive programme is still outstanding. Due to extensive callus formation at many fracture sites, it was thus not possible to diagnose different fracture types in this report. Many individuals had suffered multiple fractures. One of the more dramatic cases was the bilateral femoral shaft fractures in skeleton 3229 (Plates 18 and 19), where the left and right femora showed a shortening of 4.5 cm and 5.5 cm respectively. Whilst malalignment of the broken fragments was negligible on the left, the distal portion of the right was rotated laterally, with an apposition of 25%. Poor reduction with resultant overlap was also present in the left tibia of skeleton 3164 (Plate 17). Degenerative joint changes were noted in the hip, knee, ankle and foot joints, such that the medial and intermediate cuneiforms were fused. This was probably secondary to uneven weight distribution due to the shortening of the left leg. Although the proportion of poorly reduced fractures was not quantified in this analysis, the general impression was that many fractured elements had healed but were malaligned. This suggests that reduction of the fracture had been unsuccessful, indicating that splinting of the affected element had been ineffectual or had not been undertaken (Grauer and Roberts 1996).

Neither of the subadults showed evidence of trauma, whilst amongst the seven females, two displayed fractures (CPR 28.57%). This is considerably lower proportion than the adult male population.

Soft tissue trauma

Trauma to the soft tissues overlying the skeleton may sometimes manifest on the bones, particularly where it involves damage to the ligaments and to the tendons by which muscles attach to the bone. Such damage may manifest as enthesophytes (bony projections at the point of insertion) where ossification of the damaged tissue occurs, or as cortical defects, which manifest as depressions of the bone surface, where bony resorption took place (Resnick 1995). The former may have other aetiologies, however, including ankylosing spondylitis and DISH (see below). A particularly marked exostosis was noted on the distal two-thirds of the right femoral shaft of skeleton 3202 (Plate 20). This bony projection is likely to have formed by soft tissue damage to part of the Vastus intermedius muscle.

Analysis of the prevalence and location of soft tissue injury, together with other bony changes associated with repetitive muscle use may be used to identify handedness and suggest occupation (Steele 2000). Unfortunately, such detailed recording was not systematically undertaken during the analysis. Six particularly marked cases of enthesophytes and one cortical defect were noted in passing, but are not representative of the much higher prevalence seen but not recorded during analysis. Soft tissue injury to the upper limb appeared particularly marked, as were muscle markings, and extension of the anterior aspect of the joint surface of the distal humerus (possibly the result of hyperflexion of the elbow joint during hauling on ropes, or moving up and down the ratlines of the ship's rigging principally using the arms). Further systematic analysis of these bony changes would be very valuable to our understanding of this population but lies beyond the scope of this report.

Rupture

Another common soft tissue injury that left no trace on the skeleton, but which was responsible for major disability was 'rupture' (Lewis 1960, 394–396). Endless hauling on ropes, heaving on capstans, and the lowering and hoisting of heavy barrels (particularly water butts) resulted in often permanent damage to the abdominal muscles, which required the wearing of trusses, sometimes for life. Thousands of single and double trusses were issued by the Navy, the injury being so common that they were something like standard issue to all ships (Lewis 1960, 395). By the end of the Napoleonic Wars (1815), 29,712 seamen had been issued with trusses - approximately one in nine of all those in active service during the wars (loc. cit.). Fragments of poorly preserved leather were discovered beneath the back and around the right side in the torso region of the skeleton 6037 (grave 6039, group 6270). Although the leather was too poorly preserved to identify the garment confidently, it had perhaps formed parts of a truss worn for long-term rupture.

Osteochondritis dissecans

Osteochondritis dissecans is a fairly commonly diagnosed osteological disorder of the joint surfaces of the major long bones (Rogers and Waldron 1995). Physically active young males (such as modern athletes) are most often affected in the first two decades of life (ibid.; Aufderheide and Rodríguez- Martín 1998). This disease is due to a significant localised obliteration of the blood supply, causing necrosis of small areas of joint tissue (Roberts and Manchester 1995, 87). Repeated, low-grade, chronic trauma or micro-trauma is thought to play a role in this injury to the blood vessels (Aufderheide and Rodríguez-Martín 1998, 81). The necrotic bone plaque breaks off from the joint surface and may remain loose in the joint (a so-called 'joint mouse'), causing chronic pain and often precipitating osteoarthritis. Alternatively, the fragment may reattach in its original position or be resorbed, and no further symptoms will be experienced.

Six males and the one adult of indeterminate sex (CPR 6.67%; n = 105) displayed this pathology. Its presence is not surprising in this physically active population. From the Trafalgar Rolls (Ayshford and Ayshford 2004), it is apparent that many seamen joined the Navy in their early 20s, as did many marines. It was possible, however, to be a boy recruit joining as young as 12 or 13 years of age. Thus, the age profile of this condition concurs with the young age of recruitment into the Royal Navy of most servicemen.

Spondylolysis

Spondylolysis was present in the lumbar vertebrae of four adult males (CPR 4.12%, n = 97; CPR 3.81% of the adult population). Spondylolysis is the term given to separation of the vertebral arch from its body at the pars interarticularis. The site of predilection of this condition is the fifth lumbar vertebra (Mays 2006). Spondylolysis was identified in the fifth lumbar vertebra in all four individuals from Greenwich (CPR 4.12%, n = 97; CPR 3.81% of the adult population).

Formerly spondylolysis was considered a congenital anomaly of vertebral ossification (Newell 1995), but today the more favoured interpretation is a stress or fatigue fracture that fails to heal (Adams 1990, 191; Standaert and Herring 2000). The cause of the fracture is thought to be the result of sustained strenuous activity involving loading of the spine (Mays 2006, 352). Very few cases develop before the age of five years (Hensinger 1989). A study of a medieval rural population of Wharram Percy, Yorkshire, did not indicate that adult spondylolysis rates increased with increasing age, and thus, injury appeared to have been sustained in late adolescence or early adulthood (Mays 2006). At this young age the neural arches of the vertebrae have not reached their full structural strength, and are least able to resist the heavy biomechanical load placed on lower back during strenuous manual labour (Mays 2006). It is thus more probable that spondylolysis in the three Greenwich pensioners was sustained in early life, possibly before or during their shipboard years. As described above, lifting heavy weights (such as water butts and ammunition) formed a large component of everyday work aboard ship, particularly for landmen. It is thus not surprising that the condition manifested in these individuals.

Os acromiale

In os acromiale, the final epiphyseal element of the acromial process of the scapula fails to unite with the rest of the bone, a union that normally occurs in males by 18–19 years (Stirland 2000; 2005, 533). Whilst this non-fusion was thought to be heredity in origin, evidence from the human remains aboard the sunken Tudor warship the Mary Rose strongly suggested that strenuous use of the upper limb from a young age may induce this condition. Stirland found that 13.6% of individuals (or 12.5% of scapulae present) had os acromiale - a significantly higher rate than the 3–6% that normally occurs in modern populations. She attributed this phenomenon to long bow archery (ibid. 536).

Three adult male Greenwich skeletons (3098, 3218 and 6063) showed evidence of os acromiale. In the first, it was bilateral, but in the other two it was present on the left side only. The CPR of 3.09% is similar to normal variation found within modern populations (Stirland 2005). This finding was somewhat surprising given that most seamen were engaged in strenuous activities involving the upper body. An explanation may lie in the age at which most seamen joined the Royal Navy. The age at which the Greenwich pensioners began their seafaring lives is of considerable significance, however, and it is highly probable that the acromial epiphyses had already fused before these individuals embarked on a seafaring way of life.

Infection

Non-specific infection was identified in a large proportion of the adult males, whilst several cases of specific infections, such as tuberculosis and syphilis, were also present. Adolescent skeleton 3132 (aged 12–14 years) also showed lesions typical of tubercular spine. The extent of healing was classified as active (woven bone), partly healed (striated or lamellar bone) or fully healed (smooth bone) at the time of death.

Non-specific infection

In the Greenwich assemblage, most cases of bone infection could not be identified to a specific micro-organism, and hence, have been categorised as non-specific infection. Most lesions were classed as periostitis where reactive new bone was observed on the bone surface. Thickening of the bone was often

observed in these cases, and it would appear that the infection had penetrated to the cortical bone beneath. In the absence of a systematic radiology programme, a diagnosis of osteitis was not tenable, and such lesions were classified as periostitis. Where a cloaca or sinus was present to clearly demonstrate drainage of infective material from the marrow cavity, the bony changes were classified as osteomyelitis. The prevalence of periostitis by element is summarised in Table 10. Although the bones of the skull are not in fact covered by periosteum, superficial surface bone changes have been included in this table.

Periostitis is an inflammation of the periosteum, the fibrous sheath that covers bony tissue. This inflammation stimulates a response in which new bone is deposited on the extra-cortical surface as a result of increased osteoblastic activity. This is often secondary to infection (most commonly tracking from the overlying soft tissue, or less commonly from blood-borne microorganisms in systemic infection, or from adjacent infected compact or trabecular bone). One of the Greenwich pensioners displaying periostitis, or possibly osteitis, secondary to trauma was skeleton 3164 (Plate 17). An oblique fracture involving the right distal tibial shaft had healed but was poorly reduced, with considerable overlap and had left the distal part considerably displaced medially and posteriorly. Reactive new bone on the bone surface and thickening around the fracture showed signs of advanced healing, indicating an injury of long standing.

Periostitis may not necessarily be infective in origin, however, as inflammation may also occur in response to mild trauma, local haemorrhage, nutritional imbalances (eg scurvy or from very high levels of Vitamin A), chronic skin ulcers and in some autoimmune disorders (Aufderheide and Rodríguez-Martín 1998, 179).

Periostitis was present in 61 adult males (62.8%, n = 97) and two females (28.57%, n = 7) in the Greenwich assemblage (Fig. 18). In female skeleton 3072, lesions were distributed bilaterally on the femoral shafts, tibiae and fibulae. Skeleton 3174 also showed a wide distribution, involving both tibiae and fibulae and the left ribs (the former being well healed and the latter active).

By far the most common site of periostitis was the tibial shaft (TPR 34.5%), of which four were of females (TPR 33.3%, n = 12) and 63 were of males (TPR 35%, n = 180). Periosteal reactions were also common on the fibulae (TPR 18.2%), often found in association with lesions on the adjacent tibia, probably the result of localised infection (Table 10). In most archaeological assemblages, the tibia is the most common site of periostitis, largely because the anterior tibia is not covered by much soft tissue and lies almost directly beneath the skin. Its location on the lower legs also makes it susceptible to recurrent minor trauma (Roberts and Manchester 1995, 130). Peripheral vascular disease (sometimes associated with diabetes mellitus) may also lead to venous or arterial ulcers. Due to the poor blood supply, these are slow to heal and may become infected. If the soft tissue damage reaches the underlying bone, an inflammatory reaction of the periosteum may occur. Considering the older age of this sample, this aetiology is probable in some of the lesions present. It is important to note, however, that most lesions were well healed at the time of death.

Periostitis - multiple element involvement

Periostitis was present on more than one bone in 53 skeletons. The distribution on different elements is summarised in Table 11. Such distribution patterns aid in differential diagnosis, particularly of systemic diseases. The picture is complicated, however, by the advanced age of the assemblage. As insults accumulated over time, it is difficult to determine whether different lesions comprised a single syndrome or disease or whether different lesions had completely different aetiologies and/or occurred at very different times in

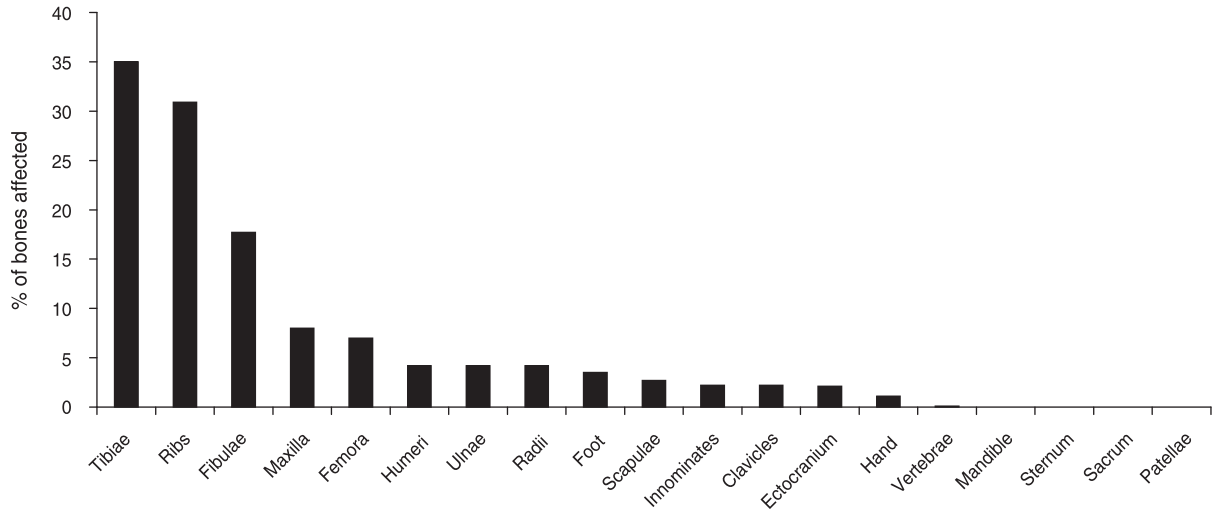

Figure 18 True prevalence (TPR) of periostitis by element in adult male sample (N = 97).

Table 10 Summary of the prevalence of elements showing periostitis (N = 105).

Elements	Males n = 97	Females n = 7	Total Adults (including one unsexed skeleton) n = 105
Endocranium	2.1% (2/91)*	0% (0/5)*	2.0% (2/97)*
Ectocranium	2.1% (2/91)*	0% (0/5)*	2.0% (2/97)*
Maxilla	8.0% (7/87)	20.0% (1/5)	8.6% (8/93)
Mandible	0% (0/88)	0% (0/5)	0% (0/94)
Sternum	0% (0/58)	0% (0/3)	0% (0/62)
Vertebrae	0.1% (2/1880)	0% (0/90)	0.1% (2/1994)
Sacrum	0% (0/85)	0% (0/8)	0% (0/94)
Ribs	30.9% (26/84)*	20.0% (1/5)*	28.8% (26/90)*
Innominates	2.2% (4/181)	0% (0/14)	2.0% (4/197)
Clavicles	2.2% (4/174)	0% (0/9)	2.1% (4/185)
Scapulae	2.7% (5/180)	0% (0/13)	2.5% (5/195)
Humeri	4.2% (8/187)	0% (0/13)	3.9% (8/202)
Ulnae	4.2% (8/189)	0% (0/15)	3.8% (8/206)
Radii	4.2% (8/188)	0% (0/13)	3.9% (8/203)
Hand bones	1.1% (1/89)*	0% (0/7)*	1.0% (1/97)*
Femora	7.0% (13/185)	11.7% (2/17)	7.3% (15/204)
Patellae	0% (0/142)	0% (0/10)	0% (0/154)
Tibiae	35.0% (63/180)	33.3% (4/12)	34.5% (67/194)
Fibulae	17.7% (32/180)	30.0% (3/10)	18.2% (35/192)
Foot bones	3.5% (3/85)*	0% (0/7)*	3.2% (3/93)*

*Rates are of skeletons with one or more ribs/ hand/ foot bones present. The number of elements were not counted here. The cranial vault was treated as a single element, rather than separating it into its different compnents.

that individual's life. For example, most periostitis of the long bones and all cases of osteomyelitis secondary to trauma and amputation were well healed and hence appeared to be of long standing. Most rib lesions, on the other hand were active at the time of death, and evidently affected these individuals up to the time of their deaths (if not actually being fatal).

Differential diagnosis has been attempted on a number of the more florid cases or where the character and distribution of lesions supported a specific diagnosis. A more detailed analysis is warranted but is beyond the scope of this report.

Osteomyelitis

Osteomyelitis was identified in adult male skeletons 3045, 3148, 3229 and 3241 (CPR 4.12%, n = 97) from the presence of cloacae draining the marrow cavity. All four were secondary to major trauma. Skeleton 3045 had undergone an above-knee amputation of his right leg. The entire element, including the head and neck and shaft, was thickly encased in new bone, which was a mixture of healed and active woven bone at the time of death (an involucrum) (Plate 21). The entire original femoral shaft was thinned and necrotic (sequestrum), the enlarged lumen being connected to the surface of the bone by five cloacae. Clearly the infection was long standing and ongoing. It is unclear if the infection had taken hold preoperatively or was introduced during or after the operation. Amputation in the Royal Navy is discussed in greater detail below.

Skeleton 3229 also displayed osteomyelitis secondary to trauma (Plate 18). In this skeleton, both femora had suffered oblique fractures of the shafts, with associated overlap and callus formation. Whilst the left femoral shaft showed only slight periostitis, two cloacae near the right femoral fracture indicate that secondary osteomyelitis had been present. The smoothness of the callus suggests that both fractures had healed well before death.

Skeleton 3241 had the dubious distinction of having sustained more fractures - at least 16 - than any of the other pensioners examined. Whilst most bones appeared to have healed without becoming infected, fracture of the femoral shaft did result in the bone becoming infected (possibly osteomyelitis), although the shaft had not become thickened. A cloaca had not been identified, however. Unlike the other skeletons in which the femora were affected, the location of osteomyelitis in skeleton 3148 was the right tibial shaft. This infection was probably secondary to fractures of the tibial shaft and of the right fibula.

Chronic respiratory disease

A total of 26 adults with ribs present displayed new woven bone overlying the visceral surface of the

ribs (CPR 28.8%, n = 90). These included one female (skeleton 3174). Active woven bone was also present on the ribs of subadult 3132, and may have been tubercular in origin (discussed below). Interestingly, three-quarters of the adults displayed lesions that were active at the time of death. This is in contrast with the bulk of other periosteal reactions which were well healed, and had occurred some time before death. Woven bone was present on multiple ribs on most of the skeletons (sometimes unilateral but often bilateral) and ranging in number from 1 to 15 affected ribs per skeleton.

The vast majority of respiratory disease leaves no trace on the skeleton. However, where a lesion (such as a bulla or abscess) approximates the ribs, resorption or new bone proliferation on the visceral surface of the rib may occur (Roberts *et al*. 1998, 56). Traditionally, such lesions were associated with tuberculosis, but Roberts *et al*. (1998) concluded that no differential diagnosis was possible without the presence of tubercular lesions in other parts of the skeleton. Acute lobar pneumonia, brochiectasis (eg emphysaema), and less likely, metastatic carcinoma, non-specific osteomyelitis and syphilis are all possible causes. In the Greenwich assemblage none of these lesions were associated with rib fractures, all of which were well healed.

The advanced age of many of the pensioners would have rendered them more vulnerable to respiratory diseases such as pneumonia and lung cancer, as did long standing social practices such as smoking or exposure to industrial pollutants that some may have encountered in civilian occupations after leaving the Royal Navy. Tobacco smoking would have predisposed many to developing lung cancer and emphysaema, and was undoubtedly a highly popular pastime amongst pensioners. Plates 6–9 all show pensioners 'blowing a cloud'. Indeed, the Hospital provided each pensioner with a ration of tobacco. Skeletally, the predilection of pensioners for smoking was revealed by the high prevalence of pipe notches in their dentition. Gibson (2002) found that of the 90 individuals he examined, 14 had pipe notches (15.56%), with some individuals showing more than one (a mean of 1.71 per person). Smoking tobacco aboard ship was prohibited, due to the high risk of fire and was inadvisable on a wooden ship packed with explosives. Seamen chewed tobacco instead (Fremont-Barnes 2005, 45). The habit of smoking tobacco probably developed after leaving active service. Given the longevity of most pensioners, many years had elapsed between discharge and death, leaving ample time for pipe notches to develop, a process that may only take a few years (Ogden pers. comm.).

Maxillary sinusitis

Maxillary sinusitis was observed in seven adult males and one female (TPR 8.6%). Lesions within the maxillary sinuses were only observed where the maxilla was already broken to reveal the cavities. In the Greenwich assemblage, a large proportion of the crania was intact, and hence, the sinuses remained unexamined. Maxillary sinusitis is therefore likely to be considerably under recorded.

The aetiology of maxillary sinusitis is multifactoral and may be caused by allergies, smoke and upper respiratory tract infections (Aufderheide and Rodríguez-Martín 1998; Roberts and Manchester 1995, 131). Air pollution in urban areas became severe during the Industrial Revolution, such that much of 18th-century London was 'cover'd by a cloud of smoke, most people being employed in lighting fires' (Werner cited in Roberts and Cox 2003). Although slightly removed from the centre of the industrial East End, air pollution in Greenwich was probably still considerable. It is also likely that after discharge from the Royal Navy many found work in the smoky industrial cities of the age, and some may also have found employment in industrial processes that generated considerable air pollution. It is thus not surprising to find chronic sinusitis in this population.

Treponemal disease (yaws and venereal syphilis)

Three adult male skeletons (3102, 3151 and 3229) showed bony modification consistent with treponemal disease (CPR 3.09%, n = 97), although it was impossible to differentiate between yaws and venereal syphilis. Treponemal bacteria are responsible for a group of closely related diseases that includes yaws, pinta, endemic syphilis and venereal syphilis. Although the above diseases are characterised by different pathological processes, it is virtually impossible to distinguish between the causative micro-organisms under the microscope, leading some researchers to conclude that it is one and the same in all four diseases (Kiple 2003, 331).

Skeleton 3102 displayed new bone formation with marked thickening of shaft of both tibiae ('sabre shins') and fibulae. Active periostitis was also present on the medial aspects of the distal humeral shafts. Unfortunately, the cranium was not present. Bony changes in skeleton 3151 suggestive of treponemal disease included caries sicca on the frontal bone and also possibly on a parietal bone. Healed periostitis was present on the shafts of the humeri, ulnae and radii, and mixed woven and striated bone overlying the femoral and fibular shafts. Both tibiae showed marked shaft thickening and new bone deposition characteristic of 'sabre shins' (Aufderheide and Rodríguez-Martín 1998). Skeleton 3229 also displayed widespread active and healed periostitis, involving the proximal ulnar shafts, the distal radial shafts, mixed lesions on the fibulae and marked thickening and new bone deposition on the shafts of the tibiae. The anterio-superior aspect of the frontal bone had an uneven appearance with three discrete sunken areas, possibly healed caries sicca.

Table 11 Summary of skeletons with periostitis on multiple elements (N = 54); L = left; R = right; numbers refer to the number of elements involved.

Skeleton	Cranium	Vertebrae	Clavicle	Ribs	Scapula	Humerus	Ulna	Radius	Metacarpals	Ilium	Ischium	Femur	Patella	Tibia	Fibula	Tarsals	Metatarsals
1572														LR			
3019														LR	LR		
3029														LR			
3035				2R, 3 L										LR	LR		
3039	maxillary sinus														L		
3045												R		L			
3068				4R, 7 L										LR			
3072	maxillary sinus											LR		LR	L		LR
3083														LR			
3098		13		6R, 8L										LR			
3099	supra-orbital ridge			7R, 5L											L		
3101				5L										LR			
3102				4L		LR								R	R		
3105												L		LR			
3106														R	R		
3108				6R, 5L	L	LR	LR	LR	L2, R2			LR		LR		1L	
3115				5R		LR											
3119				6R, 5L								LR		LR	R		
3143				6R; 6L										LR			
3144	LR maxillary sinuses														R		
3148														R	LR		
3151	frontal, parietal, palate					LR	LR	LR				LR		LR			
3152				3R										LR			
3162				5R, 6L													

3164	L zygomatic		5R, 10L												L1, R2
3168													LR		
3174			6L									LR			
3176												LR			
3189												LR			
3194		LR	6L, 11R	LR	LR			LR	LR	LR					
3208												LR	LR		
3211													LR		
3212	endocranial		2R												
3229	frontal		1R			LR	LR					LR	LR		
3241			5L, 4R								R	LR	L		
3243			5L, 6R												
3258			3L, 5R												
3261			10R												
3268			2L, 4R												
3272	maxilla		2L, 7R									LR			
3274	R maxillary sinus		5L, 3R												
3623			3L,4R												
3628			4L, 4R												
6003												LR	LR		
6023												LR			
6035												LR	LR		
6056		LR		LR	LR	LR	LR				LR	LR	LR		
6058												LR	LR		
6073												LR			
6089			4L			L	L				LR	LR	LR	LR	
6094												L	LR		
6105												LR			
6151	palate											L			

The prevalence of 3.1% is broadly comparable with the 2.99% found at St George's crypt, Bloomsbury (Boston 2006) and at the Newcastle Infirmary (3.7%), another assemblage that comprised a large proportion of sailors (Nolan 1997). Contemporary assemblages (such as Christ Church, Spitalfields (Cox 1996), and the Quaker burial ground, Kingston-upon-Thames (Bashford and Pollard 1998) reported rates of 0.21% and 0.28%.

Yaws is restricted to tropical regions, and thus is rarely considered as a possible disease in European archaeological populations. The possibility of yaws in the Greenwich assemblage must be taken into account, however, as a small proportion of individuals are known historically to have originated in the tropics, and many saw service in these regions. As yaws most commonly develops in childhood, the former group was more likely to have been sufferers, particularly those originating from Africa and the West Indies, where yaws was endemic. Yaws was a well-recognised health problem amongst plantation slave children in the Caribbean in the 18th century (Brothwell 2003, 362–4). Indeed, early experimentation of vaccination against yaws was carried out by plantation doctors, who claimed some success in its treatment. Royal Navy ships operating in America and the Caribbean are known historically to have included escaped and freed slaves in their crews (Rodger 1986, 159–61), some of whom may well have been suffering from this infection.

In 18th-century Europe, venereal syphilis had long been regarded as the most serious and dreaded of the sexually transmitted diseases. Although the origin of the disease in the Western world is still not well understood, it appears that the presence of syphilis was first felt in the 15th century AD, and that it rapidly spread across Europe (Roberts and Cox 2003, 340). By the post-medieval period, the 'Great Pox' (or the 'French pox' as syphilis was known in England) had become a significant health problem. Prevention of contagion using early forms of condoms and treatments using mercury and guaiacum were largely unsuccessful (loc. cit.). It was really only with the invention of penicillin in the 1930s that any serious inroad was made into control of this disease.

Venereal syphilis is a sexually transmitted infection caused by the bacterium *Trepanima pallidu*m, and is the only treponemal disease that may have a fatal outcome. It is transmitted by sexual contact or may be passed from an infected mother to her foetus. The latter is known as congenital syphilis. Surprisingly, no dental evidence of congenital syphilis (such as Hutchinson's incisors or mulberry molars) was noted in the Greenwich assemblage. Venereal syphilis is a chronic infection characterised by three clinical stages separated by latent stages with no visible symptoms (Arrizabalaga 2003, 316). In primary syphilis, a small painless ulcer or chancre appears on the genitals (and less commonly elsewhere) within 2–6 weeks of infection. In most cases, after a brief latent period, there is a secondary stage characterised by widespread lesions on the skin and in the internal organs, a painless rash, fever, malaise and bone ache. These symptoms disappear after a few weeks, but in 25% of sufferers they recur during the first two years (ibid.). The tertiary stage only develops in a third of untreated cases, and only following a latent phase that may vary in length from one to more than 20 years. It is this tertiary stage that causes such profound systemic damage that results in insanity and death. The bacterium causes progressive destruction of a number of systems of the body, including the skin, mucous membranes, bones, the heart and blood vessels and the nervous system. Nervous system involvement causes a loss of positional sense and sensation that manifests as locomotor ataxia (a stumbling, high stepping gait), and bouts of insanity, known as general paralysis of the insane (ibid.; Roberts and Manchester 1995, 153). Death from tertiary syphilis occurs through cardiovascular involvement, such as a ruptured aneurysm or cardiac valve failure.

The problem of venereal disease was widespread in the Royal Navy, and until 1795 ships' surgeons were entitled to 15 shillings deducted from the infected man's wages (Lloyd 1968, 262; Lavery 1989, 215). The diagnosis of sexually transmitted diseases was itself far from refined, with venereal diseases being confused with that other great naval scourge of the 18th century, scurvy. The lifestyle of seamen and marines made them particularly vulnerable to contracting sexually transmitted diseases, including the 'Pox'. Separation for prolonged periods from wives and sweethearts, the only women available to seamen were the prostitutes who plied their trade in the seaports of Britain and abroad. In his memoir 'Jack Nastyface' (Robinson, 2002, 89, 92) describes these women in the following terms:

> Of all the human race, these poor young creatures are the most pitiable; the ill-usage and the degradation they are driven to submit to, are indescribable. . . .

He concludes with the following reflection:

> I am now happily laid up in matrimonial harbour, blest in a wife and several children, and my constant prayer to heaven is, that my daughters may never step a foot on board of a man-of-war.

Plate 11 shows a scene of revelry below decks in such a ship. On these occasions, literally hundreds of prostitutes were allowed on board. The potential for transmission of venereal diseases was huge. Whilst there was little comeback for seamen in these situations, Picard (2000, 128) reports that on land the usual punishment inflicted by sailors on prostitutes, who had infected them, was to turn the girl out into the street naked except for her stays. This punishment was poor consolation for contracting one of these incurable, painful and sometimes fatal diseases.

Tuberculosis

Bovine tuberculosis (or scrofula) may be spread to humans by the ingestion of infected meat and milk. The strain responsible is Mycobacterium bovis. Alternatively, the disease may be spread from person to person by inhalation of airborne bacilli present in expectorated phlegm. The seat of the primary lesion in this form of tuberculosis is most commonly the lungs, and is caused by the strain Mycobacterium tuberculosis. Known as 'consumption' in the 18th and 19th centuries, the latter route was more common, the spread of infection being facilitated by high population density, poor nutrition and housing, and inadequate hygiene so prevalent amongst the urban poor (Roberts and Cox 2003). The privileged of society were not immune to this terrible scourge, and famous fatalities from tuberculosis included Keats, Chopin, and Emily and Ann Bronte (Dormandy 1999). These were contemporaries of many of the Greenwich pensioners. As the most vulnerable time to contract tuberculosis is in adolescence, the disease was given a romantic sheen by the young people who were tragically cut down before their time. The physical symptoms of elegantly wasting away added to this notion. Yet the reality of the disease for the majority of affected people was far from romantic, and the disease hit the working class the hardest. Tuberculosis was the leading cause of death amongst the poor in the 19th century (Humphreys 1997, 137). Bills of Mortality from the late 18th and early 19th century show a mortality rate due to consumption of around 25% (Roberts and Cox 2003, 338).

Bone involvement is not present in the majority of tubercular cases. Recent clinical studies have shown that this is present in only 1% of patients (Roberts and Manchester 1995). Before the availability of antibiotics, this figure averaged 5–7% (Aufderheide and Rodríguez- Martín 1998, 133). Most cases of tuberculosis therefore go unrecognised in palaeopathology, and this was undoubtedly the case with the Greenwich pensioners. The true prevalence of the disease was probably much higher.

On the skeletons, new bone growth on the ribs of 26 individuals may be suggestive of tuberculosis, but on their own it is not possible to differentially diagnose tuberculosis from other respiratory diseases. Characteristic lesions in other parts of the body are required. For example, lesions involving the spine have been reported in 25–50% of cases of skeletal tuberculosis (Roberts and Manchester 1995, 138). These smooth-walled lytic lesions in the vertebral bodies are caused by tubercular abscesses, which eventually cause the vertebral body to collapse, causing compression fractures. A profound hunch back (kyphosis) may result. These spinal changes are known as Pott's disease.

Two adult males (3098 and 3099) and one subadult (3132) showed lesions heavily suggestive of tuberculosis (CPR 2.8% of total population; or CPR 2.06% of adult males). A severe case of Pott's disease was manifest in the spinal column of skeleton 3098 (Plate 22). Cortical destruction of the anterior vertebral bodies was present in thoracic vertebrae 1 to 5, with multiple lytic lesions present on the anterior and/or right sides of vertebral bodies of thoracic vertebrae 2 to 5 (most severe in thoracic vertebrae 4 and 5). Similar lesions were noted on thoracic vertebrae 6 to 10, with vertical collapse and wedging of thoracic vertebra 8 and complete destruction of thoracic vertebra 7. Thoracic vertebrae 11 and 12 and lumbar vertebra 1 were ankylosed. The resultant deformity was a kyphosis or Pott's deformity, characteristic of spinal tuberculosis. Incomplete ankylosis of the sacro-iliac joint may be secondary to this deformity. Tubercular lesions were also noted in lumbar vertebra 4. Rib involvement was bilateral, with active woven bone deposited on the visceral surfaces of right ribs 5 to 10, and left ribs 3 to 11. Erosive lesions at the head and neck of six ribs are characteristic of the disease.

Subadult skeleton 3132 also displayed costal and spinal lesions indicative of tuberculosis in thoracic vertebrae 4 to 12 and lumbar vertebrae 1 and 2. Large lytic lesions were present in thoracic vertebra 4 to 12 and lumbar vertebrae 1 and 2, with collapse of the vertebral bodies of thoracic vertebrae 7 to 11. Ankylosis of many thoracic bodies and secondary deformation of many ribs resulted in a marked kyphosis, with an exaggerated anterior curvature of 45–60°. As with skeleton 3098 both new woven bone and erosive lesions were present on the ribs. Skeleton 3132 was only 12–14 years old when he died.

Skeleton 3099 did not display spinal changes, but the smooth rounded erosive lesions present on the necks of right ribs 3 to 11, coupled with new bone deposition on the visceral surfaces of seven right and five left ribs (mixed woven and lamellar bone) were suggestive of tuberculosis.

A CPR of 2.8% in the total Greenwich population was higher than the mean prevalence of 0.62% found in four post-medieval sites discussed by Roberts and Cox (2003, 339). It is considerably greater than the highest rate of 1.6% reported from Newcastle Infirmary, not unexpected in this working class assemblage. The high rate at Greenwich may reflect the working class origins of this population in which the disease was rife. Aboard ship, seamen slept cheek by jowl in their hammocks (each with an allowance of 14 inches). The close quarters of the lower decks where fresh air was often assiduously kept out to create a 'good fug', may well have facilitated the spread of the disease from an infected seamen to his mates. Chaplain Edward Mangin referred to the heat in the 'cavern' of the lower deck as 'so entirely filled with human bodies' as to be 'overpowering' (cited in Lavery 2004, 50). He wrote this in spring on the North Sea when the gunports were usually kept closed, but even in more clement weather when these were opened (dependent on the acquiescence of the captain), ventilation was never very good. It is thus not surprising that the spread of infectious disease was an ever-present threat to the wellbeing of the ship. In these conditions, droplet infection would have been particularly rife.

Joint disease

General wear and tear of the joints over years often results in degenerative joint disease (DJD) and osteoarthritis with increasing age. These changes may also occur in response to repeated stress on joints brought about by strenuous exercise. For example, carrying heavy weights may result in spinal joint degeneration, particularly the lower spine. The presence of these disorders in the Greenwich population reflects both their advanced age and the hard manual labour most undertook whilst aboard ship in the Royal Navy, on merchant ships, and in other occupations in the years preceding and following this service. Marine record papers reveal that many were labourers before joining the Navy, whilst servicemen often took up physically demanding jobs on discharge. In addition, many arthropathies may have developed secondary to trauma and amputations.

Degenerative joint disease

Degenerative joint disease (DJD) and associated osteoarthritis (OA) are two of the most common pathologies found in both living (Meisel and Bullough, 1984) and archaeological populations (Ortner and Putschar 1981, 419-33; Rogers and Waldron 1995, 32). DJD is a multifactoral systemic non-inflammatory disorder, with clinical symptoms of pain and stiffness in movable joints, which may cause major disability in severe cases (Denko 2003, 234). Symptoms, however, are not necessarily proportional to the severity of bony changes on the skeleton. Bony outgrowths or osteophytes often occur on or around the articular surfaces of joints, but resorption of bone (manifesting as porosity of the joint surface, and as subchondral cysts beneath the joint surfaces) are also common features of this disorder (Roberts and Manchester 1995). DJD is diagnosed when the above bony changes occur, but these may occur as part of the normal ageing process, being uncommon in under 30 year olds, but found in 80–90% of modern individuals over 75 years of age (Aufderheide and Rodríguez-Martín 1998, 96). Alone these changes are not necessarily diagnostic of osteoarthritis (Roberts and Manchester 1995). Waldron and Rogers (1991) recommended that osteoarthritis may only be identified if eburnation and/or at least two bony changes are present. The loss of cartilage lining covering the joint surfaces leads to eburnation (polishing of the exposed bone surfaces where they rub together). In the Greenwich assemblage, identification of osteoarthritis was based on eburnation alone.

The aetiology of degenerative joint disease is not fully understood, but its prevalence does increase with advancing age (Doyle 1986). Everyday 'wear-and-tear' over the years is believed to underlie this disorder, but may be accelerated by repeated strenuous activity, such as carrying heavy loads, throwing projectiles, and pushing and pulling heavy objects (Gunn 1974; Jurmain 1999), particularly relating to upper limb joints. Genetic predisposition to this disorder may also influence disease development (Rogers and Waldron 1995). The advanced age and the lifestyle aboard ship would have rendered the Greenwich pensioners particularly vulnerable to developing DJD. In addition, joint disease may develop as a secondary response to trauma (such as a fracture) and metabolic diseases (such as osteoporosis), amongst others. A number of examples of this secondary DJD were apparent in the Greenwich assemblage.

DJD was present in at least one vertebra of the spines of the adult males (CPR 96.9%), in five of the women and in the one adult of unknown sex (CPR 95.23% of the adult population). These took the form of osteophytes or macroporosity. The severity and distribution of these lesions were recorded during the analysis, but analysis of these data lies beyond the scope of this report. In a number of cases, osteophyte formation was so extensive that ankylosis of adjacent vertebrae resulted. Wedge fractures of vertebrae were also present (either as a result of trauma or secondary to osteoporosis), and were frequently associated with DJD or osteoarthritis.

Osteoarthritis

Osteoarthritis was diagnosed where eburnation was present on at least one surface of the joint. The prevalence of extra-spinal osteoarthritis per joint present is summarised in Table 12. The overall crude prevalence was 60.65% (n = 107).

In the Greenwich males, the joints of the elbows, wrists, hand and feet showed the greatest prevalence. Two women with the disorder suffered osteoarthritis of the hands. It is interesting that in the males, the major weight-bearing joints of the hips and knees showed little involvement. In modern western populations, osteoarthritis most commonly occurs in the hips and lower spine of males (particularly white males), and in the cervical spine, knees and finger joints of women (Denko 2003, 235; Weiss and Jurmain 2007).

The aetiology underlying the development and the severity of osteoarthritis is notoriously complex and poorly understood. Genetics, build, body mass index, sex, age and mechanical loading from strenuous repeated activities may all play a role in its development (Weiss and Jurmain 2007). The advanced age of most Greenwich pensioners may account, in part, for the high rate of the disease in this assemblage. However, mechanical loading due to specific repetitive and strenuous actions was also very likely to have played a significant role, particularly in osteoarthritis of the upper limbs, and possibly, also of the feet. In the upper body, most affected were the wrists (TPR left, 16%; right, 11.11%) and hands (left, 20%, right, 24.29%), followed by the elbows (left, 12.8%, right, 9.18%). There did not appear to be a clear pattern of handedness, with the left wrist and shoulder more affected than the right, whilst the right hand showed greater involvement than the left.

Table 12 True prevalence of extra-spinal osteoarthritis by joint in adults (N = 105).

Joint	Bones considered	Males n/N (%)	Females n/N (%)	Adults n/N (%)
Left Temporo-mandibular joint	Temporal, mandible	1/76 (1.0%)	0/4 (0%)	1/80 (1.25%)
Right Temporo-mandibular joint	Temporal, mandible	0/75 (0%)	0/4 (0%)	0/79 (0%)
Left shoulder -gleno-humeral joint	Humerus (PE), scapula	5/86 (5.49%)	0/6 (0%)	5/92 (5.32%)
Right shoulder (gleno-humeral joint)	Humerus (PE), scapula	10/84 (6.67%)	0/6 (0%)	10/92 (10.87%)
Left elbow	Humerus (DE), radius (PE), ulna (PE)	10/78 (12.8%)	0/6 (0%)	10/84 (11.9%)
Right elbow	Humerus (DE), radius (PE), ulna (PE)	9/89 (9.18%)	0/6 (0%)	9/95 (9.47%)
Left Wrist (radiocarpal joint)2	Radius (DE), ulna (DE), scaphoid, lunate and triquetral	12/63 (16%)	1/6 (16.67%)	13/69 (18.84%)
Right Wrist (radiocarpal joint)2	Radius (DE), ulna (DE), scaphoid, lunate and triquetral	9/72 (11.11%)	0/5 (0%)	9/77 (11.69%)
Left Hand	All joint surfaces of carpals, metacarpals and phalanges	17/68 (20%)	1/ 6 (16.67%)	18/74 (24.32%)
Right Hand	All joint surfaces of carpals, metacarpals and phalanges	17/70 (24.29%)	0/6 (0%)	17/76 (22.37%)
Left Hip	*Os coxa* (acetabulum), femur (PE)	4/86 (4.44%)	0/6 (0%)	4/92 (4.35%)
Right Hip	*Os coxa* (acetabulum), femur (PE)	4/88 (4.35%)	0/6 (0%)	4/94 (4.26%)
Left Knee	Femur (DE), patella, Tibia (PE)	3/83 (3.49%)	0/5 (0%)	3/88 (3.41%)
Right Knee	Femur (DE), patella, Tibia (PE)	3/83 (3.49%)	0/5 (0%)	3/88 (3.41%)
Left Ankle	Tibia (DE), fibula (DE), talus	3/82 (3.53%)	0/5 (0%)	3/87 (3.45%)
Right Ankle	Tibia (DE), fibula (DE), talus	1/83 (1.19%)	0/5 (0%)	1/87 (1.14%)
Left Foot	All joint surfaces of tarsals, metatarsals and phalanges.	19/63 (30.16%)	0/6 (0%)	19/69 (27.54%)
Right Foot	All joint surfaces of tarsals, metatarsals and phalanges.	19/61 (31.15%)	0/5 (0%)	19/66 (28.79%)

During the analysis, it was remarked that a number of the skeletons displayed extension of the anterior aspect of the distal humeral joint, a change consistent with hyperflexion of the elbow. This, together with marked muscle attachments to the long bones of the arms and hands, does suggest strenuous use of the arms in this population, particularly of flexion. This interpretation is consistent with the high prevalence of elbow osteoarthritis in this group, a location thought to be more closely associated with activity, due to the specific bio-mechanical properties of the joint (Resnick and Niwayama 1995). The repetitive and strenuous activity of pulling on ropes or stays during the general sailing of a ship, and moving aloft in the rigging, (propelled principally by the arms) may explain these phenomenon in the Greenwich pensioners.

Interestingly, the highest prevalence of osteoarthritis was not in the upper body, but in the feet, where at least one bone of 19 left and 19 right feet showed eburnation (TPR 30.16% and 31.15%, respectively). The first metatarsal was most commonly affected. The reason for this distribution is unclear, but may relate to the seamen's practice of going barefoot whilst aboard ship, and from abnormal weight distribution whilst maintaining their balance aloft. In contrast, osteoarthritis of the hip, knee, and ankle joints was low.

There has been little work undertaken on joint disease in seafarers. No discussion on the distribution or prevalence of osteoarthritis was forthcoming in Stirland's osteological analysis of the crew of the 16th century flagship, the Mary Rose, the only other report on a British ship's crew in the Age of Sail (Stirland

2005). In contemporary civilian populations, such as the named and unnamed assemblages from St Luke's church, Islington, and St George's crypt, Bloomsbury, the distribution of lesions was very different. Amongst the males of the former, the hips, knee joints, lumbar spine and big toe joints were most affected (Boyle *et al.* 2005), whilst in the latter it was the hands and feet (Boston et al. 2006; Boston *et al.* forthcoming). Overall the crude prevalence in both these populations was much lower than Greenwich: 10.1% in the former and 39% in the latter, older population. Non-spinal osteoarthritis was 13.79% in the Newcastle Infirmary assemblage (quoted in Roberts and Cox 2003, 252) a population thought to comprise a high proportion of merchant seamen.

Unfortunately, a more detailed analysis of the distribution patterns of osteoarthritis and activity-related changes in the Greenwich assemblage lay beyond the scope of this report. Further research in this specialist population is certainly warranted.

Schmorl's nodes

Schmorl's nodes are identified as indentations on the superior and inferior surfaces of the vertebral bodies, and are most common in the thoracic and lumbar regions (Rogers and Waldron 1995, 27). These are caused by the herniation of the intervertebral disc through the end plates and are therefore, in effect, pressure defects. In the Greenwich assemblage 70 adults (CPR 66.67%) displayed Schmorl's nodes, and of these, 67 were adult males (CPR 69%, n = 97), 2 were females, and 1 an unsexed adult. In addition, subadult 3249 (aged 16–18 years) also showed Schmorl's nodes on T12, L2 and L5, in the absence of other degenerative changes. There was insufficient recording to identify this condition more specifically (eg Scheierman's disease).

Schmorl's nodes are often a feature of spinal DJD, and are frequently found associated with osteophytes and porosity. Like these other lesions, Schmorl's nodes become increasingly common with age, and are present in most individuals over 45 years of age (Aufderheide and Rodríguez- Martín 1998, 97). This may account for its high prevalence in the Greenwich sample, although the carrying of heavy weights and a strenuous physical lifestyle undoubtedly exacerbated this condition.

Rheumatoid arthritis

One adult male skeleton (3265) had erosive lesions to joints of the hands and feet consistent with rheumatoid arthritis. The changes were bilateral. In both hands, the carpals, distal metacarpal joints one to three, and the proximal and inter-phalangeal joints of digits one to four were affected. The joint surface of the left interphalangeal joints two to three were completely destroyed, presenting a very ragged appearance. Bilaterally the feet showed erosive lesions to the distal first metatarsal and to the proximal joint surfaces of metatarsals one to four. The picture was somewhat complicated by co-existing osteoarthritis in this skeleton.

Rheumatoid arthritis is an autoimmune disease and affects approximately 1% of modern populations (Roberts and Manchester 1995, 116). It is three times more common in females than in males. The disease has its onset in the fourth or fifth decades (Rogers and Waldron, 1995, 55–56). Rheumatoid arthritis is a chronic inflammatory disease, which affects multiple synovial joints bilaterally, most commonly involving the hands, feet, wrists and elbows (Roberts and Manchester 1995, 116). The lesions on skeleton 3265 are consistent with this distribution. The synovial membranes of the joints are initially affected, becoming thickened and granulated. This spreads to the cartilage of the joint, eventually destroying it. The underlying bone is also eroded and ankylosis may occur. The joints become swollen, stiff and very painful. Additional physical symptoms include anaemia, weight loss and fever (Roberts and Manchester 1995, 116; Aufderheide and Rodríguez-Martín 1998, 100). A famous sufferer, who was a contemporary of many of the Greenwich pensioners, is thought to have been the poet Samuel Taylor Coleridge. His liberal use of laudanum to contain the pain caused by his affected hands led to his opium addiction, and hence, to the penning of such memorable poems as 'Kubla Khan-a fragment in a dream' and (appropriately enough in this context) 'The Rime of the Ancient Mariner' (Lefebure 1974).

Diffuse Idiopathic Systemic Hyperostosis (DISH)

Diffuse Idiopathic Systemic Hyperostosis (DISH) is characterised by the ossification of the anterior longitudinal spinal ligament causing a flowing candle-wax-like new bone formation, most commonly on the right side of the vertebral bodies (Rogers and Waldron 1995, 48–49). At least four consecutive vertebrae should be involved to warrant this diagnosis (ibid.). There is also enthesophyte formation at major ligament insertion points, and ossification of cartilage (Roberts and Manchester 1995, 120). The symptoms produced by the disease are generally mild but include stiffness and aching. Modern prevalence of the disease varies between 6 and 12%, affecting more males than females. Prevalence increases with age, 85% of cases being found in individuals aged over 50 years. There is also an association with diabetes and obesity (Rogers and Waldron 1995, 48), and hence, DISH has come to be regarded as a disease of affluence and fine living. The association of DISH with over-indulgence was borne out by the prevalence of the condition in more affluent 18th-century populations. In the upper middle class assemblages of Christ Church, Spitalfields (Molleson *et al*. 1993) and St George's, Bloomsbury (Boston *et al*. 2006; Boston *et al.* forthcoming), the rates were 5.79% and 4.17%, respectively. In the more mixed population (but still with a high proportion of the well-to-do) of St Luke's Church, Islington, the prevalence was 2.28% (Boston

and Witkin 2005) whilst in the working class population of the Cross Bones burial ground, Southwark, no cases were identified (Brickley *et al.* 1999). At St Martin's Church, Birmingham, the overall prevalence was 2.42%, with a higher rate in skeletons buried within brick-lined shaft graves and vaults compared to earth-cut graves (Brickley *et al*. 2006). Clearly, affluence influenced the prevalence of this condition.

In the light of this aetiology, it is surprising that DISH was present amongst the Greenwich pensioners, given their social class and occupations. It was recognised in two adult males (CPR 2.06%, n = 97; or 1.87% of the total population). Of the Greenwich pensioners, 90 skeletons had at least four thoracic vertebrae preserved (2.22%). Fifteen of the 1016 thoracic vertebrae present were affected (TPR 1.48%), whilst only 0.423% of lumbar vertebrae (2 of 473) were involved.

Skeleton 3182 showed the characteristic dripping candle wax lesions and ankylosis of the right side of vertebrae T7-L1, and enthesophytosis of the proximal ulnae, calcanei and tibiae. In skeleton 6085, the characteristic 'dripping candle wax' osteophyte formation was present on the right side of the vertebral bodies of T4-L1, resulting in ankylosis of these joints. Large enthesophytes were present on the anterior tibiae.

The crude prevalence of 2.06% is broadly comparable with St Martin's, Birmingham (Brickley *et al.* 2006). However, the high proportion of aged males (the highest risk group for DISH) in the Greenwich assemblage must be borne in mind when undertaking inter-population comparisons, as this may lead to erroneous interpretations.

Metabolic disorders

Iron deficiency anaemia

Thirty-four males and one female (33.33% of adults, n = 105; or 32.71% of the total population, n = 107) showed lesions characteristic of cribra orbitalia (CPR). All lesions were healed. Neither subadult displayed these lesions. Forty-nine skeletons showed pitting and thickening of the diploë of the parietal and/or frontal bones of the skull (CPR 45.79%, n = 107). Although the diagnosis was not confirmed using radiography, these changes were interpreted as porotic hyperostosis. Twenty- seven individuals with porotic hyperostosis also had cribra orbital (CPR 55.1%). Cribra orbitalia and porotic hyperostosis are thought to occur widely in response to a deficiency of iron during childhood, most commonly the result of inadequate dietary intake of iron, and/or as a result of severe intestinal parasite infestation (Stuart-Macadam 1991, 101). Iron is a central component of haemoglobin, the molecule necessary for the transportation of oxygen in the red blood cells of the blood. Red blood cells are produced within the red bone marrow of a number of bones of the body, which include the diploë of the cranial vault, the sternum and the pelvis. In childhood, the diploë are particularly important, but become a secondary site of red blood cell production later in life. In iron deficiency anaemia, the body attempts to compensate for low serum iron levels by hypertrophy of these bones (Aufderheide and Rodríguez- Martín 1998, 346). In children, this manifests osteologically as an increased porosity and thickening of the diploë of the cranial vault (known as porotic hyperostosis) and of the orbital sockets (cribra orbitalia). The latter is often used as a generic indicator of physical stress in childhood. The physical symptoms of anaemia are shortness of breath, fatigue, pallor and palpitations (Roberts and Manchester 1995, 167). Another disease that manifests similarly to iron deficiency anaemia is scurvy (a severe deficiency of vitamin C), and much of the so-called cribra orbitalia described below, in fact, may have been the result of scurvy.

The crude prevalence of cribra orbitalia in the Christ Church, Spitalfields assemblage was 14.57% (Molleson and Cox 1993), whilst in the named assemblage of St Luke's, Islington, it was 9.5% (Boyle *et al*. 2005, 235) and at St Martin's, Birmingham, it was 9.64% (Brickley *et al*. 2006, 126). Interestingly, the lowest prevalence (4.05%) was noted in the paupers of the Cross Bones, Southwark assemblage (Brickley *et al*. 1999). The association between cribra orbitalia and higher social class may reflect infant feeding practices of the day, in which pap or panada (a gruel of flour and water) were substituted for breast milk early in infancy (Roberts and Cox 2003, 307). The poor of Southwark, who through economic necessity were forced to breastfeed longer than their more affluent counterparts, appear to have spared their children some of the illnesses afflicting children of the middling sort. Historical documentation on the Greenwich pensioners attests to their working class origins, and being a childhood disorder, a similar prevalence of cribra orbitalia to the Cross Bones assemblage might be expected. The Greenwich assemblage showed by far the highest prevalence of this disorder amongst the assemblages named above.

In examining the age distribution of cribra orbitalia in the St Martin's, Birmingham, assemblage, Brickley, Buteux, *et al*. (2005, 134) found a prevalence of 20.79% in subadults compared to 5.80% in adults. This difference may be due to remodelling of lesions over time, and the possible association of iron deficiency with greater childhood morbidity and mortality. Their research makes the crude prevalence of 33.33% in the ageing adult population of Greenwich even more remarkable.

A significant proportion of the seamen of the Royal Navy were 'recruited' from seaports, and many had grown up 'using the sea'. It is to be assumed that they had a ready access to fresh fish, but their intake of meat and iron-rich vegetables was probably fairly low. Regular meat consumption lay beyond the means of most poorer families, whilst traditional diets rarely comprised much fresh fruit and vegetables (Roberts and Cox 2003). Once aboard ship, the supply of fresh vegetables and fruit was erratic, depending on the ship putting into port, as fruit and

vegetables were highly perishable, and preservation by pickling,(e.g. sauerkraut) was unpopular. Vegetable supplies most commonly mentioned in ships' logs are onions and cabbages. 'Greens', pumpkins, carrots and turnips were also listed (MacDonald 2006, 38). Harvie (2002) comments that by the later 18th century some enlightened captains, such as Captain Cook, attempted to introduce these victuals into the seamen's diet in an attempt to combat scurvy. They were met with considerable resistance from their crews, who regarded these foodstuffs as foreign to a normal diet. However, it should be noted that in the *Additional Regulations and Instructions*, published with the 1790 edition of *Regulations and Instructions relating to His Majesty's Service at Sea* it is noted that it had long been the practice of pursers, when fresh meat was served, to include 'such a quantity of greens and roots to . . . give sufficient satisfaction to the men . . .' (Macdonald 2006, 36–7; see also Rodger 2004, 484–86).

Once in the Royal Navy, a seaman could enjoy a regular supply of red meat (mostly salted), the standard issue being 2lb of beef twice a week and 1lb of pork twice a week (Fremont-Barnes 2005, 25; see also Macdonald 2006, 10, 15–44). Unless compromised by disease (eg. bleeding gastric ulcers, malaria or 'the bloody flux' - dysentery) or blood loss from trauma or rampant intestinal parasitic infestation, it is unlikely that he would develop anaemia. Given the adult age of most seamen, it is also doubtful that such deficiency would manifest on the skeleton as cribra orbitalia or porotic hyperostosis.

The most probable explanation for the high prevalence of cribra orbitalia may lie more in differential diagnosis, and it is highly possible that some of the lesions ascribed to iron deficiency anaemia were in fact scurvy (see next section).

Scurvy

The 15th-century Portuguese explorer Vasco Da Gama referred to scurvy as 'death's dire ravage'. This description was no exaggeration, for during his voyage of discovery around the tip of Africa to the East Indies, 100 of his 160 seamen are thought to have died of this disease (Harvie 2002, 14). In the 18th century, scurvy became a major problem for the Royal Navy, which had hitherto sailed mostly in home waters but who increasingly undertook long transoceanic voyages in pursuit of colonial aspirations and in protection of the merchant navy, so seminal to successful trade (ibid., 18). Scurvy and fevers were the two greatest killers of seamen. As the philosopher and evolutionary theorist, Herbert Spenser (cited in Harvie 2002, 197) commented that:

> the mortality from scurvy during this long period [the 17th and 18th centuries] has exceeded the mortality by battle, wrecks, and all the casualties of sea life, put together.

But against this Rodger (1986, 100–3) has argued that scurvy had been a widespread problem, but that few had actually died from the disease, and further that scurvy largely ceased to be a real problem for the Navy from the time of the Seven Years War. Rodger (2004, 308) also suggests that the effects of scurvy have been exaggerated. He quotes the physician Edward Strother who wrote in *An essay on sickness and health*, 1725 that

> It is yet a sufficient Answer to Patients when they enquire into their ailments to give this Return to a troublesome Enquirer, that their Disease is the Scurvy, they rest satisfied that they are devoured with a Complication of bad Symptoms . . .

Rodger argues that scurvy used as a convenient catch-all term by naval surgeons.

Scurvy is a dietary deficiency disease arising from a prolonged lack of Vitamin C (ascorbic acid), and usually develops in the absence of vegetables and fruit in the diet (French 2003, 295). Vitamin C deficiency results in defective hydroxylation of proline and lysine, two amino acids of collagen, a major structural component of blood capillaries and bone matrix (Follis 1954, cited in Maat 2004, 78). Defective collagen results in fragile capillaries and weakened bone tissue, such that minor trauma (such as a knock on the shin) will precipitate bleeding and bone infractions (fractures limited to the cortex of bone). Weight-bearing extremities (the legs and feet), the heart and digestive tract are particularly vulnerable to major haemorrhaging, which may be fatal (ibid.).

Modern experiments have revealed the following pattern of the disease: after 12 weeks without Vitamin C, a feeling of lethargy develops; by 19 weeks, the skin becomes dry and rough, and hair follicles form lumps; at 23 weeks small haemorrhages in the legs begin, and slightly later, fresh wounds will not heal. The classic symptom of swollen purpled gums appears at 30 weeks, and the potentially fatal cardiac haemorrhages at 36 to 38 weeks (French 2003, 295). This description of the disease broadly concurs with eyewitness accounts of scurvy afflicting sailors on long voyages. In 1535, Jacque Cartier exploring the St Lawrence River in Canada wrote this description of scurvy afflicting his crew (cited in Harvie 2002, 15):

> the unknownen sicknes began to spread itselfe amongst us after the strangest sott that ever was eyther heard of or seene, insomuch as some did lose all their strength, and could not stand on their feete, then did their legges swel, their sinews shrinke as black as any cole. Others had all their skins spotted with spots of blood of a purple coulour: then did it ascend up to their ankles, knees, thighes, shoulders, armes and necke: their gummes so rotten, that all the flesh did fall off, even to the roots of the teeth, which also almost fell out. With such infection did this sicknes spread itself in our

> three ships, that about the middle of February, of a hundred and ten persons that we were, there were not ten whole.

Cartier's expedition was only saved by the intervention of some friendly Indians who made them a concoction of the sap and leaves of an indigenous tree. This is one of the first successful cures for scurvy in the long history of misunderstanding of the nature of the disease and its treatment. Some naval surgeons and physicians of the 17th and 18th centuries felt that scurvy was a symptom of venereal disease, whilst others ascribed it to the 'bloody flux' (dysentery). Treatments included bleeding and cupping (a favourite treatment of a wide range of disorders at that time); cinchona bark (the source of quinine); spruce beer; molasses; fumigations of tobacco and tar; burying the sufferer up to his neck in warm sand; numerous quack remedies (some ineffective but innocuous, and some downright toxic), and the consumption of scurvy grass, strong cider, sauerkraut and citrus fruit (Harvie 2002). There were some real benefits in the last four as all contain varying amounts of ascorbic acid, but it was really only with the belated introduction of citrus fruit, particularly lemons, into the diet of seamen that significant inroads were made into the disease.

Discovering an effective cure was slow in coming, despite the merchant and Royal Navy losing large numbers of men to the disease. Famously, Commodore Anson's Pacific expedition which set out in 1740 with six warships and two supply ships and nearly 2000 men, suffered great loses from scurvy and typhoid. After circumnavigating the globe, only one ship the *Centurion* returned in 1744 with less than 200 men. One ship - the *Wager* - had been wrecked – and another – *Gloucester* – was burnt because there were not enough men to sail her.

The influence of ignorant but highly influential physicians to the Admiralty significantly delayed systematic research into treatment, and it was only when a relatively humble naval surgeon, James Lind, conducted more scientific experiments using different 'curatives' than any real progress was made. In 1753 Lind published his results, in which he recommended the use of citrus fruit, but his findings were largely ignored. It took a further four decades, and championing by two more influential surgeons, Blane and Trotter, before the Admiralty introduced the compulsory consumption of lemon juice aboard ship (Harvie 2002; French 2003, 296). From then on lemon juice was issued with the daily rum ration. The mixture of rum and lemon juice sweetened with sugar became known as 'grog' (Fremont-Barnes 2005), the drink so associated in the public mind with sailors of this period. The effect of the compulsory introduction of lemon juice was dramatic, and by 1795 the scourge of scurvy was eliminated in the Royal Navy. 'Limey', the American nickname for English seamen (from the word *limone* or lemon, *not* lime), refers to this practice.

Whilst the ubiquitous nature of scurvy in the Royal Navy of the 18th century is well recognised in documentary sources, identification of diagnostic lesions on the skeleton is less straightforward, and differential diagnosis of lesions is often problematic (Ortner *et al*. 1999). This is because many other conditions produce similar changes (Stirland 2005, 525). Deficiency in Vitamin C results in defective collagen, which in turn retards normal growth in subadults, and small blood vessel wall integrity, resulting in haemorrhage (Aufderheide and Rodríguez- Martín 1998, 312). Subperiosteal haemorrhages from minor trauma in both adults and subadults manifest as diffuse but localised new bone deposition on the diaphyses of long bones when ossification of the haemorrhage occurs (ibid.). Maat's (1982) work on Dutch sailors found that such lesions were the hallmark of scurvy, but they may be readily mistaken for periostitis associated with localised infection or other causes (such as venous ulcers or varicose veins), as discussed above. It is highly probable that some periostitis recorded in the Greenwich assemblage was scorbutic in nature, particularly where it occurred bilaterally or in multiple elements. An unusually large number of pensioners suffered multiple element involvement, particularly of the lower extremities (Table 11). It is uncertain how many of these were precipitated by scurvy.

Another skeletal indicator of scurvy is the sieve-like lesions in the eye sockets (Aufderheide and Rodríguez- Martín 1998). These are often difficult to distinguish from cribra orbitalia, and it is probable that some lesions ascribed to iron deficiency may well be scorbutic in nature. Stirland (2005, 526) attributed pitting on the parietal bones observed in 16th-century sailors of the Mary Rose to scurvy. The ectocranial surface had a thickened orange peel appearance. This appeared to be similar to cranial lesions recorded on skeleton 3255 of the Greenwich assemblage. New bone deposition on the bone surface had resulted in a nodular, bumpy appearance. The diploë were slightly hypertrophied. Of course, such lesions may not be scorbutic in nature, and may be attributed to a number of other disorders, such as iron deficiency anaemia, the presence of porotic hyperostosis being thought to be differentially diagnosis. Skeleton 3255 showed no other bony changes that might suggest a diagnosis of scurvy.

Ortner and Ericksen (1997) recognised that bony changes on the greater wing of the sphenoid were indicative of scurvy. Fine foramina were observed on these bones in 12 pensioners (CPR 12.37% of males; 11.21% of total population), and formed the basis for diagnosis of the disease in this report (Table 13). Skeleton 3152 also showed pitting and new bone formation on the infra-temporal surfaces of the maxillae, located at the insertion sites of the Pterygoid medialis and lateralis muscles. As scurvy may manifest on the bones and teeth in a number of ways, it is not unreasonable to assume that a scorbutic individual may display multiple diverse lesions. Table 13 summarises the presence of sphenoid and

Table 13 Pathology present on 12 adult males displaying bony modification of the sphenoid consistent with scurvy (N = 12).

Skeleton	Sphenoid/ pterygoid plates	Periostitis of long bone shafts	Cribra orbitalia	Porotic hyperostosis	AMTL (N = 376 sockets)
3016	healed foramina	-	-	healed	31
3024	healed foramina	-	-	-	2
3029	healed foramina	L & R tibiae	-	-	1
3035	healed foramina	L & R fibulae & tibiae	healed Grade 1	healed	28
3103	healed foramina	L tibia	-	-	32
3152	healed foramina; also lesions on maxillae	R tibia	healed Grade 1	-	1
3241	healed foramina	L & R tibiae; R femur	healed Grade 2	-	24
3272	healed foramina	L & R tibiae	healed Grade 2	healed	21
6056	healed foramina	L & R tibiae, fibulae, femora, radii, ulnae, humeri clavicles, scapular blades	-	healed	6
3086	healed foramina	-	healed Grade 2	healed	1
3144	healed foramina	R fibula	-	-	32
3253	healed foramina	-	-	-	28
Total	**12**	**8**	**5**	**5**	**207 (55.05%)**

pterygoid lesions, periostitis, cribra orbitalia, porotic hyperostosis and ante-mortem tooth loss (AMTL) in the above 12 individuals. Eight displayed periostitis, of which five involved more than one bone, usually the lower limb bones. Skeleton 6056 showed gross involvement of most of the upper and lower limb bones, the mixture of healed, lamellar bone, spicules and active bone clearly indicating a condition of long standing, which was still active at the time of death. The characteristics of the lesions and the ongoing nature of the disease in this 50+ year old male makes it unlikely that this was scorbutic in origin, as he had undoubtedly been ashore for many years prior to his demise. In this case, alternative diagnoses, such as pulmonary arthropathy, should be considered. Similarly, given the rough-and-tumble lifestyle of so many seamen (even in their dotage), periostitis may be due to a wide range of another causes. The crude prevalence of periostitis in the 12 scorbutic individuals is nevertheless higher than for the total adult male population.

Cribra orbitalia was present in five of the 12 individuals, and as would be expected in ageing adults, was healed and manifested as low grades of severity (Grades 1 and 2 according to Stuart-Macadam's criteria (1991). Five cases of 'porotic hyperostosis' were also present. Tooth loss secondary to gum involvement has been reported historically. In the 12 individuals, a true prevalence of AMTL was 55.05% of alveolar sockets present - almost 10% higher than the adult male population average (TPR 44.67 %). Whilst this is only a small group, and the presence of each individual pathology may be attributed to different diseases and advanced age, it is nevertheless interesting that all these individuals, with the exception of skeleton 3024 showed more than one pathology that may have been scorbutic in origin.

Rickets

Rickets is due to a childhood deficiency of Vitamin D (Roberts and Manchester 1995, 173). In adults, this deficiency is known as osteomalacia. Vitamin D is mainly synthesised by the skin when it is exposed to sunlight, but may also be obtained from foods, such as eggs and oily fish. The vitamin is needed for the uptake of calcium, and hence, the normal mineralisation of bone. In rickets, the bones soften, allowing them to distort, particularly the major long bones. Bowing of the weight-bearing bones of the legs (tibiae and femora) manifests most commonly in the skeletal record, but if rickets develops early in life when an infant is still crawling, the arm bones may be similarly affected (ibid.). In severe cases, the individual may become markedly knock-kneed, making locomotion difficult and painful. Large nodules of bone may also grow on the end of the ribs producing a concave or pigeon chest. The pelvic bone may also deform, making childbirth impossible later in

life. Other symptoms include muscle and joint pain, abdominal pain and muscle spasm (Beck 1997, 130). A deficiency in Vitamin D in adulthood may cause osteomalacia, which results in osteopenia, bone softening and distortion (including vertebral body compression and kyphosis) and fractures (Aufderheide and Rodríguez- Martín 1998, 308).

The industrialisation of Britain caused a substantial increase of this condition in urban areas, due to the persistent pall of smoke and smog overhanging the cities. In the overcrowded slums with their overhanging buildings, sunlight was largely blotted out. Children of the poor also had to work indoors for most of the daylight hours and were therefore even more susceptible to developing the condition. To the people of the Continent, which was less industrialised, rickets was known as the 'English Disease'. The children of the more privileged classes were also at risk from the pervasive air pollution, but infants were not helped by fashionable feeding practices described above (Roberts and Cox 2003, 308).

Skeletal evidence for rickets was present in ten adult males from Greenwich (CPR 10.3% of adult males; 9.35% of the total population). Anterior bowing of the femora was recorded in all ten cases, whilst medio-lateral bowing of the tibiae present in seven cases, and in one case, the fibulae also (Table 14). In all cases, the extent of bowing was described as slight or moderate. No other bones were affected in these individuals.

Given the predominantly working class and urban origins of the Greenwich pensioners, it is not surprising that the prevalence of rickets was relatively high in this population. It exceeded the CPR of 6.76% recorded for the Cross Bones burial ground assemblage (Brickley *et al*. 1999) and the CPR of 5.07% at St Bride's lower churchyard (West 1982 cited in Roberts and Cox 2003, 310) assemblage, both in London, and the CPR of 7.5% of the St Martin's, Birmingham assemblage (Brickley *et al*. 2006, 132). These working class populations show considerably higher CPR than the mean of 3.65% for the post-medieval period cited in Roberts and Cox (2003, 310), which included large numbers of middle class individuals.

Table 14 Summary of skeletons with rickets or possible rickets (N = 10).

Skeleton	Element affected	Severity
3051	tibiae; femora	slight
3103	tibiae; femora	slight
3189	tibiae; femora	slight
3211	femora	moderate
6016	tibiae; femora	slight
6037	femora	slight
6098	tibiae; femora	slight
6146	femora	moderate
6023	tibiae; femora	very slight
6105	tibiae; fibulae; femora	slight to moderate

Clearly, once aboard seamen and marines were exposed to an abundance of sunlight, in fact they were renowned for their tanned and leathery complexions. Even officers were not immune, as is vividly illustrated in Jane Austen's *Persuasion*, when Sir Walter Elliot, father of the heroine Anne Elliot, comments disgustedly on the appearance of Royal Navy officers, and one Admiral Baldwin, in particular:

> a sailor grows old sooner than any other man . . . they are all knocked about, and exposed to every climate and weather until they are not fit to be seen. It is a pity they are not all knocked on the head when they reach Admiral Baldwin's age [a man in his 40s].

He describes the unfortunate Admiral Baldwin as

> the most deplorable looking person you can imagine, his face the colour of mahogany, rough to the last degree, all lines and wrinkles. . .

One assumes with two brothers as admirals (one an Admiral of the Fleet), Jane Austen was writing this description from first hand experience. With such prolonged exposure to the elements, it is thus not surprising than osteomalacia was not present in the Greenwich assemblage.

Osteoporosis

Osteoporosis is a proportional decrease of both the bone mineral and the bone matrix, leading to bone which is light and brittle, and liable to fracture after minimal trauma (Steinbock 2003, 236). There are two types of osteoporosis: Type 1 or post-menopausal osteoporosis (affecting women over 50 years of age), and is commonly the underlying condition in vertebral crush fractures, and fractures of the distal radius; and Type 2 or senile osteoporosis, which affects both males and females over the age of 60 years equally, and predisposes individuals to vertebral wedge fractures and fractures of the femoral neck. Being so closely associated with advancing age, it is somewhat surprising that in the Greenwich assemblage only two older males (3241 and 6013) are recorded as suffering from this disorder. This apparent under-representation may be due to the difficulty in differentiating between bone mineral loss as a result of the disorder, and bone mineral loss due to taphonomic processes (such as leaching).

Skeleton 3241 had experienced 16 fractures, including the right distal radius and the right femoral neck, the head being forced inferiorly towards the greater trochanter. In addition, the bodies of thoracic vertebra 8 and lumbar vertebrae 2 and 3 showed severe vertical compression. The bone was brittle and very light in weight. Due the excessive trauma suffered by this individual, it is unclear which fractures, if any, were osteoporotic in origin, or which

had resulted from injuries incurred during his sailing career. The lightness of the bone does tentatively suggest that osteoporosis may have been responsible for at least some of the fractures. In the second recorded case, skeleton 6013, the bodies of thoracic vertebrae 8 - 12 and lumbar vertebra 4 had suffered wedge fractures, resulting in kyphosis of the spine. This was ascribed to osteoporosis, but will require further specialist analysis (eg. dual energy X-ray absorptiometry) to confirm the diagnosis.

Neoplasms

Osteochondroma

The left proximal femoral shaft of skeleton 6037, immediately inferio-medial to the lesser trochanter displayed an oval lesion of dense bone (measuring 25 mm x 19 mm) diagnosed as a juxtacortical chondroma. The surface of the lesion was rugose in appearance with irregular bony nodules protruding. Inferior to the lesion the shaft appeared flattened and smoothed, possibly due to the pressure of the tumour.

Osteochondromas account for nearly half of all benign tumours (Aufderheide and Rodríguez- Martín 1998, 381). They are minor clinical significance and rarely undergo malignant degeneration (ibid.).

Osteoma

A bony outgrowth or nodule on the lateral shaft of the left fifth metatarsal of skeleton 3269 (measuring 8.3 mm in diameter and 4.9 mm high) has tentatively been diagnosed as an ecchonchroma or osteoma. Both are benign tumours.

Button or ivory osteomas were present on the parietal or frontal bones of six older adults. These benign tumours manifest as small, dense, smooth oval or round outgrowths on the skull vault, and are more common in older individuals (Aufderheide and Rodríguez- Martín 1998, 375). They are of no clinical significance.

Congenital anomalies

Minor congenital anomalies were observed in 11 individuals, and are of little, if any, clinical significance (Table 15). In eight cases, these involved minor anomalies of the lowest lumbar vertebra (L5) and the sacrum. Complete or partial sacralisation, where L5 fuses with the first sacral vertebra was the most common anomaly (n = 5), whilst S1 in skeleton 3072 remained unfused to S2 on the right side. The left side morphologically resembled L5. Another midline defect present in the sacra of four individuals was spina bifida occulta. This anomaly is identified from non-union of the spinous processes of the sacrum. Unlike more severe forms of spina bifida, it is asymptomatic.

One of the right mid-thoracic ribs of skeleton 3229 was bifid at the costal end. It is unlikely that this would have had any functional effects.

Table 15 Summary of congenital anomalies (n = 11).

Skeleton	Diagnosis	Element involved
3072	S1 partly unfused; L side like L5 in morphology	S1
3098	os acromiale	L & R acromia
3099	spina bifida occulta; partial sacralisation	L5, S1-5
3176	partial sacralisation; slight spina bifida occulta	L6, S1 & 2
3194	spina bifida occulta	sacrum incomplete
3213	sacralisation	L5, S1-5
3229	sacralisation; partial spina bifida occulta	L5; S3-5
	bifid R rib (mid-thoracic) at costal end	R Rib
6019	abnormal shortening of bone- congenital dysplasia	L & R 4th metatarsal
6063	os acromiale	L acromial process
6073	os acromiale	L acromial process
6113	sacralisation (near complete)	L5

The epiphysis of the acromial process of the scapulae of three skeletons (3098, 6063 and 6073) remained unfused. This condition is known as os acromiale and may be congenital or activity-related in aetiology. The condition is discussed more fully above.

Other pathology

Pulmonary hypertrophic osteoarthropathy

Numerous elements of skeleton 3194 displayed hypervascularity and considerable periostitis, forming large plaques of active woven bone on the bone surfaces (Plates 23 and 24). This was particularly apparent at the insertion points of muscles (such as the *Supra-* and *Infraspinatous*, *Subscapularis*, *Subclavius* and *Trapezius* of the shoulder joint; the *Triceps brachii* (right only); at the intertubercular groove of the right humerus (possibly for the *Pectoralis major*); *Iliacus* and *Gluteus medius* and *minimus* on the pelvis; the *Pectineus*, *Vastus lateralis*, *medius* and *intermedius* on the femora). Woven bone was also present at the insertion points of ligaments (such as the sternoclavicular ligament of the clavicle, and the ilio-femoral and pubo-femoral ligaments of the pelvis). All of the ribs that were present displayed active woven bone, particularly at the intercostal muscle insertion sites. Hypervascularity (pitting) was evident on the head and neck and costal ends of the ribs. Similar pitting was present on the scapulae adjacent to the glenoid cavity, and around the acetabulum of the pelvis. The thoracic and lumbar vertebral bodies were also very porous.

A second skeleton (6056) also presented with periostitis of multiple elements, which involved the

diaphyses of all the major long bones (including clavicles) and the scapular bodies. The hands, feet and skull were unaffected. These lesions manifested very differently from those seen on skeleton 3194, and comprised prolific new bone growth consisting of areas of woven, lamellar bone, plaques and spicules. Spicules were most commonly sited at the insertion points of large muscles, such as at the interosseus borders of the arms and legs, and the deltoid tuberosity, the soleal line and linea aspera. Thickening of the lower limb bones was marked. Little joint involvement was noted, with the exception of moderate lipping of the glenoid fossa.

Differential diagnosis of these systemic conditions is somewhat uncertain. The original diagnosis of fluorosis in skeleton 3194 has since been revised. One strong possibility is secondary hypertrophic osteoarthropathy. This appears also true for skeleton 6056 (Plate 25). The skeletal hallmark of this disease is periostitis, usually involving the diaphyses of all the major and minor long bones, and more occasionally the scapulae, clavicles, ribs and spine (Resnick 1995, 4429–30). Unlike other conditions, such as fluorosis and syphilis, secondary hypertrophic osteoarthropathy rarely affects the skull (Aufderheide and Rodríguez- Martín 1998, 91). The appearance of the lesions varies between individuals, but the 'irregular solid areas of periosteal cloaking with a wavy contour' described by Resnick (1995, 4430) is consistent with lesions seen in skeleton 3194, whilst the 'tree bark' described by Ortner and Putschar (1981) aptly describes the appearance of lesions on skeleton 6056. Intensive overgrowth of vascular tissue surrounding tendons and joints is also a feature of this disease, and may be the cause of hypervascularity and pitting observed at insertion sites and around the acetabulae of skeleton 3194 (Plate 23), and the porosity and new bone deposition along tendon sites in skeleton 6056. Neither skeleton displayed other common features of the disease, however, such as joint involvement and tufting of the distal hand phalanges.

In modern western populations, secondary or pulmonary hypertrophic osteoarthropathy most commonly affects males in older age categories (Aufderheide and Rodríguez- Martín 1998, 91). The age and sex of skeletons 3194 (40+ years) and 6056 (50+ years) is consistent with this epidemiology. The skeletal lesions resolve when the primary disease is treated (Aufderheide and Rodríguez- Martín 1998, 91), but this remodelling may take months or years (Resnick 1995, 4429).

Traditionally associated with pulmonary disease (bronchogenic carcinoma, bronchiectasis, pulmonary fibrosis, empyema, and pleural neoplasia), this condition is less commonly also caused by diseases of other systems, including the gut (eg. ulcerative colitis, intestinal neoplasia and dysentery), kidneys (pyelonephritis), the endocrine system (thyroid disease), the liver (cirrhosis, biliary atresia), and the circulatory and lymphatic systems (Hodgkin's disease, aortic aneurysm). Bronchogenic carcinoma remains by far the most common cause, however (Resnick 1995, 4429). This cancer of the lung epithelium most commonly develops as a result of tobacco smoking, followed by prolonged exposure to industrial pollutants, such as asbestos, and heavy metals - uranium, gold, nickel and chromate - in mining (Chandrasoma and Taylor 1995, 537). Whilst some ex-Royal Navy seamen did become miners, for example John Nichol, who wrote a memoir of his experiences in Nelson's Navy, tobacco smoking is the most probable cause. As noted above (see Chronic respiratory disease), pipe smoking was a popular pastime of the Greenwich pensioners, and carried the same health risks as it does today.

Medical interventions

The Navy had very few physicians - in 1797 there were only 15, including those on half pay (Lavery 1989, 212) - but every man-of-war was provided with a surgeon and his mates (Porter 2002, 117), the quality of medical treatment in the Royal Navy was very variable. Rated as warrant officers, ships surgeons of the 18th century were poorly paid. Amongst their peers on land they were professionally despised (Harvie 2002, 27). Prior to 1795, ship's surgeons were poorly paid. But they remuneration improved dramtically during the War with France. The pay of surgeon in 1797 was less than a ship's lieutenent, but by 1815 surgeons were paid only a little less than post Captains (Lewis 1960, table viii) although they received fewer allowances.

Like other surgeons of their day, naval surgeons did not undertake the rigorous academic medical training that was required to practice as a physician. But the Royal Navy required more of its surgeons, and they were expected to deal with medical matters other than surgery, and the Navy required its surgeons to undertake a qualifying course in medicine before he could be admitted into a man-of-war (Rodger 2004, 196).

The actions of the surgeon, like all else aboard ship, fell under the jurisdiction of the captain. As a means of quality control, all surgeons were also required to keep records minutely detailing their cases, treatment and outcomes (see Lavery 1998, 481–539 for extracts from surgeons' journals). These had to be submitted to the Sick and Hurt Board at the end of the surgeon's tour of duty. Surgeons deemed as wanting in skill or knowledge would have their warrant withheld. Surgeon's assistants or mates were entirely self-taught and were even lower down the ship hierarchy. Smollett, a surgeon's mate - cum - novelist, wrote that 'the captain is too much of a gentleman to know a surgeon's mate by sight' (cited in Harvie 2002, 27).

Despite these deficiencies in training and a frequent lack of drugs and equipment, most ship's surgeons worked hard under trying conditions, which were particularly acute during outbreaks of disease (eg typhus, yellow fever or dysentery) and during and following a naval engagement. Indeed, many innovations and new techniques in surgery and medicine were developed by army and naval surgeons during

this period. Sick and injured seamen were seen by the surgeon in their hammocks on the lower deck or in the sick berth. Basic nursing care was undertaken by the surgeon's mate or by inexperienced boys (loblollies), and often left much to be desired. In his memoir, 'Jack Nastyface' (Robinson 2002, 115–6) describes how 'a steady and much respected seaman' who had stoically and wordlessly suffered the amputation of both legs and whose wounds were healing well, died 'from lying in one position for such a length of time that his back mortified' (ie. he died of bedsores, that may be easily prevented by regularly changing the patient's position).

During a battle, a temporary operating theatre was set up in the cockpit on the orlop deck, in the area normally designated as the dining area of midshipmen. The dining table or midshipmen's sea chests lashed together served as the operating table, and the wounded were seen in the order in which they appeared for attention. Surgeons were often faced with overwhelming casualties and had to work rapidly to attend to all cases. One seaman, Samuel Leech (1844, 142–43) described the cockpit in the middle of battle:

> The surgeon and his mate were smeared with blood from head to foot. They looked more like butchers than doctors . . . The task was painful to behold, the surgeon using his knife and saw on human flesh and bones as freely as a butcher in the shambles.

The principal aim was to arrest haemorrhage, initially by applying a tourniquet and later by tying off large arteries and veins with ligatures, and where limbs were badly damaged, amputation was the quickest and most effective way to save a man's life. A skilful surgeon could perform an amputation with remarkable speed - sometimes in as little as two or three minutes (Fremont-Barnes 2005, 41). Another reason for speed was the intensity of pain suffered by the soon-to-be amputee, as such battle operations were performed without anaesthetic or analgesia. The former was still unknown, and there was not the time or sufficient supplies of rum or laudanum to deaden the pain, and most patients had only a leather-covered chain to bite down upon during the procedure (Fremont-Barnes 2005, 42). Following surgery, the greatest cause of mortality was infection.

Loss of a limb or an eye was a common fate in the Royal Navy at this time (as is illustrated in Plates 2–5, 7 and 9), it's prevalence leading Princess Caroline (daughter of George III) to exclaim whilst visiting the fleet which had been fighting the Dutch off Dogger Bank in 1781: 'What! Have all the English lost either an arm or a leg?' In the Greenwich pensioner population alone, six individuals (CPR 6.19%) were missing a leg or a hand. They were in good company; the great naval hero Lord Nelson had suffered amputation of his right lower arm after being hit during an assault on Santa Cruz on Tenerife in 1797. Previous to that in 1794, Nelson had lost the use of his right eye as a result of damage from stones and sand thrown up by a French cannonade before Calvi.

In the Greenwich assemblage, skeletons 3032, 3045, 3086 and 3261 had undergone above knee amputations, skeleton 3061 a below-knee amputation and skeleton 6089 had a possible amputation of the left hand at the wrist. In the first four, the distal third or midshaft of the femur had been amputated (three left and one right), whilst in skeleton 3061, both the right fibula and tibia had been sawn off just distal to the tibial tuberosity. A partial bone cap had begun to form over the stump in skeleton 3061, but this was thin and fragile, and unlikely to have withstood weight-bearing. Bony resorption was evident in the stumps of all five leg amputees, possibly due to secondary infection and/or due to the probable lack of weight-bearing of the limbs. In skeletons 3032 and 3061, the bone was thin and porous, resorption resulting in the bone of the stump being thin and tapering to a point (Plate 26). Radiography of 3061 (Plate 27) revealed the extent of bone loss (manifesting as black on the X-ray; note the difference in density between the stump and the healthy left tibia). This demineralisation would suggest that the stump had not been used for weight-bearing and had atrophied. It is unlikely that skeleton 3061 had used a peg leg, so ubiquitous in contemporary depictions of Greenwich pensioners. He may have used under-arm crutches instead. Bony modification to the shoulder joints was not noted, but the left humerus did weigh 15g more than the left, very, very tentatively suggesting densification due to increased use. Handedness or slight variations in taphonomy of the burial environment may equally be responsible for this difference, however. Skeleton 3086 showed more convincing bony changes to the shoulder joints suggestive of crutch use. Articular facets were present on the superio-lateral aspect of the lesser tubercle and the superio-posterior aspect of the greater tubercle. Unfortunately the scapulae were too damaged to identify any morphological changes. Similar changes to the humeri were present in skeleton 3261. Better preservation of the scapulae allowed the identification of a small articular facet on the inferior surface of the right scapula, located laterally and latero-posteriorly.

Amputation was usually undertaken as a life-saving measure and little attention could be spared to form the stump carefully in order to maximise even weight-bearing and the comfortable wearing of a prostheses, although the principle of removing more bone whilst preserving the maximum amount of soft tissue, thus permitting the skin to mend over the bone, and in due course form a useable stump was understood as early as the Middle Ages (Porter 2002, 112). Prostheses were basic and consisted of a peg leg strapped to the residual stump, or a hook to replace a hand (ibid.). Balance was difficult enough in a below- knee amputation where the knee joint was still preserved, but far more problematic in higher amputations (which also were more risky to perform due to the greater risk of major haemorrhage (ibid.). Illustrations of seamen with peg legs almost always depict below knee amputees, but in his memoirs Spavens (2000, 98) described the wearing of peg legs

by above knee amputees (see Chapter 2 above). In part, this may explain why all three femoral amputees showed demineralisation suggestive of a lack of weight-bearing following amputation.

Wastage of bone may result from severe infection at the stump site, as occurred most dramatically in skeleton 3045 (Plate 21). Here very severe osteomyelitis had caused major remodelling of the femoral shaft, with the shaft been reduced to a sequestrum (see above). A sharp bony spur protruded distally beyond the limit of the prolific new bone growth. This, together with ongoing infection of the bone and overlying soft tissue, would probably have rendered weight-bearing too painful. Demineralisation is suggested by reduced weight of the affected element relative to the unaffected side in all four lower limb amputees. In skeletons 3032 and 3261, this demineralisation was thought to include the pelvic bones on the affected side also. Only in skeleton 3061 was this observation investigated using radiography, however.

During excavation and during osteological analysis, it was noted that the left hand of skeleton 6089 was missing, and that its absence could not be attributed to taphonomy or poor archaeological recovery (Witkin pers. comm.). No cut or saw marks were evident on the distal ulna joint. Severe longstanding but active periostitis / osteitis on the left distal radius and ulna suggest that the loss of the hand had been associated with severe secondary infection. The infection was still active at the time of death. Skeleton 6089 was much younger than the majority of pensioners, being 35–45 years at the time of his death. It is possible that he had died of complications from his surgery, such as septicaemia, the infection spreading from his affected arm, but this is of course pure speculation.

As was evident in three of the five amputees, secondary infection was commonly associated with amputation, not surprising given that the operation would not have been performed in antiseptic conditions. Aseptic technique during surgery had yet to be invented, and surgical implements were not cleaned between patients. It was really only with Lister's introduction of the antiseptic technique as late as the 1860s that amputation mortality rates reduced dramatically. He claimed a dive from 45.7% to 15% when his antiseptic technique was implemented (Porter 1997, 372). Many - possibly including such as skeleton 3045 - suffered lingering infections, often resulting in chronic ill health and death (Sournia 1992, 345).

Following surgery, the aftercare of the wounds and general nursing of bedridden patients left much to be desired by modern standards, but probably compared with contemporary treatment of civilian patients. Injured ratings were either nursed in the sick bay aboard ship, or transferred to hospital ships (when a large fleet had assembled), which in theory, offered better care than a lone surgeon and his mate could manage (Rodger 2004, 214). Mortality aboard these ships was high, but one surgeon serving in a hospital ship claimed that they were better than the rates that 'candid physicians in London own' (cited in Rodgers 2004, 214). Following a major sea battle, the staff on hospital ships were badly overstretched. Depending on location, the sick and injured were sometimes transferred to hospitals in port, such as Port Mahon, Minorca, and Gibraltar in the Mediterranean (where many of the injured in the Battle of Trafalgar were rehabilitated), or the three Royal Navy hospitals at home at Portsmouth, Chatham and Plymouth. Survivors were either discharged if their injuries were too severe to continue in service, pensioned off, or returned to active service in occupations where their disability was less restricting (eg ship's cooks) (Fremont-Barnes 2005, 25).

Craniotomy

Post-mortem craniotomies had been performed on four skeletons of the Greenwich assemblage (3105, 3106, 3119 and 3159). The skulls of all four had been sawed in the horizontal plane, across the frontal, parietal and occipital bones just superior to the temporal bones and the supra-orbital ridges (Plate 28). No other saw marks were present in the cranial or post-cranial skeletons. Why these three were selected for anatomisation is unclear. Two (skeletons 3105 and 3106) had porotic hyperstosis and cribra orbitalia but no other cranial pathologies were noted that might suggest why these individuals were targeted.

In the Georgian period, post-mortem dissection was an uncommon procedure, and usually one over which the deceased and their relatives exercised little control. In the 18th century, medical institutions had a growing need to be provided with cadavers on which students might learn anatomy and practice dissection. In 1752 the Company of Surgeons was granted the corpses of all executed felons (Porter 1997, 292). However, demand far outstripped supply, and many additional cadavers were supplied to anatomy halls by 'resurrectionists', who raided graveyards, exhumed corpses and sold them on for a handsome profit (Porter 1997, 317–18). Public outrage at this practice reached a height in 1829 with the notorious case of Burke and Hare. The outcome of this sentiment was the passing of the Anatomy Act (1832), which permitted the medical profession to take for dissection all 'unclaimed bodies' of those dying without family, or those dying in the workhouse or hospitals. As a result of the Act, there was a reduction in body-snatching, but it also served to deepen the fear and shame of dying on the parish amongst the poor (Rugg 1999, 222).

The antipathy to the notion of being dissected was based on religious and social perceptions. The Christian belief in the resurrection of the whole body on Judgement Day led to fears that dissection would damage the spiritual state of the dissected person. A deep-seated solicitude for the corpse causes reactions of revulsion at the indignity that the body suffered during exhumation and dissection. Particularly with regard to female corpses, the physical exposure of the naked body to the gaze of young men was perceived

as harrowing, a process tantamount to sexual assault (ibid.). It is to be assumed that most of the Greenwich pensioners ascribed to these views, and the anatomisation of four of the pensioners is surprising, given the care taken in their burial. It is of course possible that they had consented to the procedure, as was occasionally the case.

Dental pathology

Dental caries

Dental caries involves the destruction of the enamel surface, the dentine (internal part of the tooth) and the cement (outer layer of the roots) of a tooth. This is caused by the acid produced by bacteria present in dental plaque (Hillson 1996, 269). The association of acidogenic bacteria and sugars in the diet is a well established cause of cavitations (Lukacs 1989, 265). Classified as an infectious disease, caries usually progresses gradually. Oral hygiene is also a significant factor in the development of caries.

The size of each carious lesion was classified according to the universally used grading system produced by Lukacs (1989). The location of the lesion was also recorded. However, due to time constrains, frequencies pertaining to location on the tooth, the size of the lesions, and the identity of the tooth affected are not discussed here.

The prevalence of caries was calculated by dividing the total number of caries by the total number of permanent teeth present. A total of 147 caries was recorded on 1202 permanent teeth of the adult males (TPR 12.2%) and five in 56 permanent teeth of the subadults (TPR 8.93%). No caries were recorded in the female skeletons. The overall caries rate of the total population was therefore 11.67% (Table 16). The mean number of carious lesions per skeleton was 1.41 (n = 108). All lesions were located on the posterior dentition.

This prevalence compared exactly with the mean of seven late Georgian/ early Victorian assemblages (Table 17). It correlated most closely to the predominantly working class assemblage of the Newcastle Infirmary, which interestingly was partly composed of merchant sailors. Rates were higher than other working class assemblages, with the exception of the Cross Bones burial ground, Southwark, and lower than the middle class assemblages of St George's, Bloomsbury, and Christ Church, Spitalfields (Table 17).

Given the advanced age of most skeletons in the Greenwich assemblage and the progressive nature of the disease, it is surprising that the caries rate was not higher. This relatively low prevalence probably relates closely to the amount of sugar (particularly refined sugar) consumed by the pensioners throughout their lives. In the civilian population, the consumption of cane sugar gradually increased over the 18th and 19th centuries. In the 16th and 17th centuries sugar was an expensive high status luxury available only to the most wealthy (Musgrave and Musgrave 2000, 60). However, the development of sugar plantations in the West Indies in the 18th century made sugar more readily available and created a more affordable supply of the commodity to markets in Europe. As the price of sugar fell, so consumption gradually spread down the social classes, until by the latter half of the 19th century it was available to all but the most indigent (ibid.). By the early 19th century, sugar was widely available to the middle classes, but not readily accessible to the lower classes.

The amount of sugar consumed by seamen and marines aboard ship is unclear, but was not generally cited in accounts of ships rations, which comprised bread or ship's biscuit (a very hard biscuit of wholewheat flour, salt and water) every day; pease (dried peas) four times a week; pork and beef twice a week (usually salted); oatmeal three times a week (usually served as skilygalee, a gruel boiled up in fatty water); and butter and cheese three times a week (if not too rancid) (Macdonald 2006, 10; Fremont-Barnes 2005, 24–25). Fresh meat and vegetables and fruit augmented this monotonous diet when ships came into port, or when livestock aboard ship were slaughtered. In the 1808 edition of the *Regulations and Instructions*, sugar was include in the allowance of provisions to be issued at the rate of 2oz three times a week (Lewis 1960, table xiv).

The first formal set of *Regulations and Instructions relating to His Majesty's Service at Sea* published in 1733, replaced fish with a ration of oatmeal. Part of the oatmeal ration might comprise sugar or molasses, usually as a substitute for oatmeal at the rate of one pound of sugar for two quarts of oatmeal, or five and threequarter pounds of molasses for one gallon of oatmeal (McDonald 2006, 9, 35). Presumably, like other food, this depended on availability, with those ships operational in the West Indies probably receiving a larger proportion of sugar in their oatmeal ration.

Small amounts of sugar were added to 'Scotch coffee' (burnt bread boiled in water), tea and cocoa, and in the later 18th and 19th centuries to sweeten the lemon juice added to the daily grog ration (Fremont Barnes 2005). The daily oatmeal porridge or 'burgoo'

Table 16 Dental caries prevalence (N = 1303).

Teeth	Age and sex distribution				
	Females	Males	Unsexedadults	Subadults	Total (%)
All anterior	0/24	43/502	0	0/22	43/548 (7.85%)
All posterior	0/21	104/655	0	5/34	109/710 (15.35%)
Total	0/45	147/1202	0/0	5/56	152/1303 (11.67%)

Table 17 Comparison of dental pathology rates per tooth or socket in seven contemporary English assemblages.

Post-medieval assemblages	Ante-mortem tooth loss (n/N)	Peri-apical abscesses (n/N)	Calculus (n/N)	Caries (n/N)	Dental enamel hypoplasia (n/N)
Royal Hospital, Greenwich	44.6% (1172/2624)	7.35% (224/3048)	82.11% (1028/1252)	11.67% (152/1303)	14.37% (178/1239)
St George's Church, Bloomsbury	40.99% (669/1632)	2.82% (46/1632)	70.85% (592/844)	13.39% (110/844)	16.35% (138/844)
St Luke's Church, Islington	36.10% (1762/4883)	1.78% (87/4883)	46.33% (1042/2249)	9.74% (219/2249)	2.18% (49/2249)
Newcastle Infirmary, Newcastle	19.3% (604/3123)	0.9% (29/3123)	55.85% (718/1287)	11% (146/1327)	17% (219/1287)
Christ Church, Spitalfields	19.91% (324/1627)	Data not available	Data not available	19.11% (311/1627)	Data not available
St Martin's church, Birmingham	26.65% (2488/9337)	2.63% (222/8433)	63% (3684/5893)	9.88% (488/4940)	31% (110/1060)
Cross Bones burial ground, Southwark	17.30% (211/1216)	2.30% 28/1216	Data not available	25.93% (161/621)	Data not available

was also sometimes sweetened by sugar or molasses (McDonald 2006, 35), but given the cost of sugar at this time, it is highly unlikely that it was ever consumed in any great quantity aboard ship. Later the oatmeal ration was halved and two ounces of sugar issued instead. It is not unreasonable to assume that sugar consumption by the pensioners before and after their time in the Royal Navy was similar to the civilian working classes of the period.

Another factor that may have reduced the formation of caries was dental attrition, which appeared greater in the Greenwich population than in other post-medieval assemblages, such as St George's, Bloomsbury, and St Luke's, Islington. Unlike these civilian populations, the Haslar Hospital assemblage, comprising principally young and prime adult males on active service, showed a similar pattern to Greenwich, suggesting that accelerated attrition began in early adulthood in the Royal Navy, and its presence in the Greenwich assemblage was not merely due to its older age distribution. Flattening of the enamel folds of the occlussal surface of the molars reduces the risk of food entrapment and hence, of caries. Together with a diet low in simple sugars, this attrition may have contributed to the low caries prevalence amongst the pensioners.

Periapical abscesses

The development of a dental abscess may have many starting points. Bacteria may enter the pulp cavity through dental caries, excessive attrition or trauma to the crown, as well as through dental surgery. An abscess may also develop when a periodontal pocket is formed by the accumulation of bacteria within the pulp cavity, and infection tracks down to the root apex. As pus accumulates within the dental socket and surrounding alveolar bone, local pressure builds, and eventually precipitates the formation of a hole or sinus in the jaw, through which the pus drains into the overlying soft tissue of the gums (Roberts and Manchester 1995, 50). In this advanced stage, the abscess is visible as a small hole on the surface of the maxilla or mandible.

The prevalence of periapical abscesses was calculated by dividing the total number of abscesses with the combined total of teeth lost ante mortem, teeth lost post mortem and permanent dentition. In total, 224 abscesses were recorded out of a possible 3048 sockets observed in the total population (n = 107) giving a TPR of 7.35%. A total of 224 periapical abscesses were recorded (7.35%, n = 107), six of which were present in adult females, and 106 in adult males. In pensioners, 3.7% of sockets were affected, whilst 6% was calculated in adult females. None were observed in adolescents 3132 and 3249 or in the unsexed adult 6017.

A TPR of 7.35% is considerably higher than those observed in the contemporary assemblages displayed in Table 17, which ranged from 0.9% to 2.82%. The reason for this difference is unclear, but like calculus and ante-mortem tooth loss, it is probable that advanced age and poor oral hygiene played significant roles.

Ante-mortem tooth loss

The loss of permanent dentition before death is the end result of several disease processes. Calculus deposits irritate the soft tissue and the underlying bone, which may lead to the reduction of the bone (periodontal disease) and ante-mortem tooth loss (AMTL) (Roberts and Manchester, 1995, 45). Teeth may also be lost by periapical abscesses formed through the exposure of the pulp cavity, caused by caries or excessive attrition coupled with localised resorption of the alveolar margin. Dental extraction for painful teeth was also a common practice at this time. In the Greenwich assemblage an additional pathology that

appears to have contributed to AMTL was scurvy (see above). AMTL is regarded as a degenerative disease where the main contributory factors are old age and poor oral hygiene. In this aged population, it is thus not surprising that AMTL was high (44.73% in the total population (n = 107). This figure is higher than the contemporary assemblages shown in Table 17.

This rate was calculated by dividing the total number of teeth lost ante mortem by the combined total of the permanent dentition, teeth lost ante mortem and post mortem (empty sockets). In the adult male population, the AMTL rate was 44.6%, (1172/2624), in adult females 55.34% (57/103), the unsexed adult had lost all but one tooth (31/32), and the two adolescents had suffered no tooth loss (0/58). The prevalence for the total population was therefore 44.73% (1260/2817).

Dental calculus

Calculus consists of mineralised plaque composed of microorganisms that accumulate in the mouth and become imbedded in a matrix of protein and saliva. Sugar in the diet accelerates this process (Hillson 1996, 254–55). There are two types of calculus: supragingival calculus situated above the gum line and subgingival calculus found below the gum line on exposed roots. More heavy calculus deposits are commonly seen on teeth nearest to the saliva glands (Roberts and Manchester 1995, 55). Regular tooth brushing removes plaque deposits, thereby preventing the formation of calculus. In an archaeological context, some calculus may be inadvertently removed during post-excavation processing and handling.

Calculus deposits were recorded by tooth and by location on the tooth. The size of the deposit was also recorded according to the universal standards set out by Brothwell (1981), in which the deposits were scored as slight, medium or heavy. However, such detailed data are beyond the scope of this report. The prevalence of calculus was calculated by dividing the number of teeth affected by the total number of teeth present. Calculus was observed on the crowns of 981 of a total of 1150 teeth of adult males (TPR 85.3%), in 44 of 45 teeth of adult females, and in two of 56 teeth of the two subadults- a TPR of 82.11% (1028/1252 teeth) of the total population (Table 17). Although not quantified in this analysis, the general impression was that in the majority of cases, the calculus was slight.

A high prevalence of calculus is reflected in other assemblages of this time period (Table 17), but is greatest in the Greenwich assemblage, followed by St George's, Bloomsbury, assemblage (the next oldest population). This picture probably reflects the general lack of regular dental hygiene (such as tooth brushing) in the Greenwich sailors, as well as their advanced age, as calculus is accumulative. Different criteria between observers may also account for some of the wide differences in prevalence of calculus between the assemblages.

Periodontal disease

The principal predisposing factor in the development of periodontal disease is the accumulation of calculus in dental pockets. The disease begins as gingivitis (an inflammation of the soft tissues), which is transmitted to the jaw itself. Resorption of the bone commences, followed by tooth loss. There are two different ways in which this disease expresses itself. These are horizontal and vertical bone loss. In horizontal bone loss, more than one tooth is involved and often the whole of the dental arcade. All walls surrounding the teeth are lost uniformly. In vertical bone loss, the lesion is localised around one tooth or possibly two. The bone loss around the tooth is irregular and generally without horizontal bone loss (Hillson 1996, 263–65). In modern populations, there is a strong correlation between advancing age and the prevalence of periodontal disease, which is also the case with archaeological populations. However, the aetiology is multifactoral with genetic predisposition, environment, diet and hygiene being all predisposing factors in the development of the disease (ibid.).

Periodontal disease was recorded as being present or absent, and did not include the number of teeth or parts of the jaws affected. The severity of the disease was scored using the standards set out by Brothwell (1981). This method uses three grades namely slight, medium and considerable. Periodontal disease was recorded on 74 adults (including those with no teeth and incomplete records), and on the two subadults. In this group, a prevalence of 93.42% was recorded (71/76). The CPR for the adult population was 67.62% (n = 105), and for the total population was 66.36% (n = 107).

Periodontal disease was observed in 20% of the named individuals of St Luke's Church, Islington (Boston and Witkin 2005, 210), and in 50% of the named assemblage of St George's crypt, Bloomsbury (Boston and Witkin 2006). Considering the relationship between the disease, increasing age and oral hygiene, the high rate seen in the Greenwich assemblage is hardly surprising.

Dental enamel hypoplasia

Dental enamel hypoplasia (DEH) may manifest on the buccal surface of the tooth crown as pits, horizontal lines or lines of pits (Buikstra and Ubelaker 1994). These defects are caused by thinning of the enamel, and reflect an interruption or slowing of the normal deposition of enamel during crown formation in the first six or seven years of life (Goodman and Rose 1990; Hillson 1996, 165–66). DEH is thought to result from prolonged episodes of illness or malnutrition lasting at least three weeks (ibid.), but Roberts and Cox (2003, 311–312) wrote that food adulterations, used widely in 18th- and 19th-century London and other cities, may also have played a role in the interruption of normal tooth development. DEH is most apparent when normal dental development recommences following such an insult. Unlike bone, enamel does not remodel throughout life and so remains as a permanent indicator of such stress epi-

sode in the early years of life. The presence of DEH in the teeth of an individual represents an individual who was compromised physiologically, but who recovered.

In the analysis of the Greenwich assemblage, the type of defect (groove, line or pit) and the numbers of lines or grooves were recorded for each tooth. This level of detail has not been quantified here. The prevalence of DEH was calculated per crown visible, excluding crowns where the buccal surface was obscured by calculus, or where the tooth had suffered marked attrition or carious formation. Of 1239 teeth observed in the total population, 178 displayed DEH (TPR 14.37%, n = 107). In the adult males, the prevalence was 13.3%, in the adult females 24.4%, and in the two adolescents 25.86%.

Compared to DEH rates in the four other 18th- to early 19th-century populations displayed in Table 17, the Greenwich assemblage rate was higher than the named middle class assemblage from St Luke's, Islington, but lower than the other three assemblages, including the two other working class assemblages of the Newcastle Infirmary and St Martin's, Birmingham. It is, however, considerably higher than the average prevalence of 0.6% that has been reported for British post-medieval assemblages (Roberts and Cox 2003, 327). Such wide variation in the prevalence of DEH may well reflect inter-observer differences in identifying DEH, but it should be noted that much of the osteology on the St George's, St Lukes' and Greenwich assemblages was undertaken by the same observer, Annsofie Witkin, and hence, it has to be assumed that the differences observed between the populations are genuine. It is somewhat surprising that the DEH prevalence in the Greenwich assemblage was fairly low, given its known working class origins, and the prevalence of other indicators of childhood stresses, such as cribra orbitalia and low adult stature.

Dental wear

Dental attrition was recorded on the molars of the Greenwich assemblage but was not quantified in this study. The general impression, however, was that the Greenwich seamen and marines suffered considerably more attrition than other contemporary assemblages, such as St George's, Bloomsbury and St Luke's, Islington. Tooth wear was more consistent with the general pattern observed in the Haslar Hospital assemblage, suggesting that seamen of this period suffered greater tooth wear than civilians. Attrition of the molar occlusal surfaces reflects the coarseness of the diet, and in archaeological populations is heavily influenced by the amount of grit introduced into food during by processing. The daily diet of seamen aboard ship included unrefined flour (milled commercially), pulses, 'hard tack' and salted meat and cheese. The last three were often very hard and deteriorated with keeping. Fremont-Barnes (2005, 25) describes how seamen would carve and polish objects out of the salt meat, and make buttons from the cheese. It is probable that the hardness of this food was responsible for the greater attrition observed in the two Royal Navy populations.

Gibson (2002) studied extra-masticatory wear on 90 individuals from the Greenwich assemblage (which included females and one subadult), and observed dental chipping of the anterior dentition, pipe notches, microscopic lingual and labial grooves and wear. Dental chipping, particularly of the anterior dentition, was the most common of the four, with 65 chips found on 42 teeth, or 17.78% skeletons. Although some may have been dietary, Gibson ascribed most to trauma, incurred either through inter-personal violence or from accidents aboard ship. Tearing of the tough paper casing containing the gunpowder charge of a musket using the teeth may have also been responsible for some dental chipping, especially amongst marines. This prevalence was higher than observed in his study of samples from the Newcastle Infirmary (14.29%) and also amongst material from the Methodist burial ground on Carver Street, Sheffield (5.45%) (Witkin 2001).

Twenty-four pipe notches were seen in 14 individuals in this sample, predominantly on the right side of the dental arcade. Most individuals had one notch, but one individual had four. The habit of tobacco smoking was probably acquired after leaving the Royal Navy and is discussed more fully above (see Chronic respiratory disease).

Under microscopy, thick and fine linguo-labial grooves were observed on the tooth crowns. Eight thicker grooves were seen on seven teeth of the sample. Gibson (2002) attributed these grooves to wear caused by hemp fibres held in the mouth during the making of cordage, which was used to splice ropes to prevent fraying. Finer grooves (particularly on the canines) were attributed to sewing, when the thread is bitten off in the mouth. As he pointed out, sewing was an important aspect of a seaman's life, especially the repair and maintenance of the sails. In their free time, seamen were fond of embellishing their clothes with embroidery, rosettes and ribbons (Fremont-Barnes 2005, 45), which they proudly displayed when in port or on those rare occasions of being granted leave. Similar grooves were observed on the dentition of he Newcastle Infirmary sample also examined by Gibson (2002).

Gibson (2002) also observed labial and lingual wear on the dentition of the Greenwich sample. Vertical lingual wear on the anterior dentition in three individuals (skeletons 3024, 6056 and 6078) was consistent with bruxism, the habitual grinding of the teeth during sleep. The severity of the wear was consistent with a longstanding habit in all these individuals.

DISCUSSION

Although relatively small, the Greenwich assemblage is a rare example of a specialist population, in which the age, sex and occupation of this group

of skeletons is historically known. Royal Navy records of the 18th and 19th centuries have enabled historians to reconstruct many aspects of the lives of these seamen and marines. Like most records of the lower strata of a society, however, the evidence for the common ratings is often indirect, incomplete and frequently tainted with generalisations and misconceptions. The opportunity to examine the physical remains of 97 skeletons from Greenwich was a golden opportunity to interrogate another strand of evidence in order to reconstruct an accurate picture of the lives of these individuals, whose role in the defence of the realm against the French Republic, the Dutch, Spanish and ultimately, Napoleon, was so crucial to Britain's national interests.

Osteological analysis of the Greenwich assemblage revealed that the vast majority of the population comprised adult males of advanced age, with seven older females and two adolescents, probably dependants. This is consistent with the limited historical research undertaken on Greenwich Pensioners for this study. The evidence of a sample of 100 Trafalgar veterans, who were also Greenwich in-pensioners, gave a mean age at death of 70.1 years.

One interesting aspect of the assemblage was the identification of two adult males of probable negroid ancestry. Although a suite of cranial and post-cranial measurements were undertaken on all skeletons as part of the osteological analysis, further work is required in order to identify the ancestry of these and other skeletons. Forensic databases, such as FORDISC and CRANID, have yet to be utilised. Isotope work on diet and childhood origins will also be a powerful tool in addressing the question of the origins of these seamen. This highlighted the diverse national origins of the ratings of the Royal Navy in late 18th and early 19th centuries.

Historical records indicated that most ratings were working class in origin, with the majority of occupations on entering and/or leaving the Royal Navy being skilled and unskilled labourers and artisans. Given the harsh living conditions endured by the working classes of this period, it is not surprising that there were relatively high prevalences of skeletal indicators of childhood depravation in the Greenwich assemblage. Mean male stature was 5 ft 5 in (167.9 cm), most similar to the pauper assemblage of the Cross Bones burial ground, Southwark, and 2–3 cm lower than mean stature of middle class assemblages of the period. The prevalence of childhood deficiency diseases, such as cribra orbitalia and rickets, were likewise high, but the latter did not appear to have continued into adulthood. Surprisingly, dental enamel hypoplasia was not consistent with this picture of childhood depravation.

The Greenwich in-pensioners represent a select and lucky few chosen for admission by virtue of prolonged service in the Royal Navy and the extent of their physical handicap. Many out-pensioners were only admitted to the hospital in the last few years of their lives. As Lewis (1960, 416) poetically commented 'they were mostly the picked, brine-pickled survivors of a gruelling existence', and it is therefore not surprising that the skeletal assemblage contained such high rates of pathology, particularly of trauma and infection, but also of degenerative joint disease and osteoarthritis. Life at sea was dangerous and arduous, with falls, crush injuries and injuries in battle being commonplace. Although a surgeon and his assistant, or assistants, were aboard all Royal Navy ships, the high number of poorly reduced fractures indicated that setting of bones was not a priority. Six amputations were present in the Greenwich assemblage. All but one appeared healed, the exception showing severe chronic infection that was ongoing at the time of his death. Interestingly, bone resorption in the amputated limb of all of the lower limb amputees suggested that none of the amputees used the peg leg prosthesis so frequently depicted in illustrations. Indeed, two above knee amputees showed bony changes tentatively suggestive of under arm crutch use.

Isolated from the rest of society, a Royal Navy ship was a little world of its own, with its own language, customs, in-fighting and friendships. Although the Navy made considerable efforts to enforce a surprising degree of cleanliness for the time period, infectious diseases and epidemics remained a constant source of morbidity and mortality, not surprising considering the close proximity in which hundreds of men lived and worked. Although most of these diseases were acute, some, like tuberculosis, thrived under these conditions, and were observed in the Greenwich assemblage.

After 'fevers', scurvy has been cited as the greatest single cause of death amongst 18th-century sailors. Skeletally, a differential diagnosis of scurvy is highly problematic, as many bony changes (such as subperiosteal bleeding, orbital lesions and ante-mortem tooth loss) may be attributed to a range of other conditions. Periostitis was found on multiple elements in 53 skeletons (50.48%) of adults. It is impossible to know how many of these were scorbutic in nature, but it is highly probable that many can be attributed to this disorder. Of twelve skeletons displaying pitting on the greater wing of the sphenoid, eight also had periostitis, five had orbital lesions and five had porotic hyperostosis. The prevalence of AMTL was 10% higher than in the rest of the adult male population. Although a small sample, this tentatively suggests that a more holistic approach may facilitate our identification of scorbutic individuals. Identifying scurvy using biochemical markers may be a valuable avenue of future research.

Although in many ways isolated from the wider world, seamen and marines of the Royal Navy did have intermittent contact with the outside world, and diseases rife in ports were transmitted aboard. Venereal diseases were one group of infectious diseases historically known to afflict large numbers of seamen. Venereal syphilis is the only sexually transmitted infection to be recognised skeletally, and treponemal disease was seen in three adult males of the Greenwich assemblage. Although it was impossible to distinguish between venereal syphilis and yaws in this

assemblage, a prevalence of 2.8% in this population was still much higher than the CPR of 0.77% calculated for this period by Roberts and Cox (2003, 341). When one considers that bony involvement occurs in approximately 10–12 % cases of syphilis (Roberts and Manchester 1995, 152), in reality the prevalence of this disease amongst seamen would have been very high indeed.

Both historical records and osteological ageing techniques concur that the majority of the Greenwich population were ageing adults. Unlike most other archaeological populations of lesser longevity, a number of diseases more prevalent in older age groups were observed in the Greenwich assemblage. These included DISH, a high prevalence of degenerative joint disease, osteoarthritis, osteoporosis, neoplasms, and two probable cases of pulmonary hypertrophic osteoarthropathy.

Cortical defects and enthysophyte formation were not systematically recorded in the Greenwich assemblage. The overall impression was that these changes were marked in the Greenwich assemblage, particularly in the upper limbs, probably as a consequence of prolonged pulling on ropes. Alterations in the joint surfaces also may have developed in response to this hyperflexion of the elbow joint, but requires more detailed analysis.

CONCLUSION

In conclusion, the small skeletal assemblage from the ratings burial ground of the Royal Hospital Greenwich, has proved a rich alternative dataset on the lives of the seamen and marines of the Royal Navy of the mid- to late Georgian period, a period during which the Royal Navy played a pivotal role in Britain's wars with the Dutch, Spain, America, the French Republic, and Napoleon. The wide range of pathologies present reflected the origins, activities, diet, and hardships of life aboard ship, and the physical effects of advancing age. The osteological analysis discussed above was undertaken in a commercial archaeology setting, in which resources of time and money were restricted, and all results are presented with the full understanding that the analysis was far from exhaustive. Considerably more work is warranted on this unique and extremely interesting specialist assemblage, and it will undoubtedly prove a valuable resource in research in the future.