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Abstract

The value of osteology in an historical context: a comparison of osteological and historical evidence for trauma in the late 18th to early 19th century British Royal Navy.

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Keywords: trauma, fractures, documentary sources, history, Royal Navy

Trauma is arguably the most comparative and least ambiguous of palaeopathological lesions. As such, it is an ideal vehicle for exploring the respective contributions and differences between historical and osteological approaches to health in the past. A direct comparison between historical and osteological assemblages is often impossible due to the lack of comparable data, or complicated by the very different perceptions, motivations and pre-occupations of past writers and present researchers. Nevertheless, where genuine opportunities exist to compare and contrast the alternative strands of evidence, it may lead to a much richer and more nuanced understanding of the past. This study uses trauma in the late 18th- to early 19th century British Royal Navy (R.N.) to explore the differences between the two disciplines, and through this process to come to a deeper understanding of the physical effects of a maritime lifestyle on the health of late 18th- to early 19th century R.N. seamen and marines.

The 18th- and early 19th century R.N. is one of the best documented institutions of its day, with a large corpus of records accessible in the National Archives in Kew. Recent archaeological excavations in the burial grounds of the three R.N. hospitals of the 18th century in Britain- the Royal Hospitals Haslar in Gosport, Stonehouse in Plymouth and Greenwich Hospital in South-East London- have made available over 300 skeletons of seamen and marines, who were treated but died in these institutions. This study explores the osteological evidence for fractures and joint trauma patterning in 300 of these skeletons.

Eighteenth century accounts of the privations and dangers of sailing a fighting ship are well supported osteologically by the presence of 926 fractures and 14 joint dislocations. Osteological trauma patterning was compared with historical data collated from the Haslar and Plymouth Hospital musters (1792-1824) and Entry Books of Greenwich Hospital (1749-1765). The most probable aetiology of injuries was explored using insights from modern medical and forensic research, and 18th century sea surgeons' journals. Falls accounted for a very high proportion of injuries in both datasets, as did crush injuries, and to a much lesser extent, battle trauma. Extremely high rates of nasal fractures, Bennett's fractures of the first metacarpal, and anterior rib fractures in the skeletal assemblages strongly suggest very high rates of casual interpersonal violence. Interestingly, these injuries were very seldom recorded in either sea surgeon or hospital records, possibly due to seamen's fear of punishment for transgressing official naval regulations against fighting. Several unusual fractures (such as Shepherd's fractures of the talus, and third metacarpal avulsion fractures) and bony modifications (such as shallow and unstable hip and shoulder joints, *os acromiale* and Eagle's syndrome) appear to be the consequences of engaging in a maritime lifestyle, often beginning in childhood or adolescence.

Dedication

I dedicate this thesis to my father **Arthur Gordon Boston**, who died suddenly and unexpectedly on the 25th January 2012, aged 77 years.

I shall never forget his love, warmth, fierce intelligence, integrity and uncomplicated and generous outlook on life. I am so grateful to my father and my mother, Annol, who have supported me so consistently through the twists and turns of my life. And so I thank them both here, and remember with such sadness a happy, adventurous soul, whom I miss very much.

Dedication

This second dedication is to the seamen and marines of the 18th century Royal Navy, who are the subjects of this study. Many were forced into the navy against their will, yet showed astounding fortitude and courage in the face of extreme dangers and privations. They are an inspiration.

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Glossary of 18th century naval terms

Term	Definition
able seaman	the most experienced rank of seaman, these seamen carried out the most complex and dangerous operations in manoeuvring a ship; usually required at least three years of seafaring experience
boatswain	non-commissioned or warrant officer responsible for the ship's sails, rigging and boats; oversaw a small group of seamen; often supported by a mate or assistant; the boatswain and boatswain's mates usually carried out corporal punishment/ flogging under the command of a commissioned officer
bounty	a fee paid to a new recruit on enlisting
bow	the front or fore of the ship
capstan	a large winch with a vertical axis by which anchor rope was wound in, thereby raising the anchor; it comprised a vertical support into which wooden bars could be slotted; heaving on the capstan involved a large number of seamen and marines heaving on the bars or spokes, thereby rotating the capstan, and winching in the anchor rope
captain	the most senior officer commanding a ship; he was responsible for directing his ship in battle, maintaining the wellbeing of the ship and its crew, recruiting men, preparing the ship to sail, keeping records, including a daily log, records of ship's provision and repairs, and, ultimately, was accountable to the Admiralty for the wellbeing of the ship and her conduct in battle; aboard his ship the captain's will were absolute
cat-o'-nine-tails	a multi-tailed rope whip comprising nine knotted lengths of cord, each approximately 2 feet long; used for flogging in the R.N.
commissioned officer	officer holding a commission from the King; included the ship's captain, lieutenants, marine captain and, after 1806, the ship's surgeon
cutting out	to seize and carry off an enemy vessel whilst she is at anchor in a harbour, often accomplished by stealthy or surprise boarding of the enemy vessel
discharged dead	died in service
discharged to ship	returned to service aboard ship
discharged unserviceable	discharged from service due to mental or physical injury or disease
first rate ship	a ship with three masts, over 100 guns and 850- 875 men
flogging	widespread public corporal punishment for the lowerdeck for a wide range of misdemeanours; the flogged man's arms were raised and tied to the gratings, and his back was lashed with a cat-of-nine-tails.
forecastle	the raised deck at the front of the ship
fourth rate ship	a ship with three masts, 50-60 guns and 320- 420 men
frigate	a ship with three masts, 20-44 guns and 140- 300 men
hatchway	a covered opening in the deck through which access is gained to a lower deck; closed by a hatch in poor weather
heaving the lead	heaving a plummel or mass of lead attached to a line into the sea, to estimate the ship's velocity in knots; also used for sounding the depth of water beneath the ship
helm	the steering wheel of the ship through which the direction of the ship's forward motion was governed.
idler	a warrant officer or artisan who was not required to keep watch, and so slept the night through; these included carpenters, shipwrights, sailmakers, the cook, the purser, secretaries etc.
landsman	lowest rank of seaman; the 'novice' rank for those seamen with little or no previous experience of seafaring
larboard (later port-side)	the left side of the ship when facing the bow
lieutenant	commissioned officer ranked between midshipman and captain; depending on rating, a ship might carry first, second, third and fourth lieutenants; promotion to lieutenant was dependant on passing an examination, and required at least six years sea service.
lowerdeck, the	a general term for landsmen, ordinary and able seamen
man-of-war	a fighting ship, usually a first to fourth rater
marine	a sea-going soldier whose weaponry and fighting tactics were adapted to sea battles and amphibious attacks; the marines became the Royal Marines in 1802.
mast	vertical pole from which the yards and rigging are suspended

Term	Definition
mess	a mess was a group of 8-12 seamen who prepared food and ate together; a mess was a very cohesive social group in which strong friendships were forged.
mess mates	members of a mess
midshipman	lowest rank of officer (below lieutenant); often 'young gentlemen' (usually adolescents) being trained to become officers- from 1795 designated 'boys first class'; midshipmen also included adult seamen who had been recruited from the ranks, but many lacked the social and political influence to progress further in their careers
ordinary seaman	middle rank of seaman, who had some seamanship; this ranking usually required more than a year's seafaring experience
orlop	lower deck beneath the waterline; the surgeon would usually operate in the midshipmen's berth on the orlop during a battle.
porthole	an opening in the ship's side through which the great guns could be run out, and which allowed light and air to enter the lower decks when open; covered by a hatch in heavy seas and when turning the ship; the portsill is the sill of the porthole
prize money	a percentage of the value of a captured enemy vessel, paid to each crew member, which varied according to rank
quarterdeck	a raised deck behind or aft of the main mast; traditionally where the captain commanded the ship, and reserved for commissioned officers; a term used to denote commissioned officers; in battle, marines were often stationed on the higher vantage point of the quarterdeck
ran	deserted
rankings	landsmen, ordinary and able seamen; also known as the lowerdeck
second rate ship	a ship with three masts, 90- 98 guns and 700- 750 men
shrouds	pieces of standing rigging that held the mast vertical, and prevented it from swinging from side to side
starboard	the right side of the ship when facing the bow
stern	the back or aft of the ship
third rate ship	a ship with three masts, 64- 80 guns and 500- 650 men
topman	a seaman stationed high in the rigging; the most dangerous post; topmen were regarded as the cream of seamen
waist	the centre of the upper deck between the forecastle and the quarterdeck
warrant officers	non-commissioned officers holding a warrant from the King; these included boatswains, the master, the surgeon, gunners, and artisans (see idlers)
watch	a shift; at sea usually lasting four hours, with two two-hour dog watches at night
yard	the horizontal spar from which a square sail is suspended
yardarm	the end of the yard

Glossary of osteological terms

Term	Definition
aetiology	The cause or set of causes, or the manner of causation of a disease or condition
anterior	pertaining to the front or ventral aspect of the body when an individual is standing upright with the lower limbs together, and the upper limbs turned out, such that the palm is facing forward (i.e. in anatomical position).
atrophy	wasting
blunt force trauma	trauma inflicted by a blunt instrument
collagen	ubiquitous protein found in bone and soft tissue; constitutes a major structural component of many tissue types
distal	further from the midline of the body (e.g. the knee is distal to the hip)
enthesophyte or enthesopathy	injury to a tendon or muscle; osteologically visible at the insertion point into the bone; enthesophytes manifest as osteophytosis and increased porosity; cortical defects are another form of an enthesopathy that manifests are localised bone loss at the insertion site.
fracture	a break in the continuity of the bone; this is most commonly traumatic, but may also be due to repetitive strain, or occur in pathological bone weakened by disease
inferior	vertically beneath
ischaemia	inadequate supply of oxygen and nutrients to living tissue, which, if it persists, often leads to tissue death or necrosis
kyphosis	a hunchback, or anterior curvature of the spine
lateral	further from the midline of the body in the transverse plane
luxation	complete joint dislocation
medial	closer to the midline of the body in the transverse plane
necrosis	death of tissue
osteitis	inflammation of compact bone, usually due to infection
osteochondritis dissecans	localised necrosis of the cartilage and bone of a joint surface, usually a shearing injury in young, physically active males
osteomalacia	Vitamin D deficiency in adulthood
osteomyelitis	infection that penetrates to the marrow cavity of long bones
osteopaenia	demineralisation of bone tissue
perimortem trauma	trauma inflicted immediately at the time of death; in osteology this includes trauma inflicted too soon before death for healing to be macroscopically visible.
periosteum	the outermost layer of a bone, which is most richly supplied with blood vessels and nerves
periostitis	inflammation of the periosteum
posterior	pertaining to the dorsum or back of the body when an individual is standing upright with the lower limbs together and the upper limbs turned out, such that the palm is facing forward (i.e. in anatomical position).
post-mortem trauma	damage caused to bone and soft tissue after death; in osteology this comprises that inflicted on bone once it has lost a significant collagen component.
projectile trauma	trauma caused by projectiles, such as musket-balls, grape-or cannister shot, arrows or flying splinters
proximal	closer to the midline of the body (e.g. the elbow is proximal to the hand)
sequelae	a secondary result or pathological consequence resulting from a disease or injury
sharp force trauma	trauma inflicted by an edged implement or weapon
subluxation	incomplete joint dislocation
superior	vertically above
syndesmosis	Injury to a ligament
wet or green bone	bone that retains a high proportion of collagen, and hence, retains its elasticity

Movements of the body are best illustrated using diagrams. These are presented in Appendix 1.

1. Introduction

1.1. Background

Trauma is arguably the most comparative and least ambiguous of palaeopathological lesions. As such, it is an ideal vehicle for exploring the respective contributions and differences between historical and osteological approaches to health in the past. A direct comparison between historical and osteological assemblages is often impossible due to the lack of comparable data, or complicated by the very different perceptions, motivations and pre-occupations of past writers and present researchers. Meaning does not reside in text, but in the writing and reading of it (Hodder 1994). This is particularly true when investigating health in the past, where earlier medical perceptions (in this case of 18th century naval surgeons and physicians), terminologies and diagnoses were very different from the modern medical paradigm, to which osteologists subscribe. Nevertheless, where genuine opportunities exists to compare and contrast these very different datasets, the alternate strands of evidence may lead to a much richer and more nuanced understanding of the past. This study uses trauma in the late 18th- to early 19th century Royal Navy (R.N.) to explore the differences between the two disciplines, and through this process to come to a deeper understanding of the physical effects of a maritime lifestyle on the health of late 18th- to early 19th century R.N. seamen and marines.

The late 18th- to early 19th century R.N. was a vast institution engaging hundreds of thousands of seamen and marines at any one time (Rodger 2006). It also was one of the best documented institutions of its day. An extensive corpus of official R.N. records survives as the Admiralty Papers in the National Archives in Kew. A small proportion of this forms the basis of the historical component of this study. Recent archaeological excavations in the burial grounds of the three R.N. hospitals of the 18th century in Britain- the Royal Hospitals Haslar in Gosport, Stonehouse in Plymouth, and Greenwich Hospital in Greenwich, South-East London- have made available over 300 skeletons of seamen and marines who were treated but died in these institutions. The availability of these two

large datasets provides a rare opportunity for a meaningful comparison between osteological and historical sources.

Fractures and joint trauma patterning is compared with similar documentary data compiled from the muster books of Haslar and Plymouth Hospitals and the Entry Books of Greenwich Hospital. Traumatic events leading to injuries described in sea surgeons' journals is compared with probable mechanisms of injury of traumatic lesions on the skeletons, the latter borrowing insights from modern medical and forensic literature. Together these sources provide an unique insight into the very specific hardships and dangers facing R.N. seamen and marines, and their extraordinary capacity to survive often painful, disfiguring and disabling injuries.

This chapter briefly reviews some of the prolific osteological literature on trauma, and reviews naval history, in particular social history of the R.N. and naval medicine. General limitations of both disciplines are outlined. the chapter also introduces the osteological and historical datasets used in this research, and sets out the aims and objectives of this study.

1.2. Trauma studies in the historical period

Osteoarchaeologists have used trauma patterning in past populations to explore aspects of occupation, lifestyle, socio-economic organisation and the nature of inter-personal conflict. The state of healing of traumatic lesions has also been used to reflect aspects of diet, access to 'medical' care and the state of that 'medical' knowledge (Roberts and Manchester 2005). There has been considerable palaeopathological research into trauma in the last two decades, with a more recent surge in interest in the evidence for human conflict. Insights from modern medicine and increasingly from forensic science have been applied to such trauma studies, bringing fresh insights to the discipline. A comprehensive review of the literature on palaeotrauma would be impossible here, and several reviews have already been undertaken (e.g. Jurmain 1999; Knusel and Smith 2013; Larsen 1997; Walker 2001).

Osteoarchaeologists, in general, have become much more cognisant of the importance of social and cultural context to their analyses. Another trend gaining considerable momentum is investigation into post-medieval populations. The ground-breaking work at Christ Church Spitalfields in the late 1980s established post-medieval osteology and funerary archaeology as a important fields of academic enquiry (Molleson et al. 1993; Reeve and Adams 1993). Since then innumerable post-medieval burials have been excavated and analysed in developer-funded and academic projects in Britain (a few published examples being Bashford and Sibun 2007a; Boston 2009; Boston et al. 2009; Boyle 2004; Boyle et al. 2005; Boyle and Keevil 1998; Brickley et al. 2006; Brickley et al. 1999; Cowie et al. 2008; Mahoney-Swales 2009; McKinley 2008; Miles and Connell 2012; Miles et al. 2008a; Miles et al. 2008b; Start and Kirk 1998). In North America, post-medieval burial archaeology is now an established field, utilising a combined osteological, archaeological and historical approach to furnish contextualised, biocultural accounts of past populations (e.g. Buikstra et al. 2000; Grauer 1995; Rose 1985; Saunders et al. 1995a; Saunders et al. 1995b).

Increasing interest in the more recent past is very evident in the bioarchaeology of human conflict in the historical periods, in particular the 18th- and 19th centuries. There are several recent studies of military casualties of the Napoleonic Wars and associated conflicts, which provide valuable analysis of sabre and musket-ball injuries, which are directly pertinent to this study (Dutour and Buzhilova 2013; Extxeberria and Herrasti 1991; Kaufman 2001; Kaufman 2003; Meyer 2003; Van de Vijver and Kinnaer 2013).

However, there has been no comparable large-scale study on 18th– early 19th century naval skeletons. Several skeletal studies of maritime assemblages have been made but, in general, are of limited comparative value (see Appendix 2). Most useful is Stirland's work on the 16th century *Mary Rose* assemblage (Stirland 1987; Stirland 1991; Stirland 1993; Stirland 1998; Stirland 2005a; Stirland 2005b; Stirland and Waldron 1997), in which she undertook ground-breaking analysis of entheseal changes and occupation. Although a general skeletal report is available, the lack of quantitative data

precludes the calculation of true and crude prevalence rates of pathological lesions. She identifies at least 57 fractures, acetabular flange lesions and at least eight cases of *osteochondritis dissecans,* but it is unclear from the text if these lesions were observed in the 92 'articulated' skeletons, or in the much larger disarticulated assemblage. Nevertheless, this is the most comprehensive report on maritime assemblages available.

Osteological reports on human remains recovered from shipwrecks also consulted include the *Vasa* (During 1994; During 1997a), the *Kronan* (During 1997b; Kjellstrom and Hamilton 2013), the *Swan* (Black 2002), the *Batavia* (Franklin 2012) and the *Earl of Abergavenny* (Armitage 2002). Of these the only comprehensive skeletal report was of the single *Swan* skeleton. Osteological reports on the remainder were either incomplete or did not present quantitative data on traumatic lesions necessary for empirical comparison with the R.N. assemblages of this study. Three other archaeologically excavated 18th– to early 19th century R.N. skeletons were also of limited comparative value. Formal analysis of 30 casualties from the Battle of the Nile (1798) and the Egyptian campaign (1800-1802) buried on Nelson's Island, Aboukir Bay, Egypt, was prohibited by the Egyptian authorities. Thus, observations that were made on site were piecemeal and incomplete (Slope and Boston 2010). The skeletal assemblage from the R.N. contract hospital in Deal, Kent (Anderson 2002) was very small and appears to contain numerous non-R.N. individuals. Excavations in the R.N. hospital burial ground at English Harbour, Antigua, revealed some male skeletons who were probably seamen, but also contained many of the 'King's Negroes' who worked in the R.N. shipyards of English Harbour and were not mariners (Varney 2009; Varney and Nicholson 1999). Of considerable interest are the ongoing excavations by Varney and Nicholson at Galleon Bay near English Harbour, where R.N. seamen appear have been buried on the beach after dying of tropical diseases. Unfortunately, research is still in its early stages, and a report is not yet available (Varney 2013, pers.comm.). A health report on modern British trawlermen (Cross 1985) was also consulted as a comparative modern maritime study of trauma patterning and aetiology, although obviously

fundamental differences exist between the lifestyles and working environments aboard a modern trawler and an 18th century man-of-war.

Undertaking osteological research in an historical period is somewhat of a doubled-edged sword. Undeniably, the availability of an historical dataset has proved a valuable opportunity to test osteological methodologies, such as age and sex, against historically verified data (e.g. Falys et al. 2006; Molleson et al. 1993; Mulhern and Jones 2005; Smith 1991), and to provide a much richer bio-cultural context to osteological findings than is possible in prehistoric periods. However, all interpretation of the past, however recent, is coloured by the reporter or participant's experience, emotions, politics and ideology. The biases of writer and reader are all the more intense in the analysis of human conflict. In this study, the awareness that 18th century medicine operated within a very different medical paradigm to modern medicine, and by extension, to osteology, should introduce caution when applying retrospective diagnoses to the past (Mitchell 2011).

The adage that '*history is written by the winner*' may bias both the writing and subsequent reading of historical accounts. Glorification of the past is very common in contemporary and modern perceptions of 'Nelson's Navy'. Conversely, in other historical contexts, there are ideological or political motivations to underplaying of violence and conflict in the past (Knusel and Smith 2013). Glorification of the past achievements of medical men is particularly prevalent in the history of medicine, especially amongst medical doctors exploring this field, who are apt to project a rather simplistic view of a linear, upward trajectory of medical progress from the past to the present (Rodger 1997). In fact, the actual contribution of medical men towards falling mortality rates in the R.N. over the late 18th- to early 19th century remains very much in doubt (*Ibid.*) (see Chapter 3).

In addition, only the literate leave behind a written record, and these individuals often represent only a sector of the whole society. This is particularly pertinent to this study, as most seamen and marines were illiterate (Adkins and Adkins 2008; Lavery 2010). A few memoirs of seamen do exist (e.g. Leech 1857; Nicol 1822; Robinson 1836; Spavens 1796), but overwhelmingly the social history

of the R.N. has been written in reference to officers' memoirs and journals, and official documents. Indeed, this study uses just such official documents, which undoubtedly have the potential to introduce misconceptions and inaccuracies into this reading of the past.

In history, as in archaeology, the '*absence of evidence is not evidence of absence'*, and lacunae in both datasets may introduce errors in interpretation. In osteology, unrepresentative samples, poor bone preservation and methodological limitations may all bias a sample. In addition, there remains the intractable problem of the osteological paradox- how accurately the skeletons from a cemetery population represents the living population whence they originate (Wood et al. 1992). However, unlike historical records, skeletal remains provide a direct source of evidence– they are physical facts and not culturally dependant constructs (Walker 1997), and may provide a more 'unvarnished' account of the past than some historical narratives. Bone fractures in predictable ways, depending on measureable parameters, such as the angle, velocity and energy of the force applied. Trauma patterning may be thus used to reconstruct or test the veracity of historical accounts, as demonstrated in re-evaluations of the Battle of Little Big Horn (Willey and Scott 1996), the defence of Fort Erie (Pfeiffer and Williamson 1991), the mutilation of defendants of Fort William Henry, New York, by Native American warriors (Liston and Baker 1996), and the execution of brigands in Mechelin, Belgium, in the Peasants' War of 1798 (Van de Vijver and Kinnaer 2013).

Thus, careful reading of both the historical and osteological evidence is necessary to arrive at the most accurate view of the past. Osteologists working in historical periods must, and in many respects have, moved from being passive '*handmaidens to history'*. From merely providing illustrative material to the existing historical narrative, osteology must take more critical approach to text-based sources, thereby providing alternative, if sometimes contradictory, narratives of the past than is available from text alone (Perry 2007).

1.3. Studies in naval history

Although there has been a long historical tradition exploring naval strategies, sea battles and biographies of famous commanders, such as Nelson, until recently '*naval history was deeply unfashionable, and amongst academics lay on the bare margins of professional acceptability*' (Rodger 2008). This has changed radically in the last two decades, following Rodger's (1986) groundbreaking social history of the R.N '*The Wooden World- an anatomy of the Georgian Navy'*. Numerous more and less scholarly publications have followed (Adkins and Adkins 2008; Clayton 2008; Clayton and Craig 2004; Lavery 1989; Lavery 2004; Lavery 2010), many paraphrasing one another, and lacking the empirical rigour and qualitative scope of Rodger's original work.

Another aspect of naval history that has seen enormous expansion in recent years is naval medicine. Although Lloyd and Coultier's (1961) '*Medicine in the Navy 1200-1900'* remains the seminal work on this subject, more recent scholarly studies have explored a wide range of aspects of naval medicine, placing it in the wider context of war and imperialism. Studies include the influence of the R.N. in the development of tropical and imperial medicine (Alsop 2007; Harrison 2010), naval health and medical organisation over time (Crimmin 1999; Crimmin 2007; Ellis 1969; Harrison 1996; Rodger 1997), specific sea diseases and conditions (Carpenter 1986; Harvie 2002; Haycock 2002; Mills 2007; Watt et al. 1981), the origins and training of naval surgeons (Brockliss et al. 2005; Lincoln 2007), and biographies of prominent surgeons, such as Beatty and Trotter (Brockliss et al. 2005; Vale and Griffith 2011).

The R.N. hospitals have received relatively little attention, with work concentrating on naval architecture (Harland 2005; MacQueen Buchanan 2005; Stevenson 2007), and little on the treatment patients received in these hospitals. Eighteenth- to early 19th century military and naval surgical techniques have been explored by Crumplin, and to a lesser extent by Watt (Crumplin 2007; Crumplin 2009; Crumplin and Starling 2005; Watt 1985), but relatively little research has been done on the patients themselves. Care in the hospitals, hospital administration, mortality rates and

patient's profiles, such as diagnoses on admission, length of hospital stay and outcome, have received little, if any, attention.

The above research into R.N. medical history is principally qualitative in approach, and where empirical data are used to support an argument, it is often limited in scope and applied to different time periods or situations, where it may not be appropriate. By employing a more quantitative approach to historical data, this study hopes to explore aspects of naval health, specifically -trauma, which have not yet been researched by historians, and to use these empirical data to compare historical evidence for trauma with the osteological evidence from the three Royal Hospitals.

1.4. Background to the osteological and archaeological datasets

1.4.1. The osteological dataset

The osteological dataset comprised 300 articulated skeletons excavated from the burial ground of the three Royal Naval Hospitals in Britain in existence in the late 18th to early 19th centuries AD: Haslar, Plymouth and Greenwich Hospitals. Haslar (founded 1756) and Plymouth Hospitals (1762) were established within years of one another and were designed to accommodate 1,800 and 960 sick and injured seamen and marines on active service, respectively (Harland 2005). Greenwich Hospital did not treat active servicemen, but was intended as the R.N. counterpart to the Chelsea Hospital for soldiers- i.e. a prestigious retirement home for long-serving or severely disabled veterans.

Historical records indicate that burials were principally those of R.N. ratings or the 'lowerdeck' who died in the hospitals- largely comprising seamen, fewer marines, and a small proportion of petty officers and naval artisans, such ship's carpenters and sailmakers. (Stray Park Plymouth Burial Register 1813-1814).

By archaeological standards, the burials fall into a narrow time range and are broadly contemporary. The Haslar and Plymouth Hospital burial grounds date to between 1756-1824 and 1762-1824, respectively, whilst the Greenwich burial ground dates are spread more widely between 1749 and

1857. Being a hospital for R.N. veterans, most Greenwich pensioners saw active service at broadly the same time as the former two assemblages, and may be regarded as contemporaries of the other two groups.

1.4.2. Archaeological background

The skeletons of this study were excavated in four archaeological fieldwork programmes undertaken in the burial grounds of Haslar, Plymouth and Greenwich Hospitals between 1999 and 2011. The geographic location of the three sites is shown in Fig. 1.1. This section provides a brief archaeological context to the skeletal assemblages. A more detailed archaeological and historical background is presented in Appendix 3.



Figure 1.1 *Map of Southern England showing the location of the three R.N. hospitals of this study.*

(i) Haslar Hospital, Gosport, Hampshire (1756-1824)

In 2005, Oxford Archaeology (OA) undertook a desk-based assessment (Boston and Mahoney 2005) and archaeological evaluation within the Paddock, a large open area to the south-west of the hospital precinct (Boston 2005), on behalf of the Ministry of Defence (then landowners of the

hospital) (NGR SZ6150 9849). Eleven trenches were opened in order to ascertain the nature of the burials (Fig. 1.2), but no skeletons were removed. Orderly rows of single burials were present in trenches in the eastern half of the Paddock. To the west of the line of the back wall of the Memorial Garden, the burials petered out. There was minimal grave intercutting, indicating a single phase of burial. Most graves contained a single, coffined, unaccompanied skeleton, although multiple burials (up to five) one above the other were found in single-width graves towards the south-western limit of the burial ground.

Following the 2005 OA evaluation, a research excavation project, headed by Dr Andrew Shortland of Cranfield University, undertook four fieldwork seasons between 2007 and 2010. The Cranfield excavations comprised the excavation of several trenches within the Paddock and closer to the hospital (Fig. 1.2). The nature of the excavated burials was very consistent with the OA evaluation

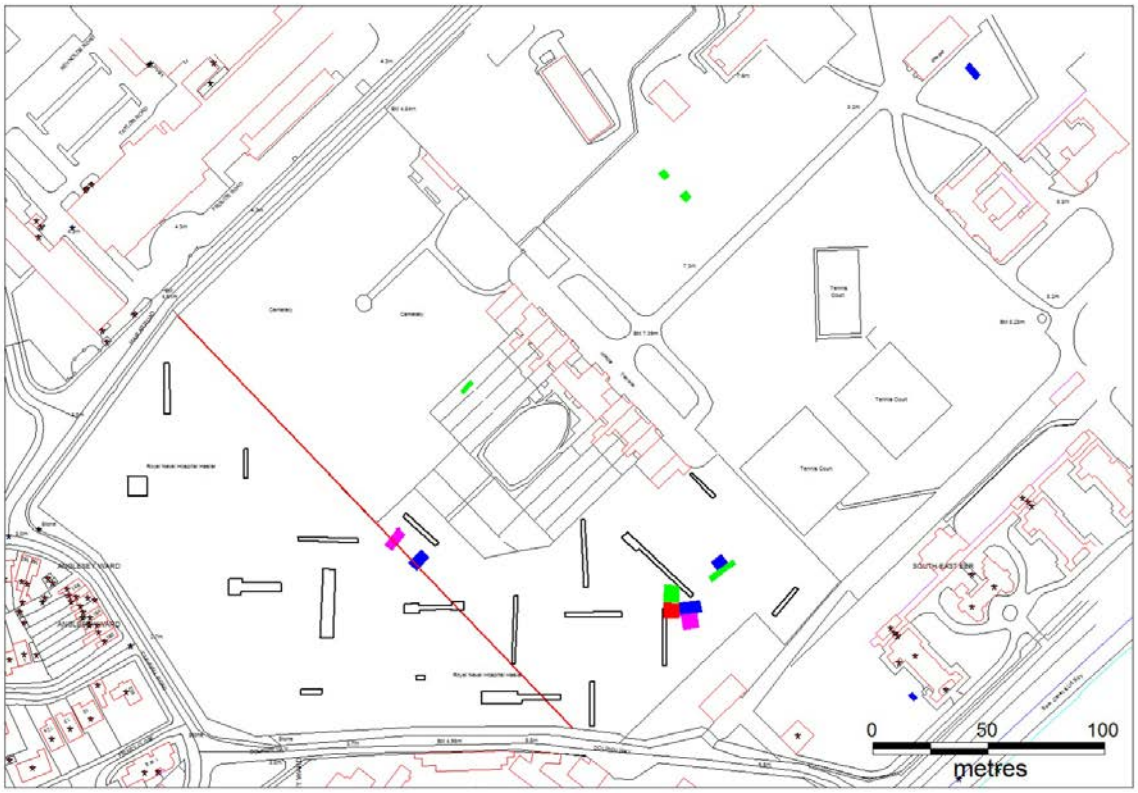


Figure 1.2 *Trench location in the Paddock, Haslar Hospital. The OA evaluation trenches are outlined in black. The Cranfield University trenches are in colour. The red line depicts the south-western limit of the burial ground. (Image courtesy of Peter Masters of Cranfield University).*

findings. Only those trenches within the south-eastern part of the Paddock contained skeletons. In total, 51 articulated skeletons were excavated, of which 49 constitute the Haslar assemblage of this study.

The Paddock was in use as a burial ground from the founding of the hospital in 1756 until 1824. Very few graves intercut, so relative dating was not possible. Nor is the wider spatial burial sequence within the Paddock known. Given their density, it is clear that only a moderate proportion of the estimated 17,000 burials in the hospital grounds could have been interred within the Paddock (see Chapter 3). Modern hospital employees have reported multiple sites closer to the hospital buildings and outside the hospital precinct where human remains were disinterred during building works, strongly suggesting that the burial area was much more extensive. To date, this has not been archaeologically verified.

The only burial in the Paddock with dateable artefacts was Haslar 213, who was buried with a local Gosport bronze token and an Abolitionist medal placed over the eyes (*c*. 1793) (Catherine Sinnott 2012, pers. comm.).

A preliminary report on the first two years of excavation at Haslar Hospital was compiled (Shortland 2007; Shortland *et al.* 2008), but the full excavation report is still outstanding. All human remains from Haslar were reburied within the Paddock in May 2011.

(ii) Plymouth Hospital, Stonehouse, Plymouth, Devon (1762- 1824)

In 2007, Exeter Archaeology was commissioned to undertake an archaeological excavation after burials were unexpectedly discovered during redevelopment work at the site of a former car showroom at Athenaeum Place, on the corner of Athenaeum Lane and the Crescent, Plymouth (NGR: SX 4748 5428) (Exeter Archaeology 2008). Historical research by City Archaeologist John Pamment-Salvatore strongly suggests that this burial ground was Stray Park, the first burial ground of Plymouth Hospital, which was in use between 1762, when the hospital was founded, until 1824

when burial was moved closer to the hospital at No-Place Field (Exeter Archaeology 2008; Pugh 1972; Reese 1962).

Due to commercial issues, Exeter Archaeology completed most of the excavation but very little post-excavation synthesis. Thus, no skeleton processing was done, and there is no site narrative on which to draw. The brief site description below and in Appendix 3 is based on primary site records kindly supplied by Exeter Archaeology before it closed for business in 2010. Approximately 190 skeletons were excavated, of which 151 of the best preserved comprise the Plymouth assemblage of this study.

The small excavation area fell within the south-eastern part of Stray Park burial ground (Fig. 1.3.), and constituted approximately a tenth of its total area of 1.03 acres (Exeter Archaeology 2008), Unlike Haslar, Stray Park burial ground had been very heavily utilised for burial, probably in consequence of its finite area. There was considerable grave intercutting, probably indicating several phases, but systematic re-use of the area could not be spatially discerned.

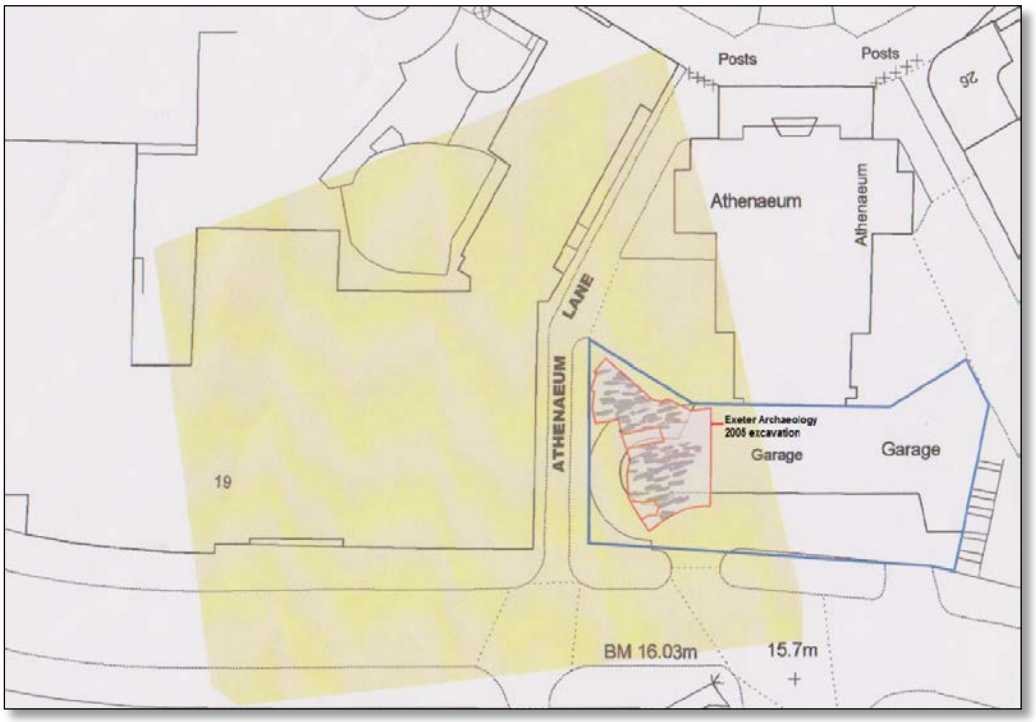


Figure 1.3 *Modern map showing the location of the Exeter Archaeology 2007 excavations. The shaded area is the total area of the burial ground projected from historical maps (Image courtesy of Exeter Archaeology).*

Like Haslar, the dead had been laid out supine and extended in plain wooden coffins, unaccompanied by grave goods. Multiple interments were much more common here than at Haslar. The only dateable artefacts were two gilded brass buttons bearing a fouled anchor motif, which were recovered from the multiple grave of Plymouth 670 and 671. Such buttons were in use in the R.N. from 1774 (Lewis 1945) and the manufacturers' mark HTD (Hammond, Turner and Dickenson) indicates a date of manufacture after 1796 (Osborne 1840).

(iii) Greenwich Hospital, Greenwich, South-east London (1749- 1856)

Two developer-funded excavations were undertaken to the south of the hospital buildings, within Goddard's Ground, the second burial ground of the Royal Hospital Greenwich. This cemetery was in use from 1749 to 1856. The first excavation by OA in 1999-2001, recovered 107 skeletons (NGR: TQ 3850 7760) (Boston *et al.* 2008). The second was a watching brief by Pre-Construct Archaeology (PCA) in 2009-2010 (Pre-Construct Archaeology 2011), when 17 skeletons were excavated (NGR: TQ 3858 7758). Ninety-four skeletons from the former excavation and six from the latter constitute the Greenwich skeletal assemblage of this study.

OA undertook archaeological excavation and watching briefs in advance of piling works and service trench excavations adjacent to the Devonport Building on King William's Walk, Greenwich. Only those skeletons affected by groundworks were removed, but mechanical stripping of the whole footprint of the proposed building revealed 164 graves.

The western half of the main area (Areas 1 and 2) contained three or four neat rows of well-spaced graves, but in the eastern quarter of the trench, moderate intercutting by later graves was present. This intercutting indicated a less organised second phase of burial, with irregular grave spacing and orientation. Most graves were only wide enough to admit one coffin, but often contained two to three coffined burials stacked one above the other. Six double graves contained two pairs of burials directly overlaying another pair. Like Haslar and Plymouth, the Greenwich burials were unclothed but shrouded. Coffins were wooden and, unlike the other two assemblages, many were decorated

with iron coffin furniture. Due to corrosion, the breastplates were illegible, however, and, no burial could be named or dated.

The PCA fieldwork was located immediately to the south-west of the National Maritime Museum building, bordering Greenwich Park (Pre-Construct Archaeology 2011)- 40m south-east of the OA excavations (Fig. 1.4). Seven graves were located in a narrow strip of the northern edge of the main trench. The absence of more southerly graves strongly suggested the southern limit of the burial ground. Seventeen fairly complete skeletons were excavated, each grave containing between one and four coffined inhumations. Osteological analysis in this study revealed that eight PCA skeletons were older females or probable females- probably hospital workers, such as laundresses and nurses. The remainder were males, of which one was an amputee, and are assumed to have been pensioners.

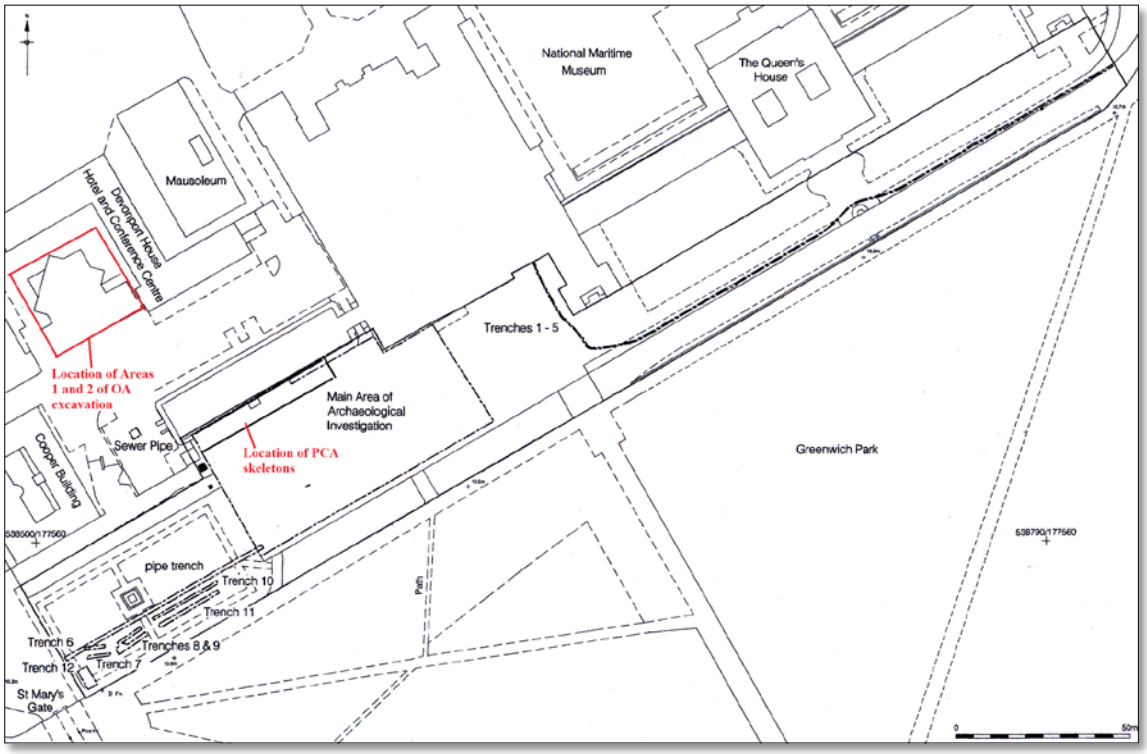


Figure 1.4 *Greenwich Hospital: location of Oxford Archaeology and Pre-Construct Archaeology excavation areas (adapted from PCA 2011 plan).*

The OA excavation is published as a monograph (Boston et al. 2008) and the PCA watching brief report exists as an unpublished client report (Pre-Construct Archaeology 2011).

1.5. The historical dataset

The late 18th to early 19th century R.N. was the largest employer of its day, requiring a vast and complex bureaucracy to manage victualling, ship building, outfitting and manpower. The Admiralty Papers in the National Archives at Kew record this official administration. Particularly pertinent to this study are documents pertaining to medical care: sea surgeon's journals, musters of Haslar and Plymouth Hospitals, and admission books of Greenwich Hospital. Numerous other primary sources were consulted (see Appendix 4 for a full list).

1.6. Aims of the research

In 1804, Thomas Trotter (1760-1832), Physician to the Channel Fleet and, arguably, the most influential medical man in the eradication of scurvy in the R.N. (Vale and Griffith 2011), wrote eloquently and movingly on the unique character of British seamen, lauding their courage and fortitude in the face of the extreme hardships and dangers, which, he wrote, were inseparable from a seafaring life (Trotter 1804b). He believed that only those initiated into this lifestyle from a young age could become inured to the '*fatigues and perils of a sea life'* (*Ibid.*, 264-6), and that, in order to learn the ropes, most seamen began their sea service very young. However, the '*laborious duty, changes of climate and inclement seasons, bring on a premature age, and few of them live to be very old'* (*Ibid.*, 266).

So, was a seaman's life really so nasty, brutish and short? And what can osteology tell about the physical demands and dangers of a naval life that history alone cannot?

This study explores these questions, by fulfilling the following more specific aims and objectives:

1. Both history and osteology are beset by diverse methodological and material problems, which may result in a partial and biased representation of the past. This research will explore how these limitations influence our picture of health in the 18th- to early 19th- century R.N.,

and through careful reading of the evidence, aims to come to a more accurate, nuanced understanding of the physical effects of this lifestyle on seamen and marines serving at this time.

2. The age, occupation, geographic and social origins of an individual have considerable bearing on an individual's health and their exposure to injury. With this in mind, this study also explores the osteological and historical evidence for the demographic composition of the 18th- to early 19th century R.N., and the evidence for youthful adaptation and early physical stress of a maritime lifestyle.
3. To explore Trotter's claims that maritime seafaring lifestyle in the British R.N. was indeed one of considerable danger and hardship, by comparing and contrasting the evidence for trauma from two very different sources: human skeletons and contemporary naval documents.
4. To explore the probable causes of many of these injuries, using insights gleaned from contemporary sea surgeon's journals and modern and forensic literature.
5. Serving aboard a fighting ship in the Age of Sail exposed seamen and marines to very specific environmental influences and dangers quite unlike those encountered by contemporary civilians. The final aim of this study is to determine what, if any, traumatic lesions and bony modifications may be seen as peculiar to seafarers, which, in the future, may be used as skeletal markers to identify seamen in more mixed skeletal assemblages.

2. Trauma studies

2.1. Introduction

Trauma is medically defined as an injury or physiological wound to living tissue caused by a force or mechanism extrinsic to the body (Lovell 1997; Martin 2010). It is generally classified as blunt force, sharp force and projectile trauma, depending on instrument inflicting the injury (Bennike 2008; Roberts and Manchester 2005; Waldron 2009). Trauma may be accidental (as in falls and collisions) or intentional (as in interpersonal violence, self-harming and surgical interventions).

In skeletal material, trauma is most commonly identified as fractures, but may also be the cause of ossified tendon and ligament (enthesophytes, cortical defects and syndesmoses), and muscle damage (*myositis ossificans traumatica*), along with sheering and necrosis of cartilage and bone of joint surfaces (*osteochondritis dissecans*) and joint dislocations (Bennike 2008; Ortner 2003; Waldron 2009). Bleeding beneath or in close apposition to the periosteum is often traumatic in origin, and may been seen on the skeleton as ossified haematomas and periostitis. A traumatic aetiology is far from certain, however, as haemorrhage may arise from other conditions, such as scurvy (Maat 1982; Maat and Uyterscaut 1984), and periostitis is a non-specific inflammatory reaction to diverse conditions (Weston 2008). As in all aspects of palaeopathology, bony trauma represents a very small proportion of the total trauma experienced by an individual or group, the majority of soft tissue trauma leaving no trace of the skeleton. This becomes very apparent when comparing historical medical accounts of trauma in the R.N. with the osteological evidence.

This chapter describes the common fracture types and their mechanism of injury, as well as the complications of fractures, which often determine overall survival and functional recovery from trauma. Distinguishing osteological features of perimortem and post-mortem fracture patterning are described, as well as the process of fracture healing. Joint trauma is also described. A more detailed consideration of the biomechanics of fracture development is presented in Appendix 5 and the more common fractures affecting different elements and their aetiologies are presented in Appendix 6.

2.2. Fractures

2.2.1. Definition of fracture

Roberts (1991, 139) defined a fracture as '*the result of any traumatic incident that leads to the complete or partial breakage in the continuity of the bone'*. Her definition bears a striking resemblance to the one given two centuries previously by naval surgeon William Northcote: '*A fracture is a solution of continuity in a bone..... The causes are all external violence, whether by a blow, fall or gunshot. There are instances where this accident has happened from internal disorders, namely from scurvy, a caries or the venereal disease, which renders the bone so brittle that it has been fractured without an external accident.*' (Northcote 1770, 221). His distinction between fractures caused by external forces, and pathological fractures are still observed in fracture classification today (Hipp et al. 1992).

Fracture is almost always accompanied by soft tissue injury and inflammation, which may affect fracture healing and medical treatment (Lovell 1997), but are often not observable on the skeleton.

2.2.2. Blunt force trauma

Blunt force trauma is non-penetrating bodily trauma inflicted by a blunt object. This may be through accidental impact with the environment (such as a fall) or through intentional trauma with a blunt weapon (such as a club or fist). Fractures as a result of blunt force trauma may be classified by several criteria, which are described below.

Fractures may be closed (the broken bone does not penetrate the skin) or open or compound (the skin is penetrated). In the latter, exposure of the broken ends to the external environment introduces a very severe risk of secondary infection (chronic osteomyelitis), and carries a much poorer prognosis than a closed fracture (Roberts and Manchester 2005).

Fractures may also be classified as direct (the fracture is at the point of impact) or indirect (referred) at a location distant to the impact. An example is fractures resulting from a fall onto the foot. A common fracture resulting from direct impact is a 'lover's tryst' fracture (vertical crush fracture of

the calcaneus) (Galloway 1999), with indirect impaction fractures of the neck of femur and burst frctures of the vertebral body occurring as the impact of the fall is referred up the lower limb and trunck (*Ibid.*).

Bone weakened through pathological processes that undermine the micro-structure and normal bone composition may fracture more easily than healthy bone, and are known as pathological fractures. Common examples are distal radius, neck of femur and vertebral body fractures secondary to osteoporosis (Buhr and Cooke 1959); bony infractions in scurvy (Maat and Uyterscaut 1984); femoral shaft fractures in. Paget's disease; and vertebral collapse in metastatic carcinoma and tuberculosis (Pott's spine) (Aufderheide and Rodriguez-Martin 1998).

Fractures may be categorised as incomplete or partial, and complete. Incomplete fractures are fractures where the whole bone remains intact as one unit. As there are often no macroscopic morphological changes, these fractures are probably under-reported in archaeological bone (Ortner 2003).

These include:

- **Greenstick fracture:** An incomplete transverse fracture resulting from bending of a long bone, which develops on the side that has been placed under tension. It is commonly a childhood fracture that may result in permanent bowing of the long bone shaft, or may heal with no residual deformity (Ortner 2003).
- **Bony infractions:** Fine hairline cracks, which may develop due to pathological weakening of bone from underlying disease (e.g. scurvy, osteoporosis or Paget's disease), or may develop as tiny stress or fatigue fractures from chronic loading.
- **Compressive fracture:** The result of sudden excessive impaction. It may involve crushing of the outer cortical bone layer and possibly some of underlying trabecular bone, but with the element still intact, albeit morphologically altered, common examples being slight depressed

cranial fractures; crushing of joint surfaces, such as the tibial plateau and patellar impaction, and crush and vertebral wedge fractures (Ortner 2003).

- **Torus fracture** is a buckling of the bone cortex produced by compressive forces, with outward displacement of cortical bone around the circumference of the bony element; most commonly located at the junction of the metaphysis and diaphysis of a long bone in subadults (Galloway 1999).
- **Vertical or longitudinal fracture** is a form of compression fracture, orientated parallel to the long axis of the long bone. It is relatively rare, and has been recognised in the form of stress fractures in modern athletes and osteoporotic individuals (Devas 1960).

Complete fractures are usually dynamic (caused by an acute event) and result in discontinuity of two (simple fracture) or more fragments (comminuted fracture). Due to this discontinuity, malignment, overlap and non-union may all occur, sometimes with significant functional sequelae.

Types of complete fractures include:

- **Transverse fracture:** The fracture is orientated at right angles to the long axis of a long bone. Under a bending load, it begins much as a greenstick fracture, by cracking on the opposite side to the point of impact, but rapidly breaks across the bone as the tensile force moves across the bone ahead of the crack (Galloway 1999). Transverse fractures are commonly associated with a direct blow, and are unstable.
- **Oblique fracture**: The fracture is orientated at an oblique angle to the long axis of the diaphysis (commonly 45°) (Galloway 1999). It may be generated by purely compressive forces (Hipp et al. 1992), but in reality, compressive forces are often combined with bending and sheering forces, the fracture beginning as a transverse fracture but then changing to an oblique direction under sheering forces. In the forearms and legs, a combined load of twisting and bending may result in oblique fractures, the paired bones acting in a manner similar to a spiral fracture, with oblique fractures in each bone located at different levels

(Galloway 1999) (e.g. paired distal tibial shaft and proximal fibular fractures). These fractures are generally more stable than transverse fractures.

- **Spiral fracture**: Spiral fractures are caused by low velocity rotational forces acting on the bone. The fracture begins as a crack at the point of greatest tension, and follows the angle of rotation (approximately 45° to the long axis), until the two ends are one above the other. A longitudinal crack then appears uniting the two ends and completing the fracture. Thus a spiral fracture circles the shaft and includes a vertical step (Galloway 1999). These fractures are generally more stable than transverse fractures.
- **Avulsion fracture**: Avulsion fractures are caused by tensile forces exerted during strenuous muscle contraction, in which a fragment of bone (often a process or tuberosity) is torn away at the point of tendinous or ligamentous insertion. This is often associated with joint subluxation (Ortner 2003).
- **Impaction fracture:** In this fracture the two broken ends of the fractured bone are driven up into one another under great compressive force (e.g. from a fall from a height). This is a stable fracture, but may cause shortening of the element (Roberts and Manchester 2005).
- **Butterfly fracture**: This is a specific bending fracture, in which a transverse fracture develops on the tensile side opposite to the point of impact, and an oblique fracture on the compressive side, producing a wedge-shaped fragment of bone (Ortner 2003). Double butterfly fractures may also occur. This fracture is commonly associated with high energy impact, as occurs in projectile trauma, such as a bullet wound (Waldron 2009).
- **Comminuted fractures:** These are fractures where the bone breaks into three or more fragments, often splinters. Due to fragmentation, these fractures are problematic to heal and, frequently, do not unite without internal or external fixation. Gross mal-alignment may also occur (Hipp et al. 1992).

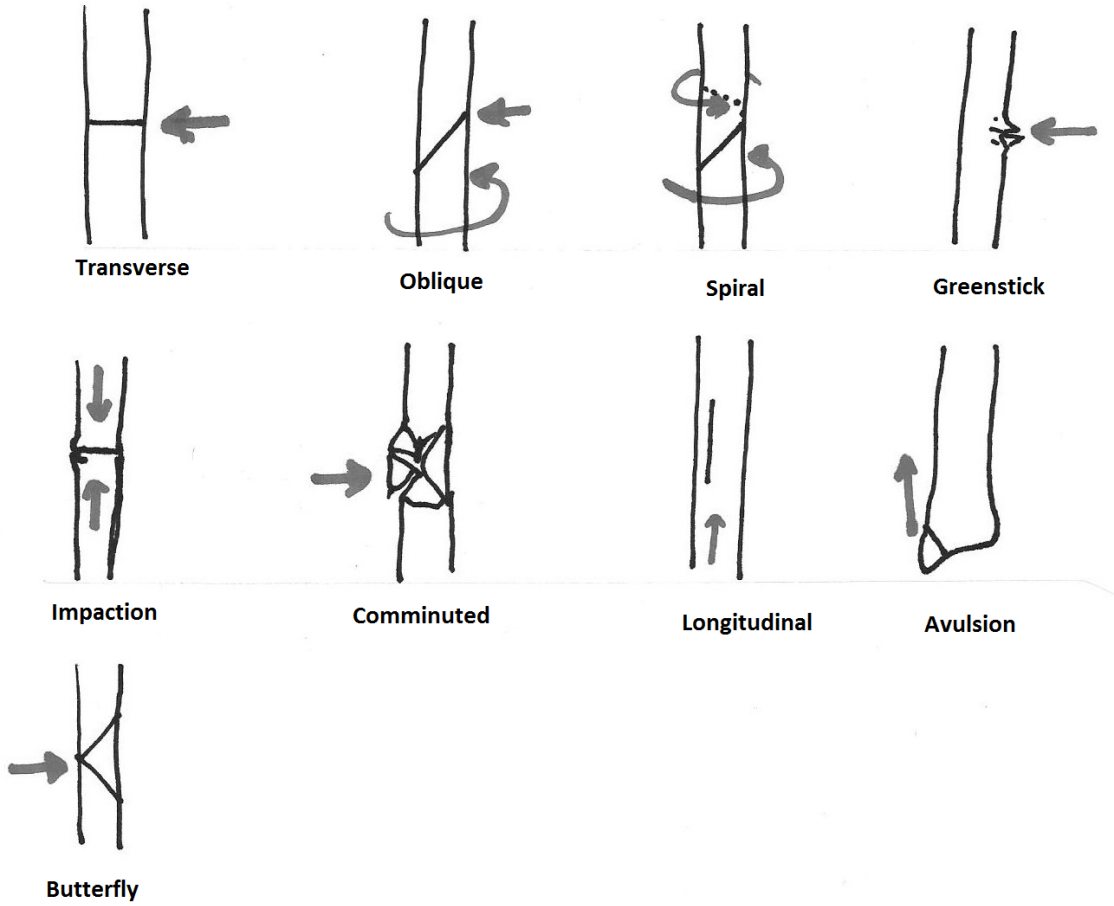


Figure 2.1 *Classification of fracture types, showing the direction of force acting on the bone to produce the fracture. Source: the author.*

2.2.3. Sharp force trauma

Osteologically, sharp force trauma is classified as a fracture, because it involves breakage in the continuity of the bone. It is most commonly the result of interpersonal violence with an edged weapon (such as a knife, sword or broken glass), but is occasionally accidental or associated with suicide. The category also includes surgical interventions, but discussion of these lies beyond the scope of this study.

Like all fractures, a bone's reaction to sharp force trauma depends on the shape and dimensions of the weapon, the magnitude and direction of the force, and the biomechanical properties of the affected bone. Sharp force trauma is categorised as punctures, incisions and notches or clefts (Byers 2008).

Incisions are probably the most common category of sharp force trauma to affect archaeological bone. They have a number of specific diagnostic criteria, namely:

- Linearity
- A narrow V-shaped profile with well defined edges and a narrow base
- One side of the cutmark is nearly vertical, with a flat smooth surface and almost polished ivory-like edge (the incision)
- The other side of the incision is more oblique and ragged, showing flaking, roughening, and sometimes lifting of the surface, due to the adherence of tiny bone flakes to the retracting blade.
- The presence of parallel scratch marks on the bone surface when viewed by light or scanning electron microscope (Boylston 2000).

Directionality influences the angle of the cutmark profile. For example, in very angled blows from a heavy slashing edge, the incision may be very oblique, with flakes or slivers of bone (spalls) removed from the bone surface in a slicing motion. Such injuries are characteristic of heavy slashing blades, such as sabres or cutlasses (Kaufman 2001; Kaufman 2003).

Puncture wounds result from the application of vertical force with a cone-shaped focal point (such as knife, bayonet or sword tip), and are often deeper than they are wide. The cross-sectional profile of the lesion is V-shaped with a narrow pointed floor. Depending on the implement, the lesion may be circular, oblong or triangular. Radiating fractures may occur in forceful blows (Byers 2005).

Cleft or notch wounds are usually more of a chopping or hacking injury using a heavier blade, such as an axe. Such injuries are usually slit-like with a V-shaped profile, but this is usually wider than the other two lesion types (Boylston 2000; Byers 2005). Wastage or bone chipping may occur, and crushing of trabecular bone is common (Humphrey and Hutchinson 2001). In cranial injuries, fractures may radiate from either end of the slit (Courville and Kade 1964).

The prevalence and characteristics of sharp force lesions observed in the R.N. skeletal assemblages give valuable insights into the reality of naval engagements. Osteologically, it is broadly possible to ascertain the type of weapon or instrument used from the general dimensions and curvature of the cutmark. Naval engagements involved a range of weaponry that caused sharp force trauma. Bayonets, pikes and knives inflicted puncture wounds, but, of course, could also cause incisions (Fremont-Barnes 2005; Fremont-Barnes 2008; Wolfe 2005). Cutlasses were used as both a slashing and stabbing weapon. Heavier blades historically known to have been employed as weapons were small boarding axes or tomahawks, which could be thrown or wielded (*Ibid*.).

The direction and force of the blow makes it possible to reconstruct some aspects of the event, such as handedness of the assailant and the relative body positions of the protagonists (Byers 2005). Due to the vertical nature of ship construction, hand-to-hand combat on board ship included a considerably greater range of relative body positions than terrestrial warfare, with the possible exception of cavalry. Hand-to-hand fighting could take place on the horizontal on the decks, but also vertically through hatchways, on ladders, on the poop, forecastle and quarterdeck and in the rigging (Adkins and Adkins 2008; Fremont-Barnes 2005). Thus, a greater range of locations and orientations of injuries should be expected in the seamen's skeletons.

2.2.4. Projectile trauma

As the name suggests, projectile trauma is due to impact by a projectile (such as an arrow, splinter, musket-ball or shrapnel) travelling through the air, often under considerable force. A projectile's mass and velocity determine the kinetic energy that it imparts on impact, the relationship determined by the formula:

$$\text{Kinetic energy} = \tfrac{1}{2} \text{ mass} \times \text{velocity}^2$$

Thus, increased mass of the projectile only increases the kinetic energy linearly, whereas velocity affects it exponentially to a second power (Knight 1996, 179-197). It is the capacity to generate vastly greater velocity that distinguishes modern firearms from their 18th century predecessors

(Magee 1995; Schats et al. 2013). The transfer of kinetic energy on impact and during its passage through the body's tissues largely determines a projectile's wounding capacity, including its capacity to fracture bone (Bartlett 2003; Berryman and Jones Haun 1996; Ross 1995). Extensive forensic research into modern ballistics and patterns of wounding from different modern firearms has revealed further complicating factors involved in the efficacy of this energy transfer, including deformation and fragmentation of the projectile on firing and impact, its stability in flight (yawing), its entrance profile, the path travelled through the body, and the different biological characteristics of the affected tissues (Bartlett 2003).

A range of projectiles were used in 18th century naval battles, with very different masses and velocities, but all had a capacity to wreck terrible carnage. Although they differed slightly in detail, weapons were generally very similar in the British, French, American and Spanish navies (Henry 2004). They included:

- **Musket**: A smooth-bored flintlock firing solid lead balls of 1¼ inch diameter
- **Pistol**: A smooth-bored flintlock firing solid lead balls of 2/3 inch diameter
- **Musketoon**: A large hand-held shotgun firing a group of small shot of 1 inch calibre
- **Hand grenades**: Hand-held explosives thrown from the rigging onto the deck below, or down hatchways
- **Grape-shot**: A bag containing several solid iron balls of 1½ inch diameter fired from a carronade or other small gun, which would spray the enemy decks
- **Canister-shot**: Small-shot, normally lead, contained within a canister, and fired from a carronade or other small gun, which had a similar effect to grapeshot
- **Anti-rigging shot** (link-shot, chain-shot, star-shot and bar-shot); iron projectiles fired at the enemy sails and rigging to destroy them, so that the ship could not be manoeuvred (was 'dead in the water'); potentially lethal to be hit directly by one.

- **Grenadoes:** Explosive shells fired from howitzers releasing shrapnel; mostly used to bombard shore batteries (not that widely used in other navies, bar the Danish)
- **Small-bore solid iron shot** of 3-4 pounds fired from small guns, such as carronades, bow chasers and swivel guns, mounted in the fighting tops and in the bow and stern of larger ships; often the principal armament of smaller vessels
- **Round-shot:** Solid iron balls of 18-32 pounds (depending on the gun) fired by the great guns in a broadside (Fremont-Barnes 2008; Henry 2004).

The most striking feature of sea battles was bombardment by the great guns. The aim was not so much to sink the enemy vessel, but to disable and disman her (Fremont-Barnes 2008; Henry 2004). Eyewitness accounts (e.g. Leech 1857; Lowry 2006; Robinson 1836) describe how a direct hit by round-shot could amputate a limb or decapitate a man, but it was the sprays of ragged wooden splinters from round-shot crashing into the ship's sides that was responsible for far greater carnage than all other ordinance (Crumplin 2007). Some eyewitness accounts, such as that of the thirteen year old William Dillon (1794) (cited in Fremont-Barnes 2005, 57) record the carnage:

> *It was a most trying scene. A splinter struck him in the crown of the head, and when he fell the blood and brains came out, flowing over the deck. The captain went over, and taking the poor fellow by the hand, pronounced him dead'.*

Experiments carried out in 1838 by firing two 32 pound balls at 1,200 yards into the hulk of the *Prince George*, revealed that both shots penetrated the ship's side, letting loose a spray of splinters, some very large, some of which traversed the width of the ship embedding into the other side, and others travelling at least half of its length (Henry 2004). These flying splinters could macerate tissue, lacerate blood vessels and shatter bone, often to the extent that the limb could not be saved and was amputated (Adkins and Adkins 2008). Secondary infection was an ever present risk, particularly in abdominal wounds, where gut penetration frequently lead to peritonitis and death (Crumplin 2007).

Small-arms fire was another source of projectile trauma in naval engagements. In late 18th century navies, these mostly comprised flintlock muskets, blunderbusses and pistols (Fremont-Barnes 2008). All three fired solid round lead shot, which often deformed or fragmented on firing or impact (Crumplin 2007). In addition, officers and some men were issued with pistols, which had a smaller calibre, usually of 0.62. The part played by these firearms in naval engagements was limited by the pistol and musket's close range (50-100 yards), their hopeless inaccuracy and cumbersome reloading (Fremont-Barnes 2005). The heaving decks and drifting smoke from bombardment by the great guns must also have greatly impaired accurate firing. In sea battles, musket fire was really only effective when handled by snipers hidden aloft, or in brief salvoes during very close encounters (such as boarding or firing down onto the deck from a higher vantage point) (*Ibid*.). In a close sea battle, the fired musket was then fixed with a bayonet, or reversed, the stock being used as a club. Greater potential for musketry existed on both sides during amphibious attacks, such as cutting out operations (taking a ship out of an enemy harbour) or storming sea defences (Henry 2004).

Whilst modern ballistics provide many useful insights into 18th century small-arms injuries, considerable differences in velocity, shape and mass are responsible for very different ballistic properties and injury patterns from these projectiles. Velocity is limited by the ball's spherical shape, poor gunpowder quality (Butler 1971) and windage (the gap between the ball and barrel) (Crumplin 2007). Experimental ballistics conducted by firing musket-balls into gelatine blocks has revealed that, with their relatively low maximum energy of 500J, musket-balls core out a well-defined track in the gelatine with minimal lateral displacement (Magee 1995; Schats *et al.* 2013). This is in contrast to modern high velocity bullets, which create shockwaves and tissue cavitation with extensive tissue damage 10-40 times greater than the diameter of the bullet (Bartlett 2003). Nevertheless, the large size and mass of the musket-ball causes severe bruising, tearing, crushing and deadening of the tissue along this track (Magee 1995) but, as little energy is transmitted laterally to the tissue surrounding the wound track, tissue damage is localised. If passing through a vital organ or blood vessel, however, the wound may be fatal (Knight 1996; Owen-Smith 1981). At close range there is

more than sufficient energy (minimum of 100J) to shatter, or lodge in, bone (Crumplin 2007), the former more often cortical bone, and the latter in trabecular bone. Secondary damage may be caused by bone and cartilage fragments displaced on fracturing, which themselves become projectiles, lacerating and severing other tissues (Knight 1996).

Musket-ball injuries to the head frequently resulted in a large entry wound in the cranium and penetration of brain tissue but, unlike modern bullets, there was not always sufficient kinetic energy to exit the cranium. Spent balls impart relatively low energy, and bony injuries from these projectiles are often difficult to distinguish from blunt force trauma.

Cranial musket-ball injuries of known clinical history, dating to the Napoleonic and Carlist Wars, curated in the Surgeon's Hall of Edinburgh University, show characteristic 'punched out' entrance wounds through the ectocranium, similar in size and shape to the ball. Several other examples are sub-rectangular and irregular in shape, probably due to the musket-ball's deformation on firing or impact. The endocranial surfaces show bevelling associated with severe cranial impact, and in some cases, there are radiating and concentric fractures. Fractures may radiate from the point of impact outwards, whilst concentric fractures encircle the point of impact but do not lead directly from it. Exit wounds are characteristically large and irregular. Very oblique shots where the ball grazed (entered and exited the skull at the same point) result in a single large irregular lesion, known as a keyhole fracture (Ross 1995). This characteristically displays internal bevelling of an entrance wound on one side of the lesion, and external bevelling of an exit wound on the other (*Ibid.*).

2.2.5. Fracture healing

(i) The physiological stages of fracture healing

One of the main features recorded in palaeopathology is the extent of healing of a lesion. Gross macroscopic changes, such as bony resorption and callus formation and maturation, are important indicators as to how long the injury preceded death, and in the case of multiple fractures, whether

they were incurred simultaneously or in multiple events separated in time (Aufderheide and Rodriguez-Martin 1998; Ortner 2003; Roberts and Manchester 2005; Waldron 2009).

Fracture healing may be viewed as a staged process that gradually restores the load-bearing capacity of a fractured bone to approximately its original strength (Hipp et al. 1992). Fracture healing varies greatly in duration, but all complete fractures heal in a similar sequence, which may be divided into four phases:

a. **Haematoma formation** (0-24 hours): Fracture healing begins with the closure of the fracture and the formation of a primary callus of woven disorganised new bone. When the bone fractures, blood vessels within the bone and in the surrounding soft tissue are torn and haemorrhage. This blood consolidates into a haematoma between and around the fractured fragments. Bony tissue deprived of blood supply from the torn vessels, dies (Lovell 1997; Marieb 1995; Roberts and Manchester 2005). The wound at this point becomes swollen, painful and inflamed (Marieb 1995).
b. **Callus formation** (3-9 weeks): Capillaries infiltrate the haematoma, bringing nutrients and phagocytic cells, which resorb the necrotic (dead) bone. Fibroblasts and osteoblasts migrate into the fracture site from the nearby periosteum and endosteum, and begin to synthesise a soft callus or osteod (unmineralised bone), pushing the haematoma aside. Fibroblasts produce collagen fibres that span the fracture and connect the broken ends. Some fibroblasts differentiate into chondroblasts to secrete a cartilaginous matrix. Within this mass of remodelling tissue, calcium salts are deposited, and the osteoid is transformed into a rigid callus of immature bone. Those fibroblasts furthest from the capillary secrete an externally bulging fibrocartilaginous callus, which 'splints' the broken ends, and begins the ossification process.
c. **Consolidation** (weeks to months): Osteoblasts and osteoclasts continue to migrate into the area and proliferate. Through deposition and resorption, the weak callus of immature bone

is gradually converted to a stronger more organised structure of lamellar bone. This gradually matures to form a solidly united fracture.

d. Remodelling (6 months-9 years): The callus is gradually remodelled and re-aligned along the lines of mechanical stress. Excess material outside the bone shaft and within the medullary cavity is resorbed, and compact bone is laid down to reconstruct the normal shaft. The final structure of the remodelled bone resembles the original bone in that area, and may be difficult to identify, even on a radiograph (Lovell 1997; Marieb 1995; Ortner 2003; Roberts and Manchester 2005). This is particularly pertinent to the elderly Greenwich pensioner skeletons, where injury may have taken place many decades before death.

(ii) Timing of fracture healing

Fractures begin to heal immediately after the bone is broken. Histological evidence of tissue remodelling may be identified within 48 hours of injury (de Boer et al. 2012), and radiographically is visible within 2-3 weeks (Lovell 1997). Although the above section gives approximate timings of each healing stage, rates of fracture healing vary considerably between elements and between bone types. In splinted healthy bones with good apposition of the fractured ends, a phalangeal fracture may take a month to heal, whilst larger long bones, such as the tibia and femur, this may take six months (Lovell 1997). Upper limb bones tend to heal faster than lower limb long bones. Repair of trabecular bone is generally quicker than cortical bone, due to the former's better blood supply and open structure, which allows for rapid infiltration by osteoblasts, which grow on opposing fracture surfaces, and eventually fuse and calcify on union (Lovell 1997).

Different fracture types also tend to heal at different rates. Spiral and oblique fractures heal more quickly than transverse ones (Lovell 1997), probably because they are more stable. Comminuted fractures are very slow and problematic to heal due to poor contact between the bone splinters and the difficulty in immobilising them. Non-union may occur (Hipp et al. 1992).

Because fracture healing is not visible macroscopically or radiographically for approximately 2-3 weeks following injury, it is problematic to distinguish between fractures that occur at the time of death, and those in the very early stages of healing. In addition, whilst bone still retains sufficient moisture and collagen (fresh or green bone), it will fracture in much the same way after death as it does before it. Thus, it is often impossible to distinguish between fractures occurring shortly before or at the time of death, and those incurred during the immediate post-mortem period (such as as may happen with manipulation of the corpse during funerary rites, or during dissection). Thus, fractures occurring at and around the time of death are collectively known as perimortem fractures. Osteologically, these are distinguished macroscopically from ante-mortem fractures by the absence of healing (Knusel 2005).

Post-mortem fractures are breakages in bone when little collagen remains. They may be distinguished from perimortem or fresh bone fractures by a number of features:

- The broken edges are often pale and chalky in the former, and the same colour of the rest of the bone surface in the latter (uniformly discoloured by mineral in the burial environment).
- The fracture edges are squared in the former and often orientated transversely across long bone shafts. Fresh bone tends to splinter, creating ragged edges. The break tends to have an oblique angle to its edge, and often a stepped fracture profile with longitudinal breaks. Bony fragments may adhere to the edges of the break.
- Concentric, circular, butterfly and spiral fractures tend only to occur when bone is fresh (Wieberg and Westcott 2008).

Breaks in bone containing a reduced but still significant amount of collagen, will share characteristics of both perimortem and post-mortem bone breakage (Knusel 2005). This occurs most commonly with secondary manipulation or disturbance of the skeletal remains some months or years after death, such as in grave intercutting.

(iii) Factors impeding normal fracture healing

Normal fracture healing may be impaired by a range of factors both intrinsic and extrinsic to the injury resulting in slow union, delayed union or non-union (Roberts and Manchester 2005). Slow union refers to longer than expected time taken for union, but otherwise the process of healing is normal. Delayed union occurs when the broken ends of bone fail to unite properly in the expected time (*Ibid.*), the ends being bridged by friable disorganised callus, which holds the broken ends together and allows for mobilisation and weight-bearing, but has little structural strength and is liable to fracture. Non-union occurs where the broken ends fail to unite. This may take a hypertrophic form, where new bone is laid down on the broken ends, which causes enlargement. These broadened flaring ends may articulate and develop into a false joint or pseudoarthrosis. Atrophic non-union occurs where the broken ends receive reduced blood supply, and, rather than hypertrophy, they resorb and become narrow, rounded and osteoporotic (Gleis and Seligson 1992; Lovell 1997; Roberts 1988).

Malunion consists of a fracture that heals with a deformity (Lovell 1997). This is the result of unsuccessful reduction, leaving the broken fragments to heal at an abnormal angulation or rotation, or with the broken ends overlapping. Grossly abnormal angulation, overlap, crushing and gross bone loss (as in comminution, avascular necrosis or secondary infection) results in shortening of the element (Roberts 1988; Roberts 1991). Shortening of greater than 20 mm in the lower leg bones has significant functional sequela as a consequence of altered gait (Lovell 1997) (see below).

Intrinsic factors

Maintenance of sustained close contact between the broken ends is seminal to bony union and, today, is usually achieved through manipulative reduction (manually manipulating the broken ends back into a correct anatomical alignment) and then immobilisation y (Connolly et al. 1992). Even if this is successfully implemented, several factors intrinsic to the injury itself may complicate or

prevent bony union. These include the fracture type and its effect on wound stability (particularly comminuted fractures); overlap or excessive mal-alignment of the broken fragments, excessive local soft tissue inflammation, and soft tissue and periosteum becoming caught between the broken fragments (Lovell 1997). In addition, interference with adequate local and systemic innervation and blood supply to the affected area may impair the supply of oxygen and nutrients necessary for the healing process (Stirling 1939).

Whilst lack of fracture stability undoubtedly delays healing, so may complete immobilisation. Local bioelectrical activity, often induced by muscle loading, promotes fracture repair by stimulating the production of closely packed collagen bundles, which stabilise and strengthen the remodelling callus (Connolly et al. 1992). The benefits of limited movement was recognised by 19th century surgeons, and underlay some surgeons' reluctance to apply rigid splinting to fractures (Colton 1992). Pathological fractures may also show delayed healing, due to an existing abnormal bone structure, which impairs bony union (Ortner 2003).

Extrinsic factors

Successful modern fracture healing with minimal functional deficits requires adequate reduction by manual manipulation and/or traction, and immobilisation of the broken fragments, usually by splinting or fixation (Connolly et al. 1992). The principles of reduction and immobilisation in fracture treatment were widely appreciated and practiced in the past, and in both Western and non-Western societies today (Colton 1992; Roberts 1988).

Fracture is almost always associated with soft tissue trauma and inflammation. Powerful muscle contraction or spasm at the time of fracture often results in mal-alignment from overlap of the broken ends, angulation and rotation (Connolly et al. 1992). This overlap must be reduced, and the broken ends be placed in good apposition (alignment) if the bone is to heal without significant functional sequelae due to element shortening or gross mal-alignment (*Ibid.*). Soft tissue damage or

inflammation following injury often complicates fracture treatment, and may significantly delay fracture reduction.

Poor immobilisation of the bony fragments leads to tearing of the delicate reparative tissue, particularly new blood capillaries. Repeated blood vessel rupture leads to alterations in the chemical components of the callus, excess callus formation (Stirling 1939) and delayed union. Adequate 'medical' treatment is thus an important extrinsic factor in successful bone healing.

Bony healing may be impaired, and in some cases even reversed, by under-nutrition and systemic nutritional deficiencies, most notably rickets and osteomalacia (Vitamin D deficiency) and scurvy (Vitamin C deficiency), and other metabolic disorders, such as osteoporosis (Brickley and Ives 2008; Chandrasoma and Taylor 1995; Stirling 1939). Vitamin D deficiency is synthesised in the skin in the presence of sunlight, or may be ingested in some foodstuffs, such as oily fish. Vitamin D is vital to the enteral absorption of calcium and phosphate, and calcium deficiency results in a poorly mineralised callus and delayed healing (Brickley and Ives 2008). However, given the seamen's outdoor lifestyle, it is unlikely that Vitamin D deficiency was a significant disease for them.

Until lemon juice rationing was introduced in the R.N. in 1795, scurvy was a significant and widespread disease of seamen (Adkins and Adkins 2008; Brown 2011; Carpenter 1986). This concurs with the high prevalence of a suite of pathological lesions in the three skeletal assemblages that have been ascribed to scurvy in this study (see Appendix 7). Vitamin C deficiency leads to the abnormal metabolism of proline and lysine, two amino acids that are the building blocks of proteins, such as collagen (Koon and Collins 2010). Defective collagen in the osteiod produces a weak fragile callus (Brickley and Ives 2008), and also the propensity for blood vessels walls to tear, resulting in an inadequate blood supply to areas of new bone healing (Poal-Manresa et al. 1970). Resorption of cellular debris is also delayed (Bourne 1946).

Not only is fracture healing delayed, but numerous historical accounts describe that in individuals with scurvy, healed wounds re-opened, and fracture calluses softened and broke down. William Walter, chaplain to Lord Anson's disastrous expedition around the world (1740-1744), described this in one seaman (cited in Bourne 1946, 515):

> *'.... who had been wounded above fifty years before at the Battle of the Boyne: for he was cured thereafter, and had continued well for a great number of years past, yet on his being attacked by the scurvy his wounds, in the progress of his disease, broke out afresh, and appeared as if they had never healed: Nay, what is still more astonishing the callus of broken bone, which had completely formed for a long time, was found to be hereby dissolved, and the fracture seemed as if it had never been consolidated.'*

In James Lind's (1753) *Treatise on the Scurvy*, he described the breakdown of a recently healed musket-ball wound in the shattered humerus of a seaman, who developed scurvy soon after the wound had healed. He also observed that '*when one has been confined from exercise by having a fractured bone, or from a bruise or hurt, these weak debilitated parts become always the first scorbutic*' (*Ibid.*, 151). In addition, soft tissue and bony callus breakdown greatly increased the risk of another serious complication of trauma: secondary infection.

2.2.6. Complications of fractures

(i) Infection

Infection both **c**omplicates and is a complication of fractures. It is most prevalent in compound fractures, where the interior of the fractured bone is exposed to bacterial contamination (most commonly *Staphlococcus aureus*) , but infection may also penetrate bone via the periosteum from surrounding infected soft tissue, or be introduced into the wound by contaminated clothing, environmental debris or medical instruments (Lovell 1997). In systemic infections, pathogens may also be introduced via the blood stream. Bacterial proliferation precipitates local inflammation in and around the fracture site, causing soft tissue to swell, thereby compromising the blood supply to the damaged area, and resulting in necrosis (tissue death) (Behrens 1992). In addition, bacterial loads consume nutrients that would otherwise be utilised by the healing bone tissue.

Even with modern antibiotics, recovery from bone infection is a long and problematic process (Mader et al. 1999). In the past, infected bone and surrounding soft tissue was usually a chronic, often lifelong condition, involving ongoing suppuration, pain, wasting and debility, with secondary amputation often providing a blessed release from suffering (Crumplin 2007; Crumplin and Starling 2005).

Bone infection is recognised osteologically as periostitis (involving the periosteal membrane and immediate bone surface beneath); osteitis (involving the cortical bone) and osteomyelitis (involving the marrow cavity) (Ortner 2003; Roberts and Manchester 2005). Periostitis appears as a plaque-like layer of new bone overlaying the bone surface, but otherwise the deeper bone layers are unaffected. Osteitis is visible in cross-section or on a radiograph as disorganised thickening of the cortical bone, where normal structure has been lost. Osteomyelitis is the most severe form of bone infection and often results in gross localised thickening. Pathognomonic for osteomyelitis is the development of cloacae or sinuses communicating between the marrow cavity and bone surfaces, through which pus drains. Gross alteration in the normal bone morphology occurs with necrosis of bone tissue due to sub-periosteal abscesses, which coalesce and impair the blood supply (forming a *sequestrum*), and periosteal production of new hypervascular bone forming a sheath of new bone (the *involucrum*) (Chandrasoma and Taylor 1995; Lovell 1997).

(ii) Muscular complications

Fracture is almost always associated with some degree of soft tissue damage, whether it be ligaments, muscles, skin, nerves or blood vessels. Inflammation and infection in overlaying soft tissue causes localised oedema (swelling), which may delay normal fracture healing, and may also introduce infection into the broken bone.

Damaged musculature may lead to disuse or altered use of an affected body part, which may be osteologically identified as osteoporosis, disuse atrophy, or altered activity-related changes, such as enthesopathies or skeletal changes due to torsion, as the musculature of that body part

compensates for specific muscle weakness or disuse (Jurmain 1999). Compensation for compromised function in one part of the body often results in increased use of another, which may manifest as hypertrophy, increased enthesopathies, premature joint degeneration and osteoarthritis (Jurmain 1999). This is particularly true of the weight-bearing joints, where reduced function of one lower limb during healing, or following mal-alignment and shortening, may result in altered gait and increased weight-bearing in the unaffected limb (Aufderheide and Rodriguez-Martin 1998). Abnormal gait alters the normal alignment of the skeleton, affecting the hip, sacro-iliac and vertebrae joints, and may result in chronic pain and degenerative changes in these joints. In addition, the use of mobility aids, such as under-arm crutches, have been identified in altered upper arm muscle use and even scapular neck fractures (Darton 2010). Morphological bony changes have also been recognised in relation to the use of lower limb 'peg leg' prostheses in the archaeological record (Lazenby and Pfeiffer 1993).

One rare form of muscle trauma that is osteologically visible is *myositis ossificans traumatica*. It is usually produced by avulsion of a muscle or tendon attachment, or occasionally by crushing of muscle against the bone (Aufderheide and Rodriguez-Martin 1998). Like bone, damaged muscle may form a haematoma, which normally resorbs but occasionally ossifies instead. This ossified tissue may be separate from the bone, or may form large bony outgrowths at the damaged muscle or tendon insertion site (Ortner 2003). The most common locations are the *M. deltoid* and *M. pectoralis major* insertions on the proximal humerus, and the extensor and adductor insertions on the proximal femur (*Ibid*). *Myositis ossificans traumatica* may occur without bony damage, however, and from relatively minor trauma (Aufderheide and Rodriguez-Martin 1998).

(iii) Vascular complications

A common complication of both bony and soft tissue trauma is bleeding. In some injuries this may be relatively trivial, but where major blood vessels or organs (such as the heart, spleen or liver) are involved, or where large areas of tissue have been damaged, haemorrhage may be extreme,

resulting in haemorrhagic shock and death. Bleeding into specific body cavities, such as the cranium, mediastinum and pleural spaces, may also cause potentially fatal compression of the brain, heart and lungs (Hinds 1987). Bleeding directly associated with fractures is greatest in the femur, where blood loss of more than a litre is not uncommon (Crumplin 2007).

Direct pressure using manual compression or a tourniquet may slow more superficial bleeding, but treatment of bleeding points in deeper tissues of the abdomen and chest is virtually impossible without open surgery (*Ibid.*). Occlusion of damaged blood vessels using cautery (diathermy) or ligatures and sutures is the mainstay of treatment for bleeding today, and were widely employed by 18th century surgeons, although the popularity of cautery using boiling oil or tar fell away in the 17th century, when its deleterious effects on tissue viability were appreciated (Brown 2011; Thurston 2000).

In scorbutic seamen, ligation of torn blood vessels was complicated by friability of the blood vessel walls (due to defective collagen), which often tore on handling (Blane 1799; Lind 1753). Aberrant clotting also increased a tendency to bleed. Secondary haemorrhage was also not uncommon in scorbutics, when ligatures slipped or blood vessel walls disintegrated. Similarly, secondary haemorrhage occurred in infected wounds when infection cause lysis of blood vessel walls, and was a not uncommon cause of death in the weeks following injury (Guthrie 1833).

Haemorrhage from large blood vessels leaves no skeletal traces, but localised bleeding beneath the periosteum lead to haematoma formation. Excessive pressure placed on the periosteum may prevent normal resorption of the haematoma, which begins to ossify a few weeks after injury, and is macroscopically visible after two months (Lovell 1997). An ossified haematoma appears on the surface of the bone as a discrete, smooth mound of new bone raised above the normal bone surface. Whilst it differs from infective periostitis in having a well demarcated margin, ossified haematomas are easily confused with chronic ulcers, which may also elicit a bony reaction when approximating bone, and share features of a raised profile and well demarcated margin (Boel and

Ortner 2011), but are often smoother and more domed in profile, however (pers. obs.). Ossified haematomas are not necessarily due to trauma, however, and may be associated with scurvy (Van der Merwe et al. 2010). Undrained haematomas may become reservoirs for infection, developing into abscesses (Gleis and Seligson 1992), and if close to bone may initiate localised lytic and/ or proliferative bony reactions (*Ibid*.).

Avascular necrosis of bone is a complication of blood vessel trauma when interference with the blood supply to bone results in necrosis (Aufderheide and Rodriguez-Martin 1998). In avascular necrosis, the broken ends of bone are resorbed, causing non-union, sometimes developing an atrophic pseudoarthrosis. Fractures particularly associated with avascular necrosis are those of the surgical neck of the humerus (the circumflex arteries), the elbow (brachial artery), the scaphoid, lunate, talus and femoral head (Aufderheide and Rodriguez-Martin 1998; Waldron 2009).

(iv) Nervous complications

Pain is one of the most obvious consequences of a fracture, particularly in the early inflammatory stage, and before the broken ends are immobilised by callus formation (Marieb 1995). Pain discourages use of the fractured element and, in this respect, facilitates the healing process. Damage to the innervation of a fractured bone may result in a loss of the pain sensation, however, and may allow for greater use of the fractured element than would otherwise have been tolerated. This premature usage may result in delayed and malunion, however (Aufderheide and Rodriguez-Martin 1998). Prolonged or excessive pain may be detrimental to the patient's recovery, however, as in discouraging mobility, the patient falls risk to the hazards of immobility (see below).

Nerves most vulnerable to local damage associated with fracture are superficial nerves, or nerves in direct relation to the affected bone. Nerve damage may be slight and temporary (as in neurapraxia). Pinching, crushing or prolonged pressure on the axions of peripheral nerves (axonotmesis) may cause more extensive longer term damage and degeneration that takes many months to heal (Lovell 1997; Roberts 1988). Complete severance or scarring of a nerve fibre (neurotmesis) results in

permanent damage. Functional sequelae to nerve damage involve a loss of varying degrees of voluntary or involuntary neuromuscular control, causing muscle weakness, tremor, palsy, incontinence and paralysis. Sensory nerve damage may result in tingling, loss of sensation and reduced fine motor co-ordination (Gleis and Seligson 1992).

Damage to the central nervous system (brain and spinal cord) and spinal nerve pathways may result in cognitive deficits and behavioural changes, and a range of functional motor and/or sensory sequelae, depending on the extent and location of nervous tissue damage (McAllister 2008; Ribbers 2010). Motor cortex damage may result in a loss of voluntary control of a specific body part or set of muscles, or complete paralysis of the contra-lateral side (hemiplegia) (Beers 2006). Cranial nerve damage may cause loss of sight, taste or olfaction, but also affects the facial muscles, impairing mastication, speech and swallowing (Marieb 1995). Depending on the level of injury, spinal cord damage may result in paraplegia or quadriplegia (*Ibid*.).

Osteological manifestations of chronic nerve damage may be observed in disuse atrophy of a limb. In subadults, nerve damage to growing long bones may result in slowed growth, and unilateral shortening of the affected element (Aufderheide and Rodriguez-Martin 1998).

(v) Fat embolism syndrome

Fractures are almost always associated with the presence of fat emboli, which travel from the fractured bone via blood vessels to other organs, most commonly the lungs, but this only has clinical sequela in approximately 1-5% of modern fracture cases (Hinds 1987). Fat embolism syndrome is potentially fatal in young adults in the days following closed long bone fracture, most commonly of the femoral and tibial shafts (Gleis and Seligson 1992), and is greatest where immobilisation of the fracture is not fully achieved, as in inadequate or inexpert splinting (*Ibid.*).

(vi) Hazards of immobility

Although not the direct consequence of fracture, patients suffering prolonged bedrest and reduced activity following fracture are at risk of developing a range of complications as a consequence of this

immobility. These include disuse atrophy of the muscles and skeleton, an increased risk of renal calculi due to greater urinary calcium excretion as a consequence of osteoclastic activity, deep vein thrombosis, chest infection and bedsores (Olson et al. 1990). If left untreated, all of these conditions potentially are life-threatening, and may well have been the direct cause of death of many of the seamen whose skeletons were examined in this study. The danger of untreated bedsores from poor nursing care is illustrated by seaman William Robinson's account of another seaman who had survived bilateral leg amputations.

> *'This man was progressing well and his wounds were healing fast; but from lying in one position for such a length of time, his back mortified, and he breathed his last, much regretted by his shipmates'* (Robinson 1836, 115-6).

As most complications of bedrest do not involve the skeleton, they are osteologically invisible, with the possible exceptions of disuse osteoporosis and chronic pneumonia. Rib periostitis may indicate chronic respiratory infection, but may be due to other pulmonary diseases (Roberts *et al.* 1998).

(viii) Functional debility

Reduction or loss of function of a body part had profound psychological, social and economic ramifications for the sufferer, such as altered self-image, social rejection, and loss of income. Mal-alignment, overlap and non-union may follow fracture healing, particularly where reduction and immobilisation was not fully achieved, and may severely impair the function of that body part. Lower limb shortening will alter gait and may impede mobility, and puts additional strain on the joints of the alternate limb and spine. Joint stiffness and reduced range of motion often follows joint injury, again adversely affecting function. Muscular atrophy often accompanies nerve damage (both central and peripheral), reducing muscle strength and control. Nerve compression, as a result of direct pressure from the altered alignment of fractured bone or bone splinters or through inflammation as a result of traumatised soft tissue and secondary infection, may result in chronic pain and debility.

(ix) Secondary osteoarthritis

Joint surface fractures often involve crushing or depression of parts of the articular surface, and abnormal articulation with the corresponding joint. This altered morphology and function may result in secondary osteoarthritis (Lovell 1997).

As discussed above, rotation, angulation and shortening of fractured elements alter biomechanics, with abnormal joint alignment and the development of secondary osteoarthritis, particularly but not exclusively in the weight-bearing joints. Eburnation is pathognomonic for osteoarthritis, but also may be diagnosed in joints showing at least two other degenerative changes, such as pitting, subchondral cysts and osteophytosis (Rogers and Waldron 1995). Distinguishing between osteoarthritis from general wear and tear over time (particularly in older adults like the Greenwich pensioners), and premature osteoarthritis occasioned by altered biomechanics as a result of trauma is problematic, and requires an awareness of altered load-bearing across the skeleton in relation a particularly injury

(x) Head injury

Cranial fractures in themselves are rarely fatal. Rather, in head injury it is the concomitant effect of the transmitted forces upon the cranial contents, such as the brain and meninges, which is so dangerous. Indeed, fatal brain damage frequently occurs in the absence of cranial fracture (Knight 1996), although, conversely, it is rare that no brain injury occurs if the cranial vault is fractured (*Ibid.*). In osteology, the presence of a cranial fracture is indicative of the type and severity of the force applied to the head, and implies that brain injury has occurred, however transient (such as concussion).

Temporary and permanent brain damage may result from raised intracranial pressure, caused by cerebral oedema (brain swelling), intracranial haemorrhage and/or secondary infection (if the meninges are penetrated) in the restricted volume within the skull (Knight 1996). Herniation of the

brain through the *foramen magnum* (Flynn and Bruce 1993)- a process known as coning- is usually fatal (Hinds 1987).

Pressure on, or direct injury to the brain, may result in a range of cognitive, motor and sensory deficits (Courville and Kade 1964; Hinds 1987; Knight 1996). Traumatic epilepsy may also result following head injury (Hinds 1987; Trotter 1804b). Deficits may be chronic, or function may gradually be restored as cerebral compression abates.

2.3. Joint trauma

Injury to the joint capsule or bursa, the joint surfaces (both cartilaginous and bony), underlying trabecular bone (bone bruising) and supportive ligaments and muscles may all contribute to pain, swelling, instability or stiffness of an affected joint (Mandalia and Henson 2008). Instability may lead to partial dislocation (subluxation) and complete dislocation (luxation), often with associated tendon and ligament tears (enthesopathies and syndesmoses) (*Ibid.*).

Most joint trauma is acute and does not directly involve bony tissue, and hence is osteologically invisible. Occasionally, skeletal lesions may be observed, however, but these are often problematic to interpret. Joint trauma involving the cartilage and/or bone of the joint surfaces may manifest as *osteochondritis dissecans* and fractures, whilst cyst formation on, beneath and on the margins of the articular surface may indicate labral tearing or detachment from the joint surfaces of the hip and shoulder (Dietz et al. 2003; Ly and Beall 2003; Mays 2005).

2.3.1. Joint dislocation (subluxation and luxation)

A complete dislocation or luxation consists of the complete and persistent displacement of the articular surfaces of a joint (Aufderheide and Rodriguez-Martin 1998). Partial dislocation or subluxation describes a less severe or partial loss of contact between the joint surfaces (Ortner 2003). Dislocation often also involves muscle, tendon and ligament tearing, and sometimes vascular and nerve damage, with associated inflammation, bleeding and necrosis. Fractures are not always present (*Ibid.*).

Although some specific congenital joint anomalies are commonly associated with dislocation (e.g. congenital hip dysplasia), acute trauma is overwhelmingly the most common cause (Ortner 2003). Most frequent dislocations involve indirect force to the shoulder joint when breaking a fall with an extended limb (*Ibid.*). Individual morphology of the articular surfaces, and the tone of the ligaments, tendons and muscles associated with that joint, may predispose the joint of one individual to dislocate more readily than another, however. This tendency may be increased in a shallower joint (e.g. in acetabular flange lesions (Mays 2005)). A reduced area of articulation of the joint surfaces is another important factor. In a modern study using CT-scanning of living subjects, 91% of anterior shoulder dislocations were associated with flattening of the anterior glenoid rim, effectively reducing articular surface area and rendering it unstable (Griffith et al. 2003). In general, the greater the anterior rim straightening, the more frequent the dislocation, with one glenoid joint with straight margin undergoing more than 200 recurrent dislocations (*Ibid*.).

Laxity of tendons and ligaments (particularly the *M. subscapularis* and the long head of the *M. biceps brachii*) may be inherent, or may develop with specific repeated activities, particularly those involving over-arm motions, and, hence, are common in sports such as swimming, baseball, tennis, gymnastics and American football (Cofield and Simonet 1984). An acute dislocation often becomes recurrent, with recurrence in 90% of non-operatively treated cases in one modern study (Taylor 1997).

Published osteological examples of dislocations include the shoulder, elbow, hand, hip, ankle and foot (Aufderheide and Rodriguez-Martin 1998). Although in theory any joints may dislocate, less stable joints, such as the shoulder, are much more vulnerable. Shoulder dislocation accounts for more than half of modern dislocations, and 85% of these affect the glenohumeral joint (Kirtland et al. 1988). The shoulder joint permits a wide range of movement, but, to enable this, the glenohumeral joint is extremely shallow, with the glenoid fossa covering little more than a third of the humeral head (Petrovecki et al. 2008), and sometimes even less.

Anterior dislocations account for 65-95% of modern glenohumeral dislocations, with 5-35% being posterior in different studies (Kirtland et al. 1988; Petrovecki et al. 2008). The remainder are superior and central impaction dislocations (Kirtland et al. 1988). A fifth common traumatic shoulder injury is subacromial or antero-superior impingement syndrome, which is commonly associated with marked rotator cuff damage (particularly of the *M. supraspinatus*) (Roberts et al. 2007). It manifests osteologically in an extension of the superior margin of the humeral joint surface, or an additional sclerotic new 'articular surface' on the tubercles, and a large, smooth, sclerotic and sometimes eburnated new 'articular surface' or facet on the inferior aspect of the acromium (Kirtland et al. 1988; Roberts et al. 2007). It is often associated with rotator cuff enthesopathies on the humeral tubercles (*Ibid.*).

Acute, successfully reduced dislocation is rarely visible osteologically, with the exception of the Bankart fracture of the antero-inferior rim of the glenoid fossa, and the Hill-Sachs lesion, a wedge-shaped compression fracture on the postero-lateral aspect of the humeral head, caused by impaction of the head on the antero-inferior glenoid rim (Miles 2000; Waldron 2009). Hill-Sachs lesions are present in 35-40% of anterior shoulder dislocations today, and in up to 80% of recurrent dislocations (Petrovecki et al. 2008). With these exceptions, osteologically visible dislocations are generally chronic.

Chronic unreduced glenohumeral dislocations may be recognised osteological by an abnormal extension of the glenoid joint surface, or in the development of a separate secondary joint surface for articulation (in anterior dislocations often located on the anterior scapular neck or body). Florid osteophytosis, sclerosis, pitting and eburnation on both articular surfaces are often present (Kirtland et al. 1988; Petrovecki et al. 2008).

Clavicular dislocation may occur at the medial or latera joint. Acromioclavicular dislocation today is much less common than glenohumeral dislocation, and is usually the result of landing on the point of the shoulder during a fall or collision, particularly whilst playing sport (Cofield and Simonet 1984).

This dislocation cannot be reduced, but conservative management (rest and wearing a broad sling) is successful in treating 80-90% of modern cases (in terms of pain and restored function) (Dias et al. 1987). Sternoclavicular dislocations are much rarer, accounting for only 10% of clavicular dislocations (an estimated 1:1,600 cases of shoulder trauma) (Salvatore 1968). Modern causes include falls, sporting contact injuries and motor vehicle accidents (*Ibid.*). Given the modern rarity of this lesion, it is unlikely to have affected a significant number of seamen.

Slight femoro-acetabular subluxation or femoral impingement has been associated with acetabular flange lesions (Stirland 2005b), but the pathophysiology remains unclear.

Dislocation of the ankle is generally the result of a twisting injury to the ankle joint, and, like other dislocations, is identified by florid osteophyte formation, altered or secondary joint surfaces and secondary osteoarthritis (Aufderheide and Rodriguez-Martin 1998).

2.3.2. *Osteochondritis dissecans*

Osteochondritis dissecans is a small, focal fracture of the cartilage and underlying bone of a joint surface, in which a roundel of necrotic cartilage and bone partially or completely separates from the joint surface, revealing the underlying trabecular bone (Resnick and Niwayama 1995; Roberts and Manchester 2005). The loose bone fragment may re-attach at the site of its origin or elsewhere on the joint surface, or float within the synovial fluid (a 'joint mouse'). The last may result in joint pain and secondary osteoarthritis.

Osteologically, *osteochondritis dissecans* manifests as a round or oval lesion with smooth discrete margins, demarcating an area of depression in which the trabecular bone is often still exposed. Occasionally the re-attached joint mouse is found elsewhere on the joint surface as a discrete nodule. Osteochondritis of the femoral condyle of the knee accounts for 85-90% of modern clinical cases (Aufderheide and Rodriguez-Martin 1998). Other commonly affected convex surfaces are the capitulum of the distal humerus and the talar dome, but *osteochondritis dissecans* of the olecranon

joint surface and the femoral head have also been recognised (Aufderheide and Rodriguez-Martin 1998).

It remains uncertain if *osteochondritis dissecans* is the result of a single acute traumatic episode or microtrauma from repeated joint stress (Aufderheide and Rodriguez-Martin 1998), but localised sheering of the blood supply to a small area of joint surface with resultant focal necrosis is probable. Although the precise aetiology is disputed, its prevalence in young athletes makes trauma the most probable cause. It is thus commonly regarded as representing strenuous physical activity in youth.

3. Historical context

3.1. Introduction

Chapter 3 places this osteological study in its the historical context. The seminal role of the R.N. in protecting Britain's global interests is briefly discussed, as well as the scale of naval operations. An understanding of onboard organisation, everyday activities, living conditions and the health of seamen and marines is necessary to interpret the bioarchaeological data of this study, and is briefly outlined here.

Manning the ships of the R.N. was a major problem in the late Georgian period (1750-1815), particularly in times of war, and the loss of so many men to death and disability made the health of seamen a priority for the Admiralty (Crimmin 1999; Crimmin 2007). The organisation and priorities of healthcare in the R.N. is discussed below, including the founding of the Royal Hospitals from whence the skeletons of this study came. The traumatic lesions in the documentary sources of this study were identified and described by sea surgeons, and as such a consideration of their professional training and experience, medical perceptions and the common sea diseases they encountered are discussed.

3.2. The role of the R.N. in the late 18th- to early 19th centuries

In the later 18th century, Britain was a burgeoning global power with colonies across the world. In this period Britain consolidated her hold on Canada from the French, but lost America; expanded her influence and ownership of many valuable sugar-producing islands of the Caribbean; consolidated her slave bases in West Africa; lost and won back Minorca, gained Malta and retained Gilbraltar in the Mediterranean; gained and relinquished the strategically important Cape Colony in Southern Africa; expanded her extensive trading and political foothold in India; claimed Australia and established convict colonies in Botany Bay and Port Arthur, and extended her trading and political influence in the Far East. At home, the Industrial Revolution was underway, placing Britain at the forefront of manufacturing and trade. The inexhaustible requirement for raw materials and a

growing need to develop new markets abroad drove on international political and mercantile expansion (Adkins and Adkins 2006; Rodger 2006).

Critical to Britain's success on the global stage was a large and powerful navy to keep the sea lanes open for trade, and to curb the colonial ambitions of equally acquisitive and aggressive neighbours. Wars with the Dutch, Spanish, Americans, French Republic and Napoleon ensued, and for much of the later eighteenth to early nineteenth centuries, Britain was at war with at least one of her European neighbours or colonies. These conflicts are summarised in Appendix 8, but the most prominent were

- 1756- 1763 Seven Years War
- 1775- 1783 American War of Independence
- 1780- 1784 Fourth Anglo-Dutch War
- 1793- 1802 French Revolutionary Wars
- 1803- 1815 Napoleonic Wars
- 1812- 1814 The Anglo-American War of 1812

In the 65 years from 1750 to 1815, there were only 23 years when Britain was not at war (*Ibid.*). The theatre of war was global, with engagements fought in the Mediterranean, Baltic, Caribbean, Atlantic and Indian Oceans (Rodger 2006). The global nature of this conflict exposed seamen and marines to prolonged sea service, the dangers of long transoceanic voyages and to new and often deadly tropical diseases, such as malaria and yellow fever. The physical and mental toll of these frequent and prolonged conflicts on R.N. seamen was immense, with the R.N. losing hundreds of thousands of men to trauma, disease and desertion over this period (Blane 1799; Lloyd and Coulter 1963). This study involves the osteological analysis of the remains of a very small sample of this vast and complex force.

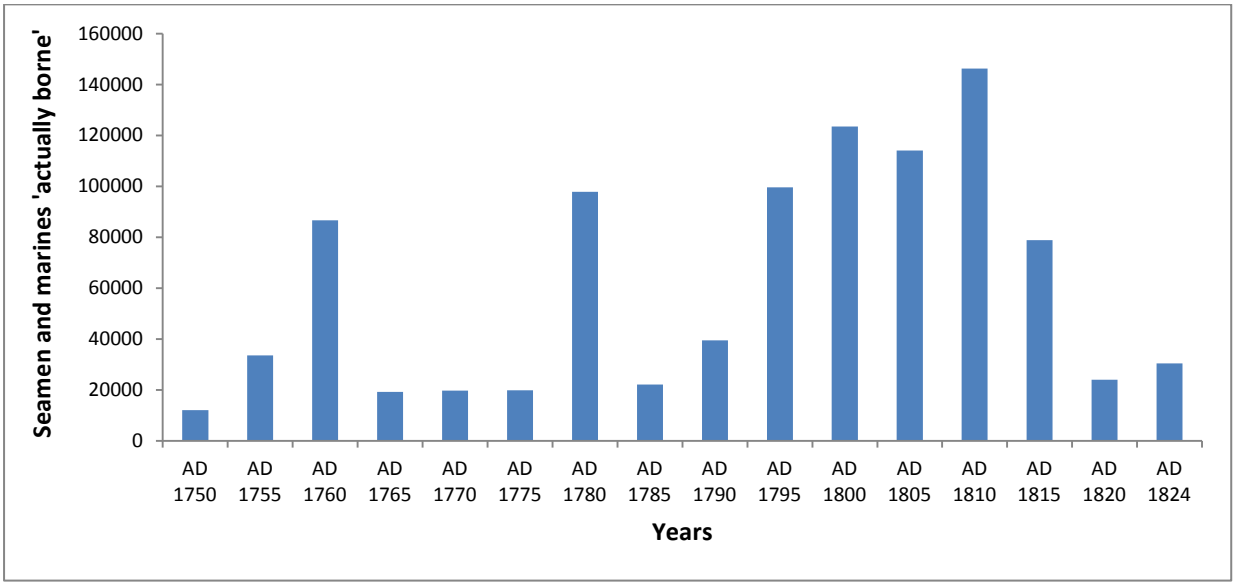
3.3. The scale of R.N. operations

With the nation's defences almost entirely dependent on the strength and readiness of the R.N., the late Georgian R.N. was an enormous institution, easily constituting the largest employer in Britain (Lavery 1989). Vast networks of contractors developed to supply the navy with ships, victuals, arms and other supplies, but manning the ships with experienced seamen in times of war was a perennial problem (Crimmin 2007).

The R.N. expanded in times of war and contracted in peacetime. It was at its height in the 1800s, comprising more than 500 ships on active service (Fremont-Barnes 2007), manned by over 145,000 seamen (Rodger 2006). There is no single source that can provide accurate figures for the number of seamen and marines serving in the R.N. in any one year, and many estimates fail to cite their sources, making their veracity difficult to ascertain (Rodger 2006). The number of seamen voted by Parliament (i.e. the number of seamen's wages that Parliament agreed to pay) is widely used by historians as a measure of the size of the R.N., but Rodger (2006, 636) discounts these figures as '*accounting fiction'*, bearing little relation, and often greatly under-estimating the true number of serving seamen (Gradish 1979).

Fig. 3.1 shows Rodger's summary of data of '*seamen actually borne'* (including officers, seamen and marines actually aboard ship) compiled by the Hardwicke Commission of 1859, which is thought to be more accurate. These data show an increase during the Seven Years War with France and Spain; a dramatic reduction in the peace of the late 1770s; a rapid rise in the 1780s with the advent of war with Holland, France and Spain; another drop in peacetime; and then a rapid increase in the second half of the 1790s at the outbreak of the French Revolutionary Wars, followed by the Napoleonic Wars, and a fall-off in the 1810s as the navy downscaled towards the end of that conflict. At the conclusion of the Napoleonic Wars seamen numbers had fallen to 23,000 (McLean 2010) and remained relatively small in the decades of peace that followed. Marines were similarly demobbed in vast numbers.

Figure 3.1 *The numbers of seamen and marines in the R.N. between 1776 and 1824 (data for 1750- 1815 from Rodger (2006, 636- 639); for 1820 and 1824 from Floud et. al (1990, 68-71).*



The precise dates of death of the R.N. seamen and marines of this study are unknown, and they may only be dated to the time that the respective burial ground was in use. Numerically, however, it is most probable that more date to periods when the R.N. was largest- that is, in times of war..

3.4. Recruitment

The 18th century R.N. could not mobilise quickly in an emergency, requiring several years to complete the process (Gradish 1979). Recruiting experienced seamen into the navy in any large numbers was highly problematic, and became increasingly difficult as the R.N. continued to expand during the Napoleonic Wars. The merchant navy acted as a reservoir of experienced seamen on which the R.N. drew in times of expansion, but the radical increase in the size of the R.N. in the 1800s far outstripped the growth of the merchant navy in this period (Rogers 2007), leaving a significant shortfall.

In peacetime, the R.N. was manned almost exclusively by a relatively small force of able seamen (Rodger 1986), but in times of war sea captains could not afford to be so selective, being forced to take on less experienced or ordinary seamen from the merchant navy, or complete novices. There were seldom sufficient volunteers, and many seamen were pressed into service, or recruited under the Quota Acts of 1795 and 1796 (Rodger 2006). Pressed men probably accounted for a significant

number of seamen, but the true proportion is difficult to ascertain from ship's musters, as on joining a ship a pressed man was encouraged to 'volunteer' and thereby be eligible for a bounty to which pressed men were not entitled (Rogers 2007). Generalisations are problematic, but on-shore impressment figures suggest that between 40-50% of men were pressed in wartime (*Ibid*). The impressment service targeted merchant seamen, and often used an elaborate network of informers to locate them (*Ibid.*). During a manning crisis, or when a captain needed to find a crew at short notice, a 'hot press' would ensue in the port concerned, in which many men were indiscriminately rounded up and forced into the navy, regardless of occupation.

The Quota Acts required English, Welsh and Scottish counties and port cities to raise a fixed number of recruits for the R.N. Local authorities saw this as a golden opportunity to rid their boroughs of prisoners in county gaols, wastrels and other undesirables. Unfortunately, many quota men were in poor health and carried infectious diseases, which posed considerable dangers to their prospective crewmates (particularly typhus).

Marines were never pressed but volunteered for a bounty. Once recruited, both marines and seamen served indefinitely- usually as long a term as their services were required. In the Revolutionary and Napoleonic Wars this could be more than 20 years, in which time seamen were rarely granted shore-leave to visit loved ones, due to the risk of desertion (Adkins and Adkins 2008).

3.5. Shipboard life

3.5.1. Hierarchy and composition of a ship's company

A ship was a self-contained, highly disciplined wooden world, regulated by a rigid hierarchy in which each man's role and status were precisely defined. Until the later 18th century, central authority of the Admiralty was only loosely enforced, such that onboard organisation and the treatment of seamen was almost entirely at the discretion of each ship's captain (Crimmin 2007). The captain exercised virtually unlimited powers aboard his ship. He was supported by his lieutenants, who in turn were supported by warrant officers, including the master, who amongst other tasks was

responsible for navigation, and boatswains and boatswain's mates, who directly oversaw divisions of seamen. In addition to seamen, a ship's company comprised a significant number of idlers, those not part of a watch (the naval term for a shift). These included carpenters, shipwrights, sailmakers, armourers, masters at arms, yeomen of the boatswain, carpenter and gunroom (overseeing stores), officer's servants, stewards, secretaries and the cook and their mates or assistants (Adkins and Adkins 2008; Fremont-Barnes 2005; Fremont-Barnes 2007; Lavery 1989). Idlers were often also supported by servants or apprentices, many of whom were boys. All these individuals were essential to the self-sufficiency, maintenance and orderly running of the ship. The skeletal assemblages in this study almost entirely comprised ratings or 'the lower deck', of which seamen were the majority.

Compared with the merchant navy, R.N. ships carried considerably more men. A first rate ship of 100 guns had a crew of 850, a third-rater of 64 guns carried 500 men, a frigate 140- 300 men, and a brig of 10 guns 75 men (Fremont-Barnes 2007). Accommodating, victualling, watering and disciplining this many men aboard one vessel created major logistical challenges, all of which impacted on the health of seamen and marines. In addition, confining so many men within the relatively small onboard space greatly facilitated the spread of infectious disease (Blane 1799; Lind 1762; Trotter 1804b).

3.5.2. Seamen

On joining a ship, each seaman was assigned a rating by the first lieutenant on the basis of his sailing experience and ability. Least experienced were landsmen, followed by ordinary seamen and then able seamen. Pay and prize money (a small percentage of the worth of a captured vessel) was dependent on this rating (Adkins and Adkins 2008; Fremont-Barnes 2005), and it was not uncommon for seamen to be demoted when it became apparent that they had exaggerated their abilities (Slope 2006).

Landsmen had no previous experience of the sea and performed uncomplicated tasks, such as hoisting and lowering sails, rigging tackle, swabbing decks and moving loads (such as barrels) from

one part of the ship to another. Ordinary seamen understood rigging but were less experienced or competent than able seamen, who could perform tasks such as reefing and steering, and generally had a decent standard of seamanship (Fig. 3.2). The most competent able seamen were the topmen who worked high aloft, and were picked for their strength, agility and seamanship (Lavery 1989). In port, seamen of all ranks were often engaged in loading, unloading and stowing supplies (such as food, water, ammunition, spare sail and rope) and preparing the ship for its next cruise.

The crew was divided into groups and assigned to specific tasks, often several at a time, depending on the ship's mission and size. A seaman was usually assigned to a particular station or part of the ship or rigging, to serve a specific gun in battle, and to work the pumps when required. Men were frequently referred to by their station (e.g. topmen, forecastlemen, afterguard and waisters) (Fremont-Barnes 2007). It was the first lieutenant's responsibility to ensure that an equal skill mix was on watch at any one time. The crew were normally divided into two (occasionally three) alternate watches- the larboard and starboard watches. Most commonly the day was divided into seven watches: five four- hour watches, and two dogwatches of two hours each. Thus, each man worked mostly four hours-on, four-hours off, with no more than four hours unbroken sleep (Fremont-Barnes 2005). This routine was often relaxed in port (*Ibid*.).

Divisions of ratings were overseen by petty officers (mostly promoted from the able seaman ranks), such as the boatswain and boatswain's mates. Each watch was overseen by a commissioned officer (usually a lieutenant) (Lavery 2004; Lewis 1960).

3.5.3. Marines

The main role of the marines was not to sail the ship but to engage the enemy. They were essentially sea-going soldiers whose principal role was to fight using virtually the same tactics and weaponry as soldiers on land (Lavery 2004). In an engagement they provided small-arms fire, usually from the higher vantage of the quarterdeck, their standard weapon being the flintlock musket (Fig. 3.3). They would also lead boarding parties or repel boarders, and took a leading role in amphibious attacks

and in cutting out operations (capturing a ship from within an enemy harbour) (Fremont-Barnes 2007; Lavery 1989). Their other significant role was to maintain onboard discipline and to prevent mutiny and desertion. Much of their time was spent as sentries guarding the officers' quarters, gunroom and liquor stores. Marines were berthed separately from the seamen in order to reduce fraternisation (Lewis 1960), usually strategically located near the wardroom (the officers' quarters), thus providing a buffer between the officers and seamen. Marines were also sometimes used for impressment duties, and to provide manual assistance in strenuous unskilled tasks. They were not required to go aloft, but many did acquire some basic seafaring skills, and in some cases became seamen (Lavery 1989). Unlike today, marines had very low status amongst soldiers, and were despised and scorned as landlubbers by many seamen.



Figure 3.2 *An 18th century seaman wearing the ubiquitous short jacket and loose trousers of his calling. Image courtesy of the National Maritime Museum.*



Figure 3.3 *A marine wearing the official uniform that earned the marines the nickname 'lobsters'. Image courtesy of the National Maritime Museum.*

Marines were deployed in small detachments aboard ship, and comprised a relatively small proportion of the ship's crew (15-17%). They were headed by a marine captain, assisted by sergeants.

The marines first became a significant element in naval warfare in the Second Dutch Wars (1665-1667). Their numbers fluctuated over the 18th century, with only 5,000 at the outbreak of hostilities in 1793 (Fremont-Barnes 2007). It was largely through their valour in naval engagements, and the championship of Admiral Jervise Lord St Vincent that their status and numbers gradually increased (Donald and Ladd 1982), peaking at 31,400 between 1807 and 1813, and thereafter dropping to 16,000-20,000 in the last years of the Napoleonic Wars (Fremont-Barnes 2007). Their value was recognised in 1802 when they became the Royal Marines (Adkins and Adkins 2008).

3.5.4. Diet

The Victualling Board provided each seaman and marine with a generous daily ration of food and drink of approximately 5,000 calories (MacDonald 2004). This diet was restricted in choice and often of poor quality, due to the expense and difficulty of preserving food on long voyages. At sea, two pounds of salt beef or one of pork was provided four days a week. On meatless or banyan days, 4oz of cheese and 2oz of butter were issued instead. Other daily standard issues were 1lb of bread a day (hard tack), 1pt of oatmeal, 0.5pt pease (dried peas), and a gallon of beer (Rodger 1986). Ships often carried livestock that was slaughtered at sea to provide some fresh meat. Some sea-going rations were replaced by local produce in foreign stations.

Whilst in port, standard sea provisions were usually replaced with locally procured fresh provisions, but exchanges were tightly constrained by the rules of the Victualling Board (MacDonald 2004). Seamen also bought their own food and drink from local vendors, who commonly rowed these provisions out to the moored ship in small bumboats. Such boats also carried large numbers of prostitutes (Robinson1836). Typically, ships appear to have spent 40-50% of time in port (Slope 2006), and hence local produce would have comprised a significant part of a seaman's diet. This is

strongly suggested by carbon and nitrogen stable isotope values of 100 Haslar and Plymouth skeletons of this study (Roberts et al. 2012).

Although monotonous, the typical naval diet provided a generous carbohydrate and protein intake, but was lacking in fresh vegetables and fruit, and consequently in Vitamin C and some Vitamin Bs (such as folic acid and thiamine) and Vitamin K (Sharman 1981). Scurvy in the R.N. is very well recognised, but contemporary descriptions of night blindness suggest that seamen also suffered Vitamin A deficiency (Watt 1985).

In 1795, lemon juice was introduced as a regular daily ration, and scurvy numbers plummeted (Vale and Griffith 2011). James Lind, as First Physician of Haslar Hospital, and Capt Creyke as Governor of Plymouth Hospital (1795- 1826) placed high priority on supplying fresh provisions to their patients. In his memoranda, Capt Creyke records that £166 19s was spent on oranges and lemons alone in the year 1795 '*excluding those sent from London'* (Creyke 1795-1799, pages not numbered).

3.6. Health care in the R.N.

3.6.1. The Sick and Hurt Board

The R.N. lost most of its men to disability, death and desertion (Blane 1799). The prevention of disease and the recovery of sick and hurt seamen were of paramount importance to the Admiralty, faced with a continual and insoluble problem of manning the service (Crimmin 2007). The Sick and Hurt Board (SHB) was established as a permanent administrative body within the Admiralty to oversee health promotion when the deleterious health effects of prolonged war, a devastating typhus epidemic and high desertion rates provoked a manning crisis in the 1740s (*Ibid.)*. The board was responsible for naval hospitals (both those administrated directly by the R.N. and private contract hospitals), and in wartime for prisoners-of-war, but only had limited responsibilities for surgeons afloat (Rodger and Cock 2006). It was disbanded in 1805, with responsibilities transferred to the Transport Board, which, in turn, was abolished in 1816, health promotion becoming part of the Medical Department of the Victualling Board *(Ibid.*).

The SHB were an administrative rather than a scientific or medical body (Rodger 1997), comprising naval bureaucrats with no medical knowledge. They relied heavily on advice of prominent civilian physicians (Crimmin 2007), most of whom had never been to sea or experienced combat situations, and who often dispensed inappropriate advice and promoted quack cures. The balance in favour of naval doctors as SHB commissioners came about in 1795 with the appointment of progressive and highly experienced naval physicians Gilbert Blane, Thomas Trotter and William Gibson in London, and Dr Johnson as resident commissioner at Haslar (Crimmin 2007).

3.6.2. Naval surgeons and physicians

(i) Medical training and status

Most surgeons joined the R.N. in their early twenties, and were generally poorly trained and very inexperienced (Brockliss et al. 2005). Most began their medical careers at 14 or 15 years by becoming apprenticed to an apothecary surgeon (Cardwell 2009), but increasingly many benefited from formal instruction and lectures in the burgeoning new medical schools in London, Edinburgh, Dublin and Glasgow. Although there was an increasing interest in morbid anatomy and pathological processes, as well as a growing appreciation of the value of practical training on the wards of large teaching hospitals, the vast majority of medical students at the turn of the 19th century attended one or two years' training and went home without submitting themselves for examination (Brockliss et al. 2005). Medical training in the 18th century was largely an unregulated marketplace (Lincoln 2007). Until 1858, most doctors were uncertificated and had never had their competency examined. There was a small but growing number of students taking a degree, however. Holding a medical doctorate gave a medical practitioner a certain social cachē as an educated man and a gentleman, and the right to call himself 'physician' (*Ibid.*).

There were very few physicians in the R.N., the overwhelming proportion of medical men being surgeons. A R.N. surgeon was regarded as inferior to a physician, both in his medical knowledge and social status (*Ibid.*). In the 18th century, naval surgeons were rated only as warrant officers on a par

with idlers, and were poorly paid. In addition, they were expected to supply surgical instruments and drugs at their own expense (Cardwell 2009). This lowly status disempowered many surgeons from effecting the changes in the service that were urgently needed (Harrison 2010). Significant improvements in pay and status came in 1805 and 1808, when surgeons were granted equivalent status to commissioned officers, given an official uniform, much improved pay, half-pay in times of peace, a comfortable pension and no longer had to supply their own medicine (*Ibid.*). Thereafter, becoming a naval surgeon was considerably more appealing, and the R.N. was able to attract a better calibre of practitioner (*Ibid.*).

To gain a warrant in the R.N. a prospective surgeon was orally examined on surgery by the College of Surgeons, but was not expected to demonstrate any practical skills (Crumplin 2009; Lincoln 2007). Nor was he examined on his knowledge of medicine or drugs. Skills were largely acquired in practice, and the quality of medical knowledge attained by surgeons depended heavily on the motivation and abilities of each individual. Undoubtedly there were idle, ignorant, cruel and neglectful surgeons (as portrayed for example by Smollett in his novel *The Adventures of Roderick Random* (Smollett 1748), but many surgeons worked hard in trying conditions, making considerable efforts at self-improvement (Watt 2000).

Sea surgeons combined the roles of surgeon, physician and apothecary, and were expected to treat a far wider range of maladies than their civilian counterparts (Brockliss et al. 2005; Brown 2011; Vale and Griffith 2011; Watt 2000). They faced many challenges and diseases specific to the seagoing environment and the global scale of operations of the R.N., but opportunities for the sharing of professional experiences and knowledge were very limited (Harland 2005). Unlike contemporary army surgeons, R.N. surgeons worked very much in isolation, usually being the only surgeon on board. Many surgeons were keenly aware of this professional isolation, forming the Association of Navy Surgeons in 1747, which met formally for lectures, and encouraged informal discussion (Harland 2005). Self-improvement was also encouraged through printed manuals, which provided

much needed theoretical and practical advice on medical and surgical treatments at sea (Atkins 1734; Blane 1799; Lind 1753; Lind 1762; Northcote 1770; Trotter 1804b; Turnbull 1800).

(ii) Medical perceptions and traditions in the 18th century

Late 18th century naval medicine stands at a fascinating juncture in the history of medical theory and practice. From the Middle Ages, Western physicians and surgeons based their treatments on Galenic concepts of balancing of the four bodily humours (blood, black bile, yellow bile and plegm). Illness was perceived as an imbalance of one or more of these humours, which could be redressed through an individually designed programme of diet, purging and bleeding (Porter 1997). Whilst civilian doctors sought to treat a patient by re-balancing his humours, such an individualistic approach was untenable in the Army and Navy, where mass disease prevention and treatment of thousands of combatants was required. The military emphasis on recognising diseases as entities and developing medical or surgical cures *en masse* was a major departure from earlier approaches (Hudson 2007a).

In contrast to these medieval traditions, a more modern scientific approach of observation and analysis of the Enlightenment was rapidly developing, as dissection enabled the effects of disease to be anatomically traced through the body (Harrison 2010). Although a significant number of medical men were seeking a more scientific empirical basis for medicine, this new approach often lacked a conceptual framework on which to hang these observations. One example is the perception of infectious disease. Predating the Germ Theory by more than 50 years, it was widely held that infectious disease was caused by bad odours and stale air, and considerable trouble was taken to ventilate the lower decks with windsails or ventilators (Turnbull 1800), and in case of disease outbreaks with fumigation. Similarly, the architecture of purpose-built R.N. hospitals, including Haslar and Plymouth, were explicitly designed to facilitate the throughput of fresh air (MacQueen Buchanan 2005; Stevenson 2007). Numerous writers, including Blane and Lind, associated noxious effluvias from swampy ground in tropical climates with 'intermittent fever' or '*mal aria*', but observed that the effects of these nefarious miasmas were lessened when a ship was moored

further out to sea, or in a prevailing breeze. Men sent on land in such places often contracted tropical fevers, which was observed to be lessened by treating them with Jesuit Bark (containing quinine) before disembarking and on their return (Blane 1799). These insightful observations were wrongly ascribed to air quality.

The relationship between empirical medicine and humoral theory was far from clear-cut, with both approaches incongruously being concurrently practiced. For example, in a discussion on head injury and fractured skull, Turnbull (1800) gives a detailed, highly accurate description of the central and systemic signs of raised intracranial pressure, which may be readily recognised by modern clinicians. In keeping with modern thinking, he suggests the elevation and removal of bone splinters and underlying clot (trepanning if necessary), but then goes on to recommend a very humoral treatment of bleeding, blistering and purging. Bleeding and purging remained the cornerstones of a wide range of naval medical treatments, despite undoubted deleterious consequences.

The empirical tradition was also inherent in the growing regard for quantitative analysis and record-keeping in naval medicine. Physician-to-the-Fleet Gilbert Blane, amongst others, insisted on the need for regularly kept summaries of patient records, but also for mass observation and numerical analysis of such data (Trohler 2011). His '*Observations on the diseases of seamen'* contains some of the first large-scale quantification of morbidity and mortality aboard ship and in naval hospitals, and the prevalence of common sea diseases (Blane 1799). In the R.N., Blane was not alone in this empirical approach, with naval surgeon Robert Robertson tabulating common sea diseases of patients under his care, and indicating the number of deaths following given treatments; and John Clark publishing very detailed tables of the diseases and fates of seamen in his care in India (*Ibid*).

Instead of assessing the worth of therapies by whether they accorded with medical theories, surgeons and physicians were beginning to base the efficacy of treatment on their own or others' observations (Trohler 2011). The most famous was James Lind's 'fair test' trial in 1747 aboard the *Salisbury*, in which he gave 12 scorbutic seamen one of six treatments for scurvy: cider, oranges and

lemons, elixir of vitriol (sulphuric acid), vinegar, seawater, or an electuary of garlic and barley water (Bartholomew 2002). Lind recorded the differential effects of these 'treatments' but, although noting marked improvements in the citrus group, he did not put forward any clear recommendations (Bartholomew 2002; Milne 2012). Later he became convinced that scurvy was caused by the ingestion of indigestible salt meat and bad water, which in the damp atmosphere of a ship would block perspiration (Vale and Griffith 2011). Despite Lind's emerging empiricism, such muddled thinking was common, and arose from a medical tradition in which practitioners were not in the habit of attempting to isolate cause and effects, but instead collected more and more diverse information, without a means for sorting fact from fancy (Rodger 1997). Another empirical study was conducted by John Millar on the comparative efficacy of bleeding and cooling medicines, and of opium and Peruvian or Jesuit bark (quinine-containing cinchona) on 'contagious fever' (probably malaria) in Senegal in 1779. In 1783, he insisted that '*the stubborn evidence of arithmetic demonstration could not be shaken by argument*' in showing numerically the supremacy of cinchoca over conventional bleeding and purging (Trohler 2011). Indeed, such progressive studies in the R.N. did much to promote empiricism more widely in medicine, and to usher medical thinking into the modern age (Harrison 2010; Rodger 1997).

3.6.3. Duties of a surgeon

There was usually only one surgeon per ship, assisted by surgeon's mates, who often had some training in surgery but were too inexperienced to practice alone (Crumplin 2009) and loblolly boys, who performed basic nursing care (Fremont-Barnes 2005). Between 1795-1815, there was approximately one surgeon to 100 men (Crumplin 2009).

A surgeon was required to visit his patients twice daily, and to provide a daily sick list to the captain (Crumplin 2009). He was also expected to promote preventative health measures, although in all these he was subordinate to the captain and his officers (*Ibid.*). He also assessed those individuals too disabled for future sea service, and issued them with a Smart ticket, so that they could claim a pension (*Ibid.*).

Medical care in the sick berth usually involved the preparation and administration of different combinations of analgaesics, purgatives, emetics and stimulants. An antiphlogistic regime to reduce inflammation and fever was widely practiced on febrile patients with sundry infectious and inflammatory conditions (Crumplin 2009; Hickox 2005). This involved bleeding (600-900ml), a purgative and an emetic. To this the Jesuit Bark was often added, which in malarial cases had genuine benefits.

A surgeon was required to record his treatments and operations in two separate journals: the *Physical Practice in Disease*, which was submitted to the Sick and Hurt Board or the Physician of Greenwich Hospital, and *Chirurgical Operations* to the governor of the Surgeons' Company (Crumplin 2009). The former have been extensively used in this study (Sea Surgeons' Journals 1793-1824).

3.6.4. Surgical treatment of trauma

Surgical care largely involved setting fractures, drawing teeth, lancing abscesses and evacuating haematomas, debriding infected wounds, closing wounds (by suture or adhesive plaster), dressing wounds, and occasionally amputation and trepanation, although both Northcote (1770) and Turnbull (1800) agreed that the latter was best avoided wherever possible whilst at sea, as the delicate control necessary for the operation was very difficult to achieve on a moving deck.

In a battle, the surgeon commonly operated in the half-dark of the cockpit on the orlop deck, below the waterline. Treatment was usually in order of presentation, with only a few surgeons operating a crude triage system (Watt 1985). The sheer scale and severity of injuries required rapid treatment, the most urgent being to arrest haemorrhage through manual compression, tourniquet, tying of bleeding vessels with silk or linen ligatures, pressure dressings or amputation (Crumplin 2007; Crumplin 2009). If there was time, fractures were reduced or temporarily immobilised with pasteboard splints, wounds were searched for debris and bone splinters, and dressed. More careful

bone setting and wound debridement and drainage (infection being regarded as inevitable, and often as laudable) often came later (Crumplin 2007; Crumplin 2009).

Closed fractures were reduced, where possible, and immobilised in tight many-tailed bandages, splints or in a fracture apparatus, a wooden box packed with wadding that contained and immobilised the fractured limb (Crumplin 2007). Interestingly, Northcote (1770, 239) also describes an early form of traction for fractures and dislocations that could be manually reduced. However, this treatment did not appear to be widely in use.

Compound fractures were always approached with considerable caution due to the very high risk of infection, and affected limbs were often a candidate for amputation. Amputation was also a potentially life-saving treatment for uncontrollable haemorrhage, severely macerated wounds, comminuted fractures where union could not be effected, 'mortification' or dry gangrene, chronic infection, spreading infection that posed a danger to life, and for persistent severe pain, numbness or deformity that rendered a limb useless and debilitating (Crumplin 2007). It carried high mortality rates, however, ranging between 20-50%, particularly for femoral amputations (Crumplin 2007; Crumplin 2009).

Long-running warfare allowed army and naval surgeons considerable scope for experimentation with new surgical techniques. Important advances made by 18th century naval surgeons included the rediscovery of the principle of debridement; delayed wound closure in gunshot wounds; fasciotomy in compartment syndrome; a posterior flap technique for amputation; common carotid ligation in young subjects, and cutting ligatures short so as not to be conduits for infection in amputated limbs (Watt 1985). Unfortunately, many preventative health measures and surgical advances made in the long-running French Republican and Napoleonic Wars were lost in the peace that followed, and had to be rediscovered in the Crimean War three decades later (*Ibid.*).

3.6.5. The changing pattern of health in the R.N. over time

Eminent naval physicians James Lind (Lind 1762), Gilbert Blane (Blane 1799), and Thomas Trotter (Trotter 1804b) all commented that the overwhelming majority of medical cases in the R.N. was due to disease rather than trauma. 'Fevers' (a collective term for any febrile disease) were by far the greatest cause of morbidity and mortality, particularly earlier in the period. In the tropics, thousands of seamen and marines succumbed to yellow fever and malaria. New recruits often brought with them diseases suffered in civilian life, including typhus and smallpox, which could sweep through a crowded ship with devastating effect. A more chronic but nevertheless deadly endemic infection in this period was tuberculosis (often known as consumption or pthisis). Dysentery or 'the *bloody flux*' was another mass killer, which was readily transmitted in the close confines of a ship (Haycock 2002). The global nature of R.N. operations exposed seamen to prolonged periods on ship's rations, and in the absence of fresh produce many succumbed to scurvy or co-morbidities. Venereal diseases also comprised a significant proportion of a sea surgeon's case-load and of hospital admissions (Haslar Hospital Musters 1792-1824; Plymouth Hospital Musters 1792-1824; Sea Surgeons' Journals 1793- 1824).

The R.N. was ahead of its time in appreciating the relationship between environment and health. By the 1800s the importance of onboard sanitation, improved ventilation below decks, and improved food and clothing had been widely acknowledged by the Admiralty and adopted by many captains (Brown 2011; Crimmin 2007; Watt 2000). The separation and cleansing of new recruits (particularly Quota men from county gaols) and their apparel radically reduced the transmission of typhus to the ships. In time, receiving ships for new recruits became virtual quarantine stations, where recruits were washed and observed for disease before joining their ship (Adkins and Adkins 2008). Together with improved hygiene onboard ship these measures radically reduced shipboard outbreaks of typhus, smallpox and other infectious diseases (Vale and Griffith 2011). In addition, separating infective cases on board from the well (particularly with dysentery) greatly curtailed the spread of disease.

The introduction of lemon juice rationing in 1795 caused a dramatic drop in scurvy numbers (Adkins and Adkins 2008; Brown 2011; Carpenter 1986; Lloyd and Coulter 1963), and presumably in co-morbidities, such as dysentery and tuberculosis. This drop is particularly apparent in Haslar and Plymouth Hospitals from 1800 onwards (Sinnott 2013). Some success had been achieved in large-scale vaccination against smallpox in the fleet (using Jenner's cowpox technique), as well an increasing use of the Jesuit Bark in the prevention and treatment of malaria (Crimmin 2007).

Thus, crews were in general healthier, experiencing less infectious disease and scurvy than earlier in the period (Brockliss et al. 2005). Presumably too after many decades of war, sea surgeons had become adept at managing surgical cases. Naval sick rates had fallen from one man in 2.45 in 1779, to 1 in 10.73 by 1813, and death rates from one man in 42 to one man in 142 in the same years (Mathias 1979, 280).

Although undoubtedly, long years of conflict provided naval surgeons ample experience of a wide range of diseases and trauma cases, and unprecedented opportunities to experiment with new techniques and treatments, Rodger (1997) has argued with considerable justification, than it was the preventative health measures instituted by non-medical officers that was principally responsible this radical fall in morbidity and mortality rather than any major advances in medicine. Indeed, as Nelson succinctly summed up on 11 March 1804:

> *'The great thing in military service is health, and you will agree with me that that it is easier for an officer to keep men healthy, than for a physician to cure them.'*
>
> (cited in Ellis 1969, 192).

3.6.6. Disability and pensions

Thousands of late Georgian R.N. seamen and marines were '*discharged unserviceable'*- that is discharged from the R.N. due to disability. These veterans faced an uncertain future, particularly as many lacked skills that could be employed in civilian life. During and following the Napoleonic Wars, the country they were returning to was wracked by economic depression, failed harvests and the spiraling cost of grain (Nicholas and Steckel 2009). In 1815, hundreds of thousands of demobilised

seamen and soldiers returning from the wars struggled to find employment in these difficult times, many of them being physically or mentally damaged. Encumbered by a post-war debt of £800 million, the British government did little to alleviate the desperate plight of their erstwhile 'heroes', providing disabled soldiers and seamen with only a meager pension (Crumplin 2007).

Disabled R.N. veterans could claim financial assistance from the Chatham Chest, a 'pension scheme' to which all seamen and marines contributed a shilling monthly. Sixpence to Greenwich Hospital was also deducted monthly from their pay (Rodger 1986). The Chatham Chest had been set up by Hawkins and Drake in the 16th century (Lavery 2010). It was amalgamated with the Greenwich Hospital pension in 1814. In addition to seamen's contributions, Greenwich Hospital was funded by the unclaimed prize money, wages of seamen who 'ran' (deserted), and from the confiscated estates of the disgraced Jacobite Earl of Derwentwater (Newell 1984).

Assistance from the Chatham Chest for wounds incurred in service was dependent on the presentation of a smart ticket or certificate of relief, issued by the onboard surgeon. It had to be renewed six monthly or annually at a review. In his memoir, seaman William Spavens described the pitiful state of many discharged seamen at such a review:

> *'Here you may behold 500 mutilated creatures of different ages and appearances, some clean and decently appareled; some dirty and almost naked, so that the cloth on their backs would scarcely make a kitchen-girl a mop; some in meager and emaciated looks, who appear as if they never had a good meal of meat, while here and there some indeed retain some vestiges of their former likeness; some have lost an eye, and others both; some have a hand, some an arm off; some, both near their wrists, some, both close to their shoulders; others, one at the wrist and the other above the elbow; some are swinging on a pair of crutches; some with a wooden leg below the knee; another above the knee; some with one leg off below the knee and the other above; some with a hand off and an eye out and his face perforated with grains of battle-powder, which leaves a lasting impression as though they were injected by an Italian artist [tattooed]; some with their limbs contracted; others have lost part of a hand or part of a foot; some have a stiff knee from the fracture of the petella bone; some have lost the tendons, and others the flesh from their arm pits; while another has lost a piece from the back of the neck; another has had his skull fractured and trepanned, and a silver plate substituted in room of what was taken out; some with their noses shot off; others with a piece torn from his cheek; another with his jaw bone of chin shot of, and c. and c. and c.....'* (Spavens 1796, 97-98).

Despite their disfigurements and disabilities, only a small proportion of these men would eventually have gained a place in Greenwich Hospital. In theory, all R.N. seamen and marines were eligible

when too old or incapacitated to support themselves, but, in reality, places were limited. The situation was alleviated in 1764 when a system of out-pensions was instituted, in which veterans could draw a pension but remain resident in their community (Newell 1984). This allowed the support of vastly more Greenwich pensioners- a critical change given the major expansion of the R.N. by the end of the century.



Figure 3.4 *Contemporary caricature satirising the extreme disability of two Greenwich pensioners in the Helpless Ward of Greenwich Hospital. Courtesy of the National Maritime Museum.*



Figure 3.5 *'The Distressed Sailor' by Fores vividly illustrates the desperate plight of disabled R.N. veterans and their dependants. Courtesy of the National Maritime Museum.*

3.7. The Royal Hospitals in Britain

3.7.1. Introduction

The skeletons of this study were excavated from the burial grounds of the Royal Hospitals Haslar, Plymouth and Greenwich. These institutions will be discussed briefly below.

3.7.2. The founding of Haslar and Plymouth Hospitals

In the earlier 18th century, the care of sick and hurt seamen on land was undertaken by private contract hospitals (such as at Deal, Plymouth, Gosport, Sheerness, Woolwich and Rochester) and by private individuals (often publicans or indigent widows) in their inns or homes (Harland 2005; Lloyd and Coulter 1963; MacQueen Buchanan 2005). Growing criticisms of corruption, high costs and the widespread neglect of vulnerable patients, as well as the awareness that existing services had proved grossly inadequate in the typhus epidemic of 1739-41, led the SHB to question whether the existing system provided adequate care. In addition, the R.N. was haemorrhaging seamen through desertion once they were on shore recuperating (Lloyd and Coulter 1963).

The answer was to found and directly administer purpose-built naval hospitals in Britain, where the best possible health care could be achieved, the aim being to return sick and injured seamen to active service as quickly as possible (Crimmin 2007; Lloyd and Coulter 1963). The two Royal Hospitals were Haslar, established on the Haslar Peninsula, Gosport, in 1756, and Plymouth Hospital at Stonehouse, Plymouth, in 1762 (Brown 2011; Harland 2005; Pugh 1972; Stevenson 2007; Tait 1906). Topographically isolated, surrounded by high walls and patrolled by sentries, the hospitals also limited desertion.

Haslar and Plymouth Hospitals were part of a much broader network of medical care in the R.N. This included onboard sea surgeons, hospital ships and a growing number of R.N. hospitals abroad: at Port Mahon, Minorca (founded 1711); Gilbraltar (1741); Port Royal, Jamaica (1744) (Harland 2005; Stevenson 2007); English Harbour, Antigua (1793) (Varney 2009), Malta (1804) and Simonstown, Cape Colony (1813). Smaller private contract hospitals both at home and abroad also continued to be used (Crimmin 2007).

Haslar and Plymouth Hospitals received the sick and hurt directly from fighting ships, from hospital ships, and from transports returning patients to England from naval hospitals and ships abroad. The time lapse between sustaining an injury and being received at either hospital could range

considerably from days to several months. This has important ramifications in terms of the extent of healing of traumatic lesions in the skeletons from these hospital burial grounds.

3.7.3. The founding of Greenwich Hospital

Greenwich Hospital was founded by Royal Charter in 1692. In the words of its Charter, it was an institute for '*the relief and support of Seamen serving on board the Shipps or Vessells belonging to the Navy Royall... who by reasons of Age, Wounds, or other disabilities shall be incapable of further service at sea and be unable to maintain themselves'* (cited in Newell 1984). Other aims included the '*sustenance of the widows of seamen'* and the '*maintenance and education of children of seamen'*, which it did through the Greenwich School established on the site.

Being selected as a Greenwich pensioner carried considerable prestige in the R.N. and beyond. In-pensioners were provided with a generous food ration, a cabin within a ward, a uniform and medical care, but the regime was rigidly prescriptive, if not draconian, in many ways reflecting life aboard ship (Hudson 2007b).

3.7.4. Care in the Hospitals

There are conflicting reports on the quality of care received by patients in Haslar and Plymouth Hospitals, and standards appeared to have varied considerably over time. During his long tenure as first physician at Haslar, James Lind instituted many of the preventative measures in place elsewhere in the R.N., namely a great emphasis on personal and environmental hygiene, nutritious diet, good ventilation of the wards, isolation of the infected from other patients, and allocation of patients with the same disorders to the same ward. He even suggested that hand washing might prevent the spread of infection (Lind 1762). New admissions were bathed and their clothes removed and washed (fever victims' clothes were baked with vinegar and fumigated with sulphur). Similar measures were instituted at Plymouth Hospital (*Ibid.*).

Nursing care was basic but including keeping patients clean, administering medicine, turning bedridden patients and feeding the weak (Lloyd and Coulter 1963). Most memorable are lurid

complaints about nurses at both hospitals, included being neglectful, assaulting patients, soliciting, giving patients alcohol, and stealing from the dead and dying (Creyke 1795-1799; Lloyd and Coulter 1963; Tait 1906). It is difficult to ascertain how widespread were these abuses.

The efficacy of the medical administration of both hospitals varied over time. In some years the hospitals were lauded for their discipline, order and cleanliness (Pugh 1972; Tait 1906), and in others lambasted for disorder, neglect and malpractice (Lloyd and Coulter 1963). Medical care at Haslar was undertaken by a small team comprising the physician, surgeons and several assistants, an apothecary and two dispensers (Lloyd and Coulter 1963). Doctors of both hospitals were permitted to also take on lucrative private patients, but abuse of the system led to the scandalous neglect and death of hospital patients, and the privilege was revoked in 1805 (Lloyd and Coulter 1963). As medical treatment (with the exception of quinine) was generally ineffectual, it is probable that the greatest benefit the hospitals offered medical patients was cleanliness, rest and fresh food. However, surgical patients did have their wounds searched, debrided and dressed, lanced and occasionally amputated.

Although not primarily a hospital in the modern sense, many of the elderly and severely disabled pensioners in Greenwich Hospital did receive medical care in the Infirmary of the Hospital, under the jurisdiction of the hospital physician (Newell 1984). Over the course of the 18th century care in the hospital became increasingly medicalised and restrictive (Hudson 2007b).

3.7.5. Mortality in Haslar and Plymouth Hospitals over time

The skeletons of this study were excavated from the burial grounds of Haslar, Plymouth and Greenwich Hospitals. A brief archaeological background is given in Chapter 1, and a more detailed account in Appendix 3. Burial in the Paddock of Haslar Hospital took place from the founding of the hospital in 1756, until the burial ground was closed by the then Superintendant and Residential Commissioner Henry Garrett in 1824. Similarly, Stray Park, the burial ground of Plymouth Hospital, opened in 1762 with the founding of that hospital, and also closed in 1824. The Greenwich skeletons

of this study were excavated from the second of three burial grounds of the hospital, located on Goddard's Ground on King William's Walk. This was used for burial from 1749 until 1856. Unfortunately, with the exception of one Haslar and one Plymouth skeleton, there was no archaeological evidence to date the burials more precisely.

Numerically, the burials probably date to the years of greatest mortality, when admission numbers and/or mortality rates were highest. Considerable fluctuations over time were present in all three hospitals. Fig. 3.6 displays the mean annual number of deaths in Haslar in five year periods throughout the use of the burial ground, using the following sources: the period 1753-1764 (Blane 1799; Death of Seamen at Haslar Hospital Register 1753- 1764); 1764-1791 (Blane 1799), and 1792-1824 (Haslar Hospital Musters 1792-1824). Fig. 3.7 shows comparable data for Plymouth Hospital deaths in the years that the Stray Park burial ground was open, based on Blane (1799) for the years 1765-1791, and calculated from Plymouth Hospital Musters for the years 1792-1824 (Plymouth Hospital Musters 1792-1824).

The annual death rates in the two hospitals before 1800 were closely associated with admission numbers, which predictably rose rapidly in times of war (1756-1763; 1775-1783 and 1793-1815) and declined in peacetime, as the R.N. expanded and contracted. Interestingly, although Plymouth Hospital showed a similar general pattern to Haslar, fluctuations were not as steep. Nor did it display the high numbers of patient deaths in the first years of the hospital's opening, as Haslar did (being then the only Royal Hospital operational in Britain in the closing years of the Seven Years War). An breakdown of annual admission numbers, deaths and mortality rates in the two hospitals (1756-1824) is presented in Appendix 8, alongside historical events involving the R.N., such as Britain's wars and significant naval engagements and operations.

In the 18th century, fluctuations in patient deaths broadly followed the expansion and contraction of the R.N., but in the 1800s and 1810s, patient numbers in both hospitals dropped, despite being the years that the R.N. was at its height (Fig 3.1). The reason for this 'misfit' suggests that either (1)

fewer seamen and marines in the later Napoleonic Wars fell sick and required hospitalisation, (2) that a higher proportion were being effectively treated onboard ship or in remote R.N. hospitals in foreign stations, and were not admitted to Haslar or Plymouth, or (3) more patients survived hospitalisation in the two hospitals. There is probably no single explanation.

Figure 3.6. *Annual number of deaths (in blue) and mortality rates (in brown) in Haslar Hospital 1756- 1824 (N= 16,848); Sources: Death of Seamen register 1753-64, Blane (1799) for 1756- 91; and Haslar Hospital musters 1792-1824.*

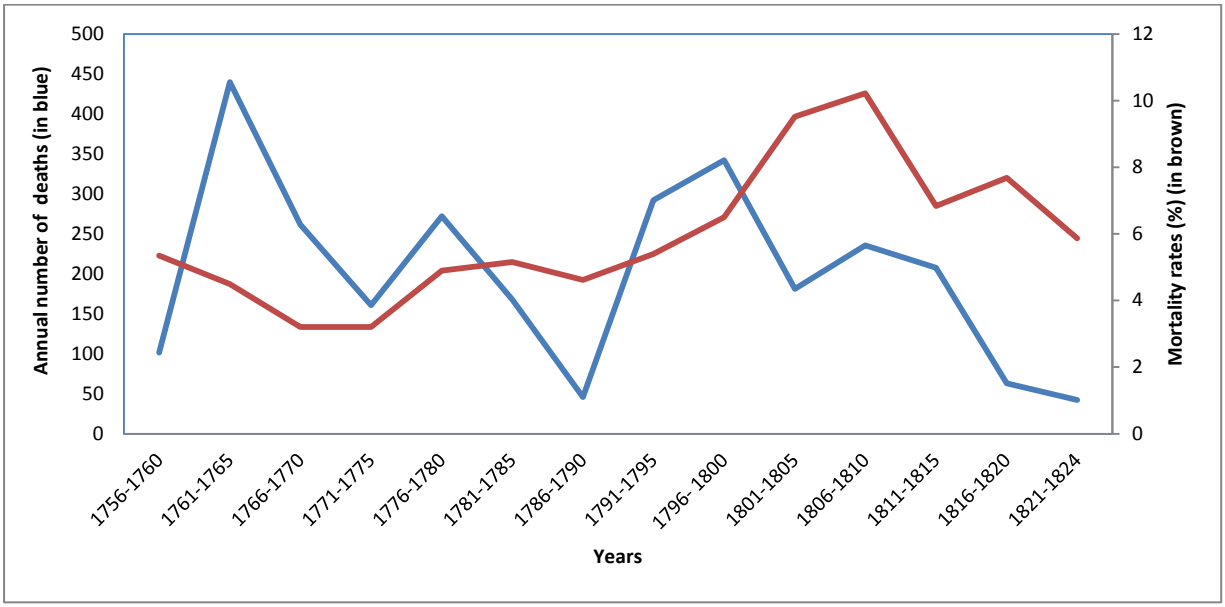
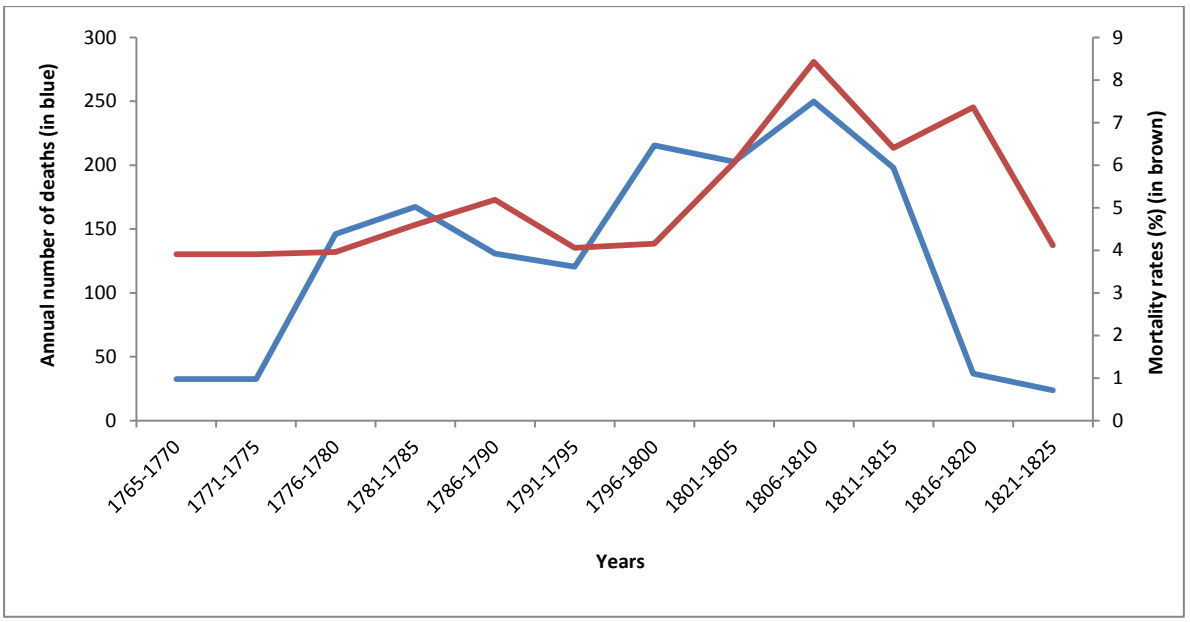
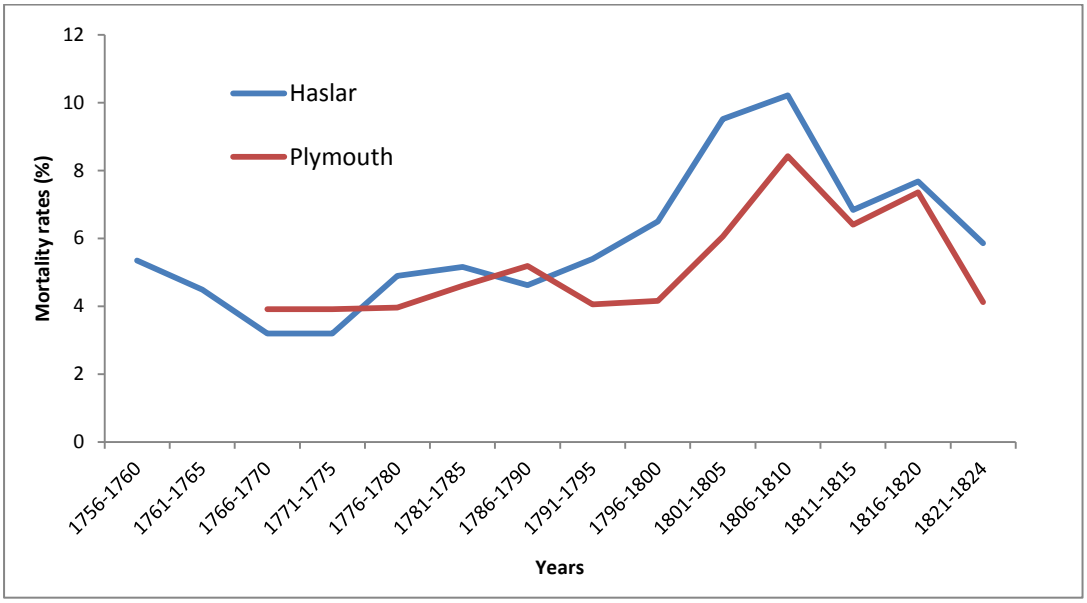


Figure 3.7 *Annual number of deaths (in blue) and mortality rates (in brown) in Plymouth Hospital between 1765 and 1824 (N = 7,822).Sources: Blane (1799) for 1762-1791; Plymouth Hospital Musters for 1792- 1824.*



As discussed above, there was a temporal improvement in seamen's health with the success of preventative measures in combating common sea diseases, such as fevers and scurvy. There certainly was an expansion of R.N. hospitals in foreign stations over this period (Stevenson 2007), making it probable that more acute cases were treated abroad, with more chronic or incurable cases ultimately being returned to Haslar and Plymouth Hospitals. It is possible, but unproved, that changing battle tactics involving more amphibious attacks changed the trauma profiles, with more suffering serious gunshot injuries. Thus, patient profiles had probably changed over time.

Figure 3.8 *Mortality rates (deaths as a percentage of hospital admissions) in Haslar and Plymouth Hospitals (1756-1824). Calculated from Blane (1799) for 1756- 91; Haslar and Plymouth Hospital musters for 1792- 1824.*



Given the number of conflicts in the late Georgian period, it might be assumed that naval medical and surgical practices had improved, that hospital administrators were experienced and efficient, and that these improvements would be reflected in lower mortality figures. Fig. 3.8 reveals that instead, mortality figures rose over time, peaking in the years 1805 to 1810 at 10.2% at Haslar, and 8.46% at Plymouth Hospital- more than double the rate in the 1760s and 1770s. The extent to which this mirrored pattern was due to the changing quality of care in the two hospitals, a changing patient profile, or factors extrinsic to the hospitals or the R.N. is uncertain. Both hospitals were alternatively praised, or lambasted for poor administration, a lack of discipline and order, and neglect by medical

and nursing staff at different times (Lloyd and Coulter 1963; Pugh 1972; Tait 1906). Although Plymouth Hospital consistently achieved lower mortality rates than did Haslar, the similarity in mortality profiles suggests factors external to the two hospitals were responsible for these worsening rates.

3.7.6. Greenwich Hospital over time (1749- 1857)

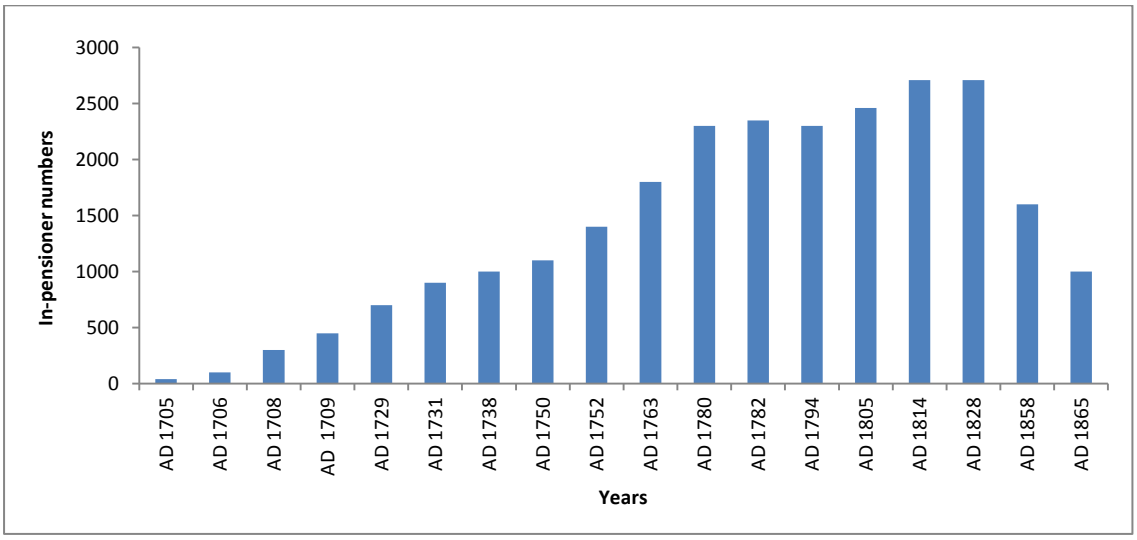
The only burial registers of Greenwich Hospital post-date the closure of Goddard's Ground graveyard (Greenwich Hospital Burial Register 1844- 1860). It was possible to calculate the number of deaths (presumably buried in the hospital) from Wilcox (2011)'s database between 1749 and 1763 (the last year entered), however. In the first 14 years of the burial ground, there were 2,026 deaths (a mean of 142.5 deaths/year). The annual death rate increased from 120 in 1749 to 172 in 1763. The length of time that in-pensioners admitted in the 1750s-60s lived in the hospital varied from a few weeks to over 50 years. Seamen's biographies in the Ayshford Trafalgar Roll indicate that in the early 19th century, most veterans were admitted in the last few years of life, presumably as they became increasingly infirm and could no longer cope with civilian life (Boston et al. 2008).

The annual death rate in later years, when the hospital was at its height, has not been calculated, but is highly likely to correlate with changing hospital numbers over time (albeit with a probable time lag of a few years). In-pensioner numbers increased steadily over the 18th century- from 42 when the hospital opened in 1705 (Lloyd and Coulter 1963), to 1,100 in 1750, and peaking in the late 1810s and 20s (2,710 in 1814 and 1828) (Newell 1984) (Fig 3.9). The hospital still had waiting lists for beds in the 1840s, but as veterans of the Napoleonic Wars died off, numbers dwindled. By 1857 there were 900 empty beds, and by 1865 in-pensioner numbers had fallen to 1,000 (Newell 1984). The hospital had clearly outlived its function, and was finally closed in 1869.

Although there is no way of knowing more precisely when between 1749 and 1857 the skeletons of this study date, numerically, it is more probable that they date to the later time period, as veterans

of the Seven Years War and then the Revolutionary and Napoleonic Wars grew old and retired to the hospital.

Figure 3.9 *In-pensioner numbers in Greenwich Hospital (1705-1865); data taken from Newell (1984) and Lloyd and Coulter (1961).*



3.8. Conclusion

The late Georgian R.N. was a massive institution, particularly in times of war. Long years of conflict, a vastly enlarged navy and heightened hospital numbers in wartime make it highly probable that a very high proportion of ratings, whose skeletons are studied here, were involved in conflict. A high proportion served on foreign stations, particularly in the West Indies, Mediterranean and in the English Channel, and were exposed to the manifold hardships of prolonged voyages with poor-quality water and a sea diet, scurvy, the burning heat and infectious diseases of the tropics, or the damp and bitter cold of the Channel or North Atlantic in winter.

Seamen were a valuable and often scarce commodity, and the Admiralty was acutely aware of the necessity to limit manpower losses through death and disability. Hence, health promotion and the treatment of the sick and hurt were a priority., and considerable declines in mortality and morbidity rates was achieved over the course of the 18th- and early 19th centuries. The extent to which these advances were attributable to medical and surgical improvements is debatable, but, undoubtedly, by the end of the Napoleonic Wars, naval surgeons had had an unprecedented opportunity to practice,

experiment and advance current thinking on the progress of disease, if not its treatment. However, assessing the efficacy of surgical treatments is highly problematic and has not yet been historically examined.

4. Materials and Methods

4.1. Introduction

This chapter describes the materials used in this study, including a general description of the skeletal assemblages and of the principal primary documentary sources. In addition, osteological and historical methods are described, as well as their limitations.

4.2. Materials

4.2.1. The skeletal assemblages

(i) Assemblage size

The total skeletal assemblage of this research comprises 300 articulated skeletons from four excavations at the three hospitals:

- **Greenwich Hospital**: 94 (OA 1991-2001 excavation)
  : 6 (PCA 2005 excavation)
- **Haslar Hospital** : 49
- **Plymouth Hospital** : 151

Disarticulated bone was not included.

How representative these assemblages are of seamen and marines serving in the R.N. of the late 18th- to early 19th centuries is discussed in Section 7.2.1.

(ii) Bone preservation and completeness

Bone preservation and completeness have significant impact on the identification of pathological lesions, as well in the determination of demographic parameters. Taphonomic factors affecting bone preservation are multiple, complex and interacting. Most significant is surrounding soil acidity, but also the pH of the immediate micro-environment around the corpse, and subsequent skeleton (Henderson 1987; Janaway 1996; Nawrocki 1995). Bone preservation may be altered by materials placed within the coffin. Common in this period are grave clothing and a layer of wood shavings or sawdust beneath the corpse (Garland 1989). Other major taphonomic factors are temperature, the quantity and ease of passage of water and oxygen and bioturbation (root damage, animal and anthropogenic mechanical disturbance) (Turner-Walker 2008).

Cortical bone surface condition was recorded using McKinley's six-point scale ranging from pristine (0) to near-destroyed (5) (McKinley 2004). Bone preservation varied considerably between and within each R.N. assemblage (Table 4.1) but, overall, the Greenwich material was best preserved. Haslar and Plymouth bone condition was very variable. At Haslar, skeletons buried in the gravel and sand matrix that comprised the geological strata of much of the site were worst preserved, whilst bone condition was very good in burials dug into brick earth. The Plymouth burials lay within a clay soil matrix and overall, bone preservation was good. Damage was principally through mechanical crushing by heavy machinery during construction and demolition works at the site. Some chemical leaching was also present.

Table 4.1 *Bone condition and skeletal completeness in the three R.N. assemblages (N= 300)*

	Greenwich	**N = 100**	**Haslar**	**N = 95**	**Plymouth**	**N = 151**	**Combined**	**N = 300**
Scale	**Condition**	**Completeness**	**Condition**	**Completeness**	**Condition**	**Completeness**	**Condition**	**Completeness**
1	49 (49%)	0 (0%)	6 (12.2%)	5 (10.2%)	67 (44.4%)	25 (16.6%)	122 (40.7%)	30 (10%)
2	33 (33%)	4 (4%)	12 24.5%)	2 (4.1%)	58 (38.4%)	25 (16.6%)	103 (34.3%)	31 (3.3%)
3	7 (7%)	22 (22%)	7 (14.3%)	12 (24.5%)	23 (15.2%)	35 (23.2%)	37 (12.3%)	69 (23%)
4	11 (11%)	42 (42%)	19 (38.8%)	21 (42.9%)	3 (2%)	54 (35.8%)	33 (12.3%)	117 (39%)
5	0	32 (32%)	5 (10.2%)	9 (18.4%)	0	12 (7.9%)	5 (1.7%)	53 (17.6%)

Rodent and canid gnawing was evident on two skeletons. The osteological potential of the worst preserved Plymouth skeletons was very limited, and hence, only the best preserved 151 were included in this analysis.

Skeletal completeness was rated as 0-25% (1); 26-50% (2); 51-75% (3); 76-95% (4), and near complete (5) (Mays et al. 2004), determined by the approximate proportion of body parts in the skeleton present (approximately 15% for the skull, 25% the torso, and 15% for each limb). At Haslar, there was minimal truncation, either from later graves or modern disturbance, and most missing bone was due to chemical leaching. The bulk of skeletons (85.8%) were over 50% complete, however, of which 61.3% were at least 75% complete.

Despite better general bone preservation than at Haslar, the Plymouth skeletons were the least complete of the three assemblages, with a third of skeletons less than 50% complete. This was largely due to dense grave intercutting, which truncated many earlier burials, and mechanical destruction of more shallow burials during building works. Many single graves contained two to three skeletons stacked one above the other. Inevitably, there was some mixing of smaller elements. These mixed elements were sorted and re-assigned during osteological analysis, wherever possible.

Due to minimal grave disturbance and good bone condition, the majority of Greenwich skeletons were more than 75% complete (74%). In the OA excavation, there was slight mixing of elements in multiple burials or in intercutting graves, but most were fairly easily re-assigned to the original skeleton by the experienced osteoarchaeologist on site. Missing elements were largely due to excavation methodology, in which body parts that lay beyond the limit of excavation were left *in situ*, and were not included in the skeletal assemblage. Elements were also lost to landscaping in a minority of cases.

Considerable mixing of skeletal elements had occurred in the PCA excavation of the multiple burials, and re-assigning elements to a specific skeleton during the osteological analysis was highly problematic. In this group, bone preservation was much more variable than in the OA skeletons, ranging from very good to destroyed. Those skeletons that could not be sorted with confidence were excluded from the osteological analysis, as were the poorly preserved and female skeletons.

Patchy surface preservation may have obscured or destroyed evidence of more subtle pathology. That said, fine active periostitis was visible on many less well preserved Plymouth and Haslar skeletons, making it probable that the effects of taphonomic damage were not that significant in pathological identification in these assemblages.

4.2.2. Documentary sources

The Admiralty Papers held in the National Archives, Kew, London, comprise thousands of original documents that detail the complex administration of the R.N., and the professional and personal experiences of officers and men that sailed and fought in her ships. Most pertinent to this study are the ADM101 and ADM102 sections, which contain records of the Sick and Hurt Board, including surgeons' logs, hospital musters, Death of Seamen registers and Hospital Entry Books.

More regionally-based archives, such as the West Devon and Plymouth Records Office, Plymouth, and Portsmouth City Museum, Portsmouth, were also consulted for primary records pertaining to Plymouth and Haslar Hospitals, respectively. Capt Rotherham's letterbooks held in the Caird Library of the National Maritime Museum were also examined. The following section details the main primary documents consulted. A more comprehensive list is presented in Appendix 4.

(i) Haslar and Plymouth Hospital Musters (1792- 1824)

The muster books of Haslar and Plymouth Hospitals date from 1792 to beyond the closure of the two burial grounds in 1824 (Haslar Hospital Musters 1792-1824; Plymouth Hospital Musters 1792-1824). They are the principal documentary source on trauma prevalence and distribution used in this study.

The hospital musters record seamen and marines received into the hospitals from ships. They stood in place of ships' musters as official pay records, so that those servicemen being treated in hospital would still be paid. Thus, there was considerable emphasis on accurate recording. Annual death numbers in musters were found to be consistent with hospital pay lists in randomly selected years (pay lists record payment to the vicars of Alverstoke and East Stonehouse for funeral services conducted at Haslar and Plymouth, respectively) (Haslar Hospital Pay Lists 1802- 1805; Plymouth Hospital Pay Lists 1810-1812).

The number of new admissions, the patients still in hospital from the previous month, discharges to ships (presumably recovered), '*discharged unserviceable'* (invalided from the service), '*discharged*

dead' (DD) and '*ran*' (deserted) were summarised in hospital musters at the end of each month. These summaries comprised the data from which annual patient numbers, deaths and mortality rates in the hospitals were calculated. Annual mortality rates were calculated by dividing the sum of the dead each month, multiplied by 100, with the number of patients in the hospital on 1 January that year plus new admissions each month of that year.

$$Annual\ mortality\ rate = \frac{\Sigma(DD\ each\ month)\ x\ 100}{(remaining\ patients\ on\ 1\ January) + \Sigma(new\ monthly\ admissions\ )}$$

Each muster entry records the seaman or marine's name, his ship, rank, date of admission and very brief diagnosis on admission (e.g. '*fractured arm'*, '*contused loins'*, '*rupture*', '*amputated thigh'*). This diagnosis was based on a note from the sea surgeon of the man's respective ship, which was handed to the hospital clerk or administrator on the patient's admission to the hospital (Tait 1906). The discharge date and the patient's fate on leaving the hospital were added later by hospital staff. If the patient died, the cost and location of the funeral (e.g. '*in hospital grounds'* or '*buried in Portsea at widow's expense'*) were recorded.

In both hospitals, the vast majority of ratings were buried in the hospital burial grounds at R.N. expense, but by the early 19th century, a small proportion were buried privately (sometimes in the local parish church, sometimes in the hospital burial ground). The few officers who died in the hospitals were generally buried in local parish churches at private expense, although a few headstones relocated to the Memorial Gardens of Haslar record the burials of several officers (South- East Geneology Society 1974). The headstones pre-date the later cemetery, and are believed to have originally stood in the Paddock (Boston and Mahoney 2005).

Unfortunately, the musters do not record hospital medical treatment. Thus, amputations listed in the musters are those that had been performed before admission, either in more peripheral naval hospitals, hospital ships or at sea by the onboard surgeon of the patient's ship.

In addition to living men, a small number of corpses were brought from ships moored at Spithead (off Portsmouth) or Hamoaze (in Plymouth Sound) to the hospital for burial. The cause of death is not noted in the muster list (listed only as '*a corpse'*), but from *c.* 1810, captains sent a brief report detailing the circumstances of death. These were pinned to the respective muster. Cause of death included many falls, drowning (often whilst deserting or whilst drunk) and suicides.

A separate list of sick hospital workers treated in the hospitals was also found in the musters, including their diagnoses and the burial of a small number of fatalities in the hospital burial grounds.

(ii) Sea surgeons' journals (1793- 1824)

The National Archives hold R.N. surgeons' journals (Sea Surgeons' Journals 1793- 1824), many of which have been electronically transcribed. From the late 17th century, sea surgeons were required to submit a log of the cases that they had treated, detailing the disease or injury and the treatment given. The journal was submitted to the Surgeon's Company at the completion of each tour (Crumplin 2009). Earlier journals have not survived, and those held in the Admiralty Papers date from 1793.

Surgeons' journal entries vary considerably in detail, with many limited to the patient's name, a very brief diagnosis, the date that he was treated, and the date that he returned to duty, was discharged unserviceable, died or was transferred to a hospital. Many entries describe the circumstances of the injury, however. The correct use of anatomical terminology is more evident latterly, indicating the growing professionalism of surgeons in early 19th century.

Several hundred surgeons' journals exist, and examination of the complete archive lay beyond the scope of this study. A convenient sample of journals was made, selecting those ships that transferred their sick and hurt to the R.N. hospitals between 1793 and 1818. The journals were not used for quantitative analysis, but as illustrations of the most common causes of trauma aboard ship. Trauma entries in these journals are presented in Appendix 9.

(iii) Stray Park Burial Register (1813- 1814)

Only two years of burial records for Stray Park cemetery of Plymouth Hospital (1813-1814) have survived. The register was compiled by the vicar of St George's Church of East Stonehouse, who conducted the burial services for 2s 6d apiece. The register is part of the Bishop's Transcripts, held in the West Devon and Plymouth Records Office, Plymouth (Stray Park Plymouth Burial Register 1813-1814).

It comprises a list of 380 seamen, marines, petty officers, idlers and two American prisoners-of-war buried in Stray Park cemetery at R.N. expense. The list records the name of the deceased, his rank, the date of burial, and the ship, marine barracks or receiving ship, whence he came to the hospital.

A separate list in the same manuscript details the burials of 44 French prisoners-of-war between 14/12/1813 and 31/12/1813 (presumably from the nearby Millbay Prison) at which the same vicar officiated (also for 2s 6d apiece). These entries are briefer, only listing the date, the prisoner's name and the transport or prison ship that had brought him to England. The location of burial of the French prisoners-of-war is not well understood, but historical accounts suggest that it was within or very close to Stray Park cemetery. Given the antipathy of R.N. seamen to being buried with their French enemies (Pugh 1972), it is unlikely that the prisoners-of-war were buried in and amongst R.N. seamen burials. Indeed, in the Burial Register 1813-14, French burials are listed separately from R.N. hospital casualties, and dates suggest that they were buried as 'job-lots'. It is more probable that these graves were located together, possibly in a separate part of Stray Park cemetery, or in a different burial ground altogether. This has not been archaeologically or historically verified, however.

(iv) Death of Seamen at Haslar Register (1756- 1764)

The Death of Seamen Register records the death of seamen in Haslar Hospital between 1756 and 1764 (Death of Seamen at Haslar Hospital Register 1753- 1764). Each record states only the name of the deceased and the date of death. Its greatest value to this study lay in quantifying the annual

number of deaths at Haslar in years before muster books were available. No equivalent register exists for Plymouth Hospital.

(v) 18th- to early 19th century medical manuals

The following naval and army medical texts were consulted, in order to gain an insight into the common illnesses and injuries in the late 18th century R.N., and the treatments that were available:

- Blane *Observation on the diseases of seamen* (Blane 1799)
- Lind *A treatise on the scurvy* (Lind 1753)
- Lind *An essay on the most effectual means of preserving the health of seamen* (Lind 1762)
- Northcote *The marine practice of physic and surgery* (Northcote 1770)
- Trotter *Medicina Nautica* (Trotter 1804b)
- Turnbull *The naval surgeon comprising the entire duties of professional men at sea* (Turnbull 1800)
- Bell *Memorial concerning the present statue of military and naval surgery* (Bell 1800)
- Guthrie *Treatise on gunshot wounds* (Guthrie 1833)

These texts also give an invaluable insight into 18th century medical perceptions of illness and injury, which underlay treatment and influenced the outcome for their patients. In addition, Blane's work is the first large-scale quantification of sea diseases and hospital admissions. His record of annual death numbers and mortality rates between 1755-1763 are the only records of mortality in the first decade of Haslar Hospital, and for the years 1764-1792 at Plymouth Hospital.

(vi) Letterbooks of Capt Rotheram (1805- 1808)

The letterbooks of Capt Edward Rotheram (Rotheram 1799- 1815) contain a very detailed list of 382 seamen of the 74-gun *Bellerophon*, who was under his command for 2½ years immediately after the Battle of Trafalgar (1805), in which the *Bellerophon* had participated (Cordingly 2003). Although stigmatised by Admiral Collingwood as ungentlemanly, a stupid man and a poor sailor (*Ibid*), Rotheram's list provides modern historians with an invaluable wealth of information not obtainable from ships' musters. Arranged alphabetically by surname, it lists individual seamen, detailing name,

age, length of service in the R.N. and in the merchant navy, occupation before going to sea, place of birth and the place of residence of parents or wife, stature (to the quarter inch), complexion, hair and eye colour, injuries, scars, tattoos or other identifying features, and where in the ship each seaman worked and was berthed.

Rotheram did not state the motivation behind compiling this record. It may well have just been an intellectual exercise of a bored captain on tedious blockade duty (Cordingly 2003), but such personal details were invaluable in recapturing a deserting seaman by providing an accurate visual description, and the places to which he was likely to '*run*' (i.e. desert). Indeed, Rotheram's list bears a striking resemblance to convict transportation records to Australia (Convict Transportation Registers 1791- 1868), compiled specifically for this purpose.

(vii) Wilcox's Greenwich Pensioner database (1749- 1762)

Martin Wilcox of Greenwich University kindly made available his recently completed database *The Poor Decayed Seamen of Greenwich Hospital 1705-1762* (Wilcox 2011). This database incorporates information from the Greenwich Hospital Entry Books, which by the 1740s gave every pensioner's age on admission, his birthplace, place of abode, occupation, rank, marital status, number of children, and whether and how he was injured. It also listed the date of leaving the hospital (often dead). The Entry Book information was often complemented by Hospital directors' minutes and letters, and from petitions of pensioners seeking re-admission after discharge or expulsion from the hospital (usually for drunkenness, brawling or insubordination). The database contains over 8,000 entries.

Entries dating from 1749 (the year that the Goddard's Ground burial ground was opened) until 1762 (the last year of entries) were selected for this study. Only those entries recording the pensioner's death were included, as these pensioners were probably interred within the cemetery. The total number of entries was 2,497.

From the above data, age-at-death was calculated. The description of injuries on admission forms the historic basis for fracture and amputation distributions, but it is clear that only the most visual or debilitating injuries are described. Thus, calculation of fracture prevalence could not be undertaken.

(viii) Ayshford and Ayshford Trafalgar Roll database (1805)

This comprehensive commercial database draws on a wide range of primary sources, in order to present a biographical account of each R.N. crewman who fought at Trafalgar (Ayshford and Ayshford 2004). Age-at-death of a convenient sample of 100 Trafalgar veterans, who became Greenwich in-pensioners and died in the hospital, was used to calculate mean years of service and age-at-death in the later years of the Hospital. The database was also used to explore diagnosis on admission to Plymouth Hospital towards the end of, and following, the Napoleonic Wars.

4.3. Methods

4.3.1. Osteological methodology

(i) Age estimation

Osteological age and sex determination was undertaken in accordance with accepted standards (Brickley and McKinley 2004; Buikstra and Ubelaker 1994). Both genetic and environmental factors affect the rate and nature of ageing, resulting in considerable intra- and inter-populational variation. Thus, all age-at-death estimates presented in this study are expressed as a range, and multiple ageing methods were utilised wherever possible. Ageing methods are not without their limitations, however.

(a) Subadult ageing methods

Subadult ageing methods allow narrower age ranges than in adults, as the growth and maturation sequence is fairly predictable and uniform (Scheuer and Black 2000). In this study, there were no infants or young children, and only one older child (Plymouth skeleton 624), but several adolescents. The following ageing methods were used in older subadults:

- permanent dental development (Moorrees et al. 1963)
- diaphyseal long bone length (Hoppa 1992; Maresh 1955)
- epiphyseal fusion in males (Schaefer et al. 2009).

Dental development is less influenced by adverse environmental factors (such as disease and malnutrition) than skeletal development (Mays 1998), and hence is regarded as the most reliable ageing method for subadults. With a few exceptions (e.g. the second molars and premolars), the third molar was the only tooth still developing in the R.N. skeletons. Unlike other teeth, the highly variable rates of its development limits its usefulness as an age-at-death determinant and, hence, was only used as a very general indicator of younger age (Hillson 1996).

Similarly, diaphyseal long bone length in age-at-death determination was limited to a handful of the youngest skeletons (the upper age limit of the method being 12 years). Most of those whose long bone lengths fell within this range in fact were older when aged by epiphyseal fusion and dental development, and were stunted for their age.

Adolescent age-at-death determination was based principally on the timing of epiphyseal fusion. Late fusing epiphyses, such as the medial clavicle, sacral segments and superior iliac crest were also used to age adults up to the age of 28 years. Delayed cessation of longitudinal growth results in delayed epiphyseal fusion in chronically deprived individuals. In such individuals, under-ageing may be significant.

(b) Adult ageing methods

Adults were aged from stages in the degeneration of the male

- iliac auricular surface (Buckberry and Chamberlain 2002; Lovejoy et al. 1985)
- pubic symphysis (Brooks and Suchey 1990)
- sternal rib ends (Iscan et al. 1984).

The auricular surface was the principle site employed for adult ageing in this study, as it survived much better than the pubic symphysis. Both Lovejoy *et al*'s (1985) and Buckberry and Chamberlain's methods were used. The accuracy of both methods have been questioned (Falys et al. 2006; Mulhern and Jones 2005; Murray and Murray 1991; Osborne et al. 2004), with critiques that both employ overly narrow age ranges. They found greatest inaccuracy in the middle age category. In the Lovejoy *et al.*'s method, under-ageing in the older age category was also cited. A blind study of this latter method on named skeletons from St George's crypt, Bloomsbury, London, found good correlation between chronological and osteological age in the younger adult age categories, but also found under-ageing in the mature and older ones (Boston et al. 2009). Auricular surface ageing was found to be the most accurate method when compared with the symphysis pubis (Brooks and Suchey 1990) and sternal rib end methods (Iscan et al. 1984; Iscan et al. 1985) in this study.

Pubic symphysis age-at-death determination has also been found to be accurate in younger age bracket, but markedly under-aged older adults (Cox 2000). Under-ageing of older adults was seen in blind testing performed on the named skeletons from Christ Church Spitalfields (Molleson et al. 1993), St Luke's Church, Islington (Boyle et al. 2005) and St George's Church, Bloomsbury (Boyle et al. 2005).

Sternal rib end analysis was employed where possible, but identification of the fourth rib was problematic, due to rib fragmentation in most skeletons, markedly limiting the use of this method.

Ectocranial suture closure stages were recorded (Meindl and Lovejoy 1985), but this method was not used to determine age, as the accuracy and precision of this method is not high (Cox 2000). It was used only to broadly indicate a younger or older adult.

Other features taken as general indicators of older age include cross-sectional cranial thickening; arachnoid granulations; generalised degenerative joint changes and ossified cartilage (although, interestingly, the last was also present in several prime and mature adults in the R.N. assemblages).

Dental attrition was not used as an age-at-death determinant, due to much slower rates of tooth wear in the post-medieval period compared to that of earlier agrarian societies– probably due to commercial milling and a more refined diet. Attrition models developed for post-medieval populations (e.g. Roden 1997) have not proved to be accurate or reliable when tested on named assemblages (Boston et al. 2009). Although slightly more wear was generally observed on seamen's teeth compared to terrestrial contemporaries (probably due to the consumption of tough salt meat and hard tack), the rates were not comparable to prehistoric/early medieval assemblages on which the standard ageing methods were devised (Brothwell 1981; Miles 1963).

Two adolescents were identified in the Greenwich assemblage but were not included in the analysis as they were highly unlikely to have been Greenwich pensioners, and were probably pupils of the Hospital School, the infirmary of which lay within the burial ground (Newell 1984). The majority of subadults from Haslar and Plymouth probably did serve aboard ship and thus have been included.

Age categories presented in Table 4.2 were employed in both the osteological and historical analysis in order to facilitate comparison.

Table 4.2 *Age categories used in this study*

Older child	6-12 years
Adolescent	13-17 years
Young adult	18-25 years
Prime adult	26-35 years
Mature adult	36-45 years
Older adult	45+ years
Subadult	< 18 years
Adult	>18 years

(ii) Sex determination

Sexually dimorphic traits emerge after the onset of puberty and, hence, can only be ascribed with any degree of accuracy in skeletons aged greater than 16-18 years. Standard sexually dimorphic skull

and pelvic features were used in this study (Buikstra and Ubelaker 1994; Ferembach et al. 1980), and are tabulated in Appendix 10.

The pelvis is the most sexually dimorphic element, exhibiting features that directly relate to functional evolutionary differences between the sexes, most significantly childbirth (Mays 1998). Blind studies of known sex individuals reveal that sexing from the pelvis has an accuracy as high as 96 % (Meindl et al. 1985; Sutherland and Suchey 1991). The skull is the next most sexually dimorphic element, from which sex may be correctly inferred in up to 92% of cases (Mays 1998). Sex estimation from the cranium alone has an accuracy of 88%, whilst there is a 90% accuracy when the mandible is also present (Krogman and Iscan 1986). This observed sexual dimorphism arises as the result of the action of testicular hormones on the male skull, which is characterised by a general increase in robusticity and enlargement of muscle attachment sites. Blind studies undertaken on the named Christ Church, Spitalfields, assemblage revealed an accuracy as high as 98% in skeletons where both complete skulls and pelves were present (Molleson et al. 1993).

Osteologically, sex may be ascribed 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: male or female where there was considerable certainty of the sex; probable male or female, where some ambivalence or uncertainty existed but where the sex of the individual could be ascribed with some confidence; and possible male or female, where there was only weak indication of sex. Female skeletons were excluded from the analysis on the basis that it was highly unlikely that these skeletons were of female seamen or marines.

R.N. crews were an eclectic group originating from many different regions of Britain and abroad (Adkins and Adkins 2008; Lavery 1989; Lavery 2010; Lewis 1960a; Rodger 1986). It is thus not surprising that the R.N. skeletons showed considerable variation in build and in cranial morphology. Due to this marked intra-population variability and the dearth of female skeletons for comparison,

population–specific 'male dimensions' could not be established. Thus, although 'sexually diagnostic' measurements were made, these were not used to assign sex.

(iv) Ancestry

Osteological assessment of ancestry remains a sensitive and problematic field but, nevertheless, ancestry remains an important aspect of cultural identity. Morphological and metrical criteria used to assign ancestry are based on cranial morphology of four broad geographic groups:

- Caucasian: European, West Asian and Mediterranean population groups
- Mongoloid: Eastern Asians, American Indian, Polynesian
- Negroid: sub-Saharan Africans
- Australoid: Melanesian/ native Australians (Gill 1984).

Historical records indicate that a significant proportion of R.N. crews were non-Britons (Chapter 5). Craniofacial features of the R.N. skulls were systematically analysed in order to assign each individual to one of the above ancestry groups (Bass 1995; Byers 2005). These traits are listed and illustrated in Appendix 11-. Only limited dental variants were used (e.g. crenulated crowns and shovelled incisors). Metrical analysis of ancestry using craniofacial discriminant function analysis programmes, such as CRANID (Wright 2014) and FORDISC (Ousley and Jantz 2005), and post-cranial metric analysis (such as Craig 1995) lay beyond the scope of this study, however, as did systematic oxygen and strontium isotope analysis for childhood provenance, and mitochondrial and nuclear DNA studies.

(iii) Stature estimation

Stature was calculated by applying maximum length measurements of complete long bones to

Table 4.3 *Regression equations for stature estimation used in this study (Trotter 1970)*

Ancestry groups	**Regression formula (for femur in cm)**
Adult white males	(2.38x maximum femoral length) + 61.41±3.27
Adult black males	(2.11 x maximum femoral length) + 70.25 ±3.94

regression formulae developed for black and white males (Trotter 1970) (Table 4.3.).

In this study, all intact long bones were measured, as well as those that had suffered no more than one post-mortem break that could be readily reconstructed. Lower limb long bones are preferred over those of the upper limbs, as these directly contribute to stature and have been shown to be more accurate (Brickley and McKinley 2004), particularly the femur (Waldron 1998). Although stature was estimated from all complete major long bones (see Appendix 12), only left femoral measurements were used in stature analysis, in order to increase accuracy.

As this study was concerned with estimated stature of seamen and marines in the prime of life, no correction for the older age of the Greenwich pensioners' stature was undertaken.

(iv) Stress lesions

Stress lesions discussed in this study include scurvy, *cribra orbitalia* and porotic hyperostosis, periostitis and rickets. Diagnosis of childhood scurvy was made using accepted palaeopathological descriptions (Brickley and Ives 2006; Brickley and Ives 2008; Ortner and Ericksen 1997). The skeletal manifestation of adult scurvy is less certain. Palaeopathological lesions used to diagnose this common seafaring disease in adults are presented in Appendix 7.

Cribra orbitalia was recognised and graded using Stuart-Macadam's (1991) criteria, and true prevalence was calculated as a percentage of preserved orbits. Differentiation between well-healed, slight *cribra orbitalia* and orbital lesions associated with scurvy and, possibly even, rickets was sometimes problematic, however. Porotic hyperostosis was recognised by diplőe thickening and ectocranial porosity of the frontal and anterior parietal bones. This was distinguished from the ectocranial orange-peel porosity of scurvy by its finer texture, outer table thinning and more restricted anterior location on the cranial vault (see Section 5.2.4).

Periostitis was identified using features described in Section 2.2.5, and was recorded by element, so that its distribution across the skeleton could be established.

Residual skeletal changes associated with rickets, used in this study, was bilateral bowing of the major long bone shafts (most commonly anterior bowing of the femora, and medial or lateral bowing of the tibiae and fibulae, and in a few cases of infantile rickets, of the radii and ulnae). Severity of long bone bowing was graded as slight, moderate and severe (as described in Brickley 2010). In adolescents, it was diagnosed from abnormal anterior angulation of the sacrum (Brickley and Ives 2008).

(v) Trauma

Fractures

Macroscopic analysis

Fractures were identified by macroscopic examination and individually described using features recommended in Roberts (1988; 1991):

- fracture location
- fracture type
- angulation of fractured parts
- extent of overlap and shortening of the element
- apposition of fractured ends
- presence of complications (e.g. infection, nervous or vascular damage, non-union; atrophy)
- extent of healing (callus formation and maturation)

Wherever possible, long bone fractures were classified using the AO system (AO Foundation 2010). However, many of these features cannot readily be applied to short, irregular, sesamoid or flat bones. These were recorded in accordance with fracture classifications set out in Galloway (1999), which are based on modern clinical fracture classifications.

The precise location of each fracture was described and measured relative to accepted anatomical landmarks. To calculate the prevalence of long bone fractures in particular locations, each element

was divided into proximal (epiphysis and metaphysis), shaft and distal (epiphysis and metaphysis) sections.

Rib fractures were described as being anterior, lateral (near the angle of the rib) or posterior. Vertebral fractures were described as being either of the body or neural arch.

True prevalence rates (TPR) were calculated as a percentage of the number of affected parts of an element (e.g. proximal, distal or shaft), divided by the sum of the total number of that part of the element present. In this way, the incomplete elements could be included in the study without erroneously skewing the fracture rates. This approach was necessary in the R.N. assemblages, as many elements were incomplete.

Crude prevalence rate (CPR) was calculated as the percentage of a particular fracture/ fractures *per capita* (i.e. the number of fractures multiply by 100, divided by the total number of skeletons involved).

Radiography

The majority of long bone fractures were radiographed, in order to identify the specific features of fractures listed above that were not visible by macroscopic inspection. This was especially important in well-healed lesions where advanced callus remodelling obscured many features. This was the case in most Greenwich skeletons in which several years, if not decades, had probably elapsed between injury and death. Undoubtedly, some very well remodelled, well aligned fractures were no longer identifiable from radiographs, just as they may no longer be visible with the naked eye (Mays 2008).

Due to the very high fracture numbers, it was not possible to radiograph every fracture. Priority was given to long bones and those elements where the features of the fracture were most enigmatic, or where complications, such as osteopaenia and infection, were present. Suspected projectile injuries were analysed for lead scatter.

All but the worst preserved skeletons from Haslar were radiographed for the Cranfield Forensic Institute, Cranfield University, as part of a separate study, but were kindly made available for this study by Dr Andrew Shortland. The Greenwich skeletons displayed considerably higher fracture prevalence than the other two assemblages and, hence, far more radiographs were taken. Long bone fractures in the Plymouth assemblage were rare, and hence, proportionally fewer radiographs were taken.

Radiography was undertaken by radiographers of Inforce Foundation using a portable x-ray facility. Standard antero-posterior and medio-lateral views were taken of each fracture. Radiographs were digitally stored in the efilmLt (publisher MERG Healthcare) programme.

(a) Joint trauma

Joint subluxation and luxation were identified by bony changes to the joint surface and surrounding bone, most obviously the formation of separate new articular surfaces or abnormal extension of existing ones, and from Hill-Sach's and Bankart's fractures in the case of shoulder subluxation. Degenerative changes, particularly eburnation, were often present. The association between dislocations and fractures, entheseal changes and joint surface changes were noted.

4.3.2. Historical methods

(i) Age estimation

Ships' musters record the age reported by each seaman to the first lieutenant on recruitment to the ship. Corroborating evidence was not requested, and as much of the lowerdeck at this time were illiterate (Adkins and Adkins 2006), it is probable that there were some inaccuracies in seamen's age recall. Since there was no institutional incentive for seamen to exaggerate or under-estimate their age, however, it is improbable that systematic skewing was present.

From these data, Rodger (1986) and Slope (2006) constructed age profiles for each class of seaman on board. Rodger (1986) collated data from 31 ship's musters (including third-raters and sloops, cutters and yachts) during and after the Seven Years War (1764-1782). His total sample size was

3,726. Slope (2006) did a similar study on four Amazon frigate crews active in the French Revolutionary and Napoleonic Wars (1793-1815). His sample comprised 2,534 entries.

Capt. Rotheram's letterbooks were consulted to construct the age profile of the third-rate *Bellerophon* of 74 guns, sometime between 1805 and 1808. Rotheram's letterbooks do not record when in this period each entry was made, but the 382 entries are considerably fewer than the expected crew of 550-650 in ship of this size (Fremont-Barnes 2007). The list is incomplete, however, with a small number of names listed but without associated details. Thus, it may be regarded as a 'snapshot' of the crew composition aboard a third-rate ship in the Napoleonic Wars when the R.N. was at its height.

Marine Description Books record personal details of marines on recruitment, including age and stature, and were extensively analysed by Floud et al (1990), and synthesised in this study. Their samples numbered 5,000 entries per decade.

(ii) Sex estimation

The pay lists and musters of Haslar (Haslar Hospital Musters 1792-1824; Haslar Hospital Pay Lists 1802- 1805) and Plymouth Hospitals (Plymouth Hospital Musters 1792-1824; Plymouth Hospital Pay Lists 1810-1812) record that small numbers of hospital nurses and laundresses were interred in the hospital burial grounds. There was a similar arrangement at Greenwich Hospital (Newell 1984). It is thus very probable that female skeletons recovered during the excavations were such hospital servants and had never been to sea. Thus, they were excluded from the analysis. With very rare exceptions, the R.N. was manned by men and boys, and hence all the analysis in this study assumes male sex.

(iii) Stature estimation

The routine recording of marines' stature on recruitment in Marine Description Books made it possible for Floud *et. al.* (1990) to collect large samples of 5,000 entries per decade (dating 1745-

1881). They calculated the mean stature in five yearly intervals for marine recruits at ages 18, 19, 20, 21, 22, 23 and 24-29 years (Floud et al. 1990, Table 4.1, 140). Rather than the year of recruitment, the year of birth was used, so that temporal trends might be better explored. These data were utilised to explore marine stature data in Chapter 5.

Seamen's stature was not routinely recorded in ships' musters, and hence it was impossible collect a large dataset. Rotheram's letterbooks (1799-1815) are particularly valuable in providing age and stature of 382 seamen aboard the *Bellerophon*. Stature was listed to the quarter-inch, and, although it is nowhere explicitly stated, would suggest systematic stature measurement on board. This record is assumed to be more accurate than written descriptions of deserters, which were sporadically broadcast to identify and recover said men. Stature was one of the many personal features described, but these are assumed to be rough estimates as best remembered by the officer compiling the description and hence, probably lack accuracy. Thus, they do not form part of this study.

The place of birth of seamen was entered in the ship's muster on entering the ship, and in Marine Description Books on the recruitment of marines. Skin colour was not routinely recorded in the former, but occasionally '*black*' or '*blk*' is entered above the name. It is clear from these documents that '*black*' referred not just to those of sub-Saharan African ancestry, but, more generally to non-Europeans (Boston *et al*. 2008). In Rotheram's list (1805-1808), the detailed visual description of each seaman includes complexion. In black seamen, the entry was '*negro*' or '*sambo*'. Marine Description books similarly describe the visual appearance of each recruit.

(iv) Socio-cultural background

Several historians have synthesised place of birth entries in ships' musters and marine description books, to explore the geographic distribution of 'British' seamen and marines, as well as information listing seamen and marines' occupations previous to going to sea (Adkins and Adkins 2008; Ayshford

and Ayshford 2004; Cordingly 2003; Floud et al. 1990), which may inform on socio-economic background.

(v) Trauma

Historical data on trauma in this study was obtained from the Haslar and Plymouth Hospital Musters, which recorded the diagnosis in every seaman or marine on admission to the hospital. Trauma rates were calculated as a percentage of total hospital admissions and total trauma admissions in the years in question, and as a percentage of mortality rates. Fracture rates per body parts were expressed as a percentage of the total number of fractures present in the entire skeleton.

From 1792 to 1824, there were more than 100,000 hospital admissions to Haslar and over 90,000 to Plymouth Hospital. Trauma analysis of the entire dataset was impracticable, so sample years were selected. These were 1792-1796, 1800 and 1810-1811. These were selected to include the earliest year recorded in the surviving musters (1792)- a year of peace; 1793-1796 when Britain was at war with the French Republic, when hospital numbers soared; 1800 in the early years of the Napoleonic Wars, and 1810 and 1811 when the R.N. was at its height. There were over 4,450 trauma admissions in total, including 851 fractures.

Trauma admissions were assigned to the following categories:

- Fracture
- Dislocation (luxation and subluxation)
- Amputation
- Contusion (contusion, bruising and 'hurt')
- Wound (cuts, wounds, excoriations and lacerations)
- Rupture (rupture and hernia)
- Burns (burns and scalds)
- Lumbago

- Nerve damage (lameness, palsy and hemiplaegia)

Distinction was made between wounds and contusions, on the basis that the former broke the skin, whilst the latter did not. In most cases, the anatomical location of the trauma was broadly described (e.g. *amputated arm; dislocated ankle, contused back; fractured thigh*), but left or right location was only mentioned in a minority of cases. The injured element was seldom described by its anatomical name, with the exception of the patella and clavicle. These data were synthesised to produce the trauma distribution prevalences in this study.

Sea surgeons' journals were used to ascertain the circumstances and mechanisms of common injuries aboard ship, but were not used for quantitative analysis.

4.3.3. Data analysis methods

Data on skeletal inventories, preservation and completeness, palaeodemography (e.g. age, sex and ancestry), metrics, some non-metric traits, and the presence of pathological lesions were recorded directly into a Microsoft Access database, developed by the author for this study. In most instances, a presence/absence coding system of 1 (lesion present), 0 (lesion absent) and 9 (part or feature not present for analysis). A written description of each pathological lesion was made in a separate digital Word file for each skeleton. A detailed digital photographic record accompanied each written description. A copy of this digital archive will be submitted to Oxford University on submission of the thesis. A summary of the results of the osteological analysis of each assemblage is presented in Appendix 13-15.

The author is the source of all figures, tables and photographs, unless otherwise stated in the text.

4.3.4. Statistical methods

Descriptive statistics (such as mean, range and median) were calculated for stature, age distribution, and fracture prevalences. True prevalence rates (TPR) of pathological or traumatic lesions were calculated as a percentage of the total number of that part of the element that was present in an

assemblage. Crude prevalence rates (CPR) were expressed as the percentage of individuals displaying a perticularl lesion (i.e. the *per capita* rate).

Significance testing of the differences between two populations was undertaken using Pearson's chi-squared test for nominal data (such as side dominance), using Yate's correction where only two cases were tested (i.e. where there was only one degree of freedom (df). The student t-test was used when testing the significance of differences between parameters of ordinal data (such as fracture numbers and stature). A 1% probability level was used ($p<0$ 0.01).

5. Results: Palaeodemography, normal and abnormal variation

5.1. Introduction

Consideration of the demographic composition and social background of skeletal assemblages is central to meaningful osteological interpretation, particularly with regards trauma patterning (see Section 7.2.1.). The age and sex distribution of a population has considerable bearing on the number and type of fractures in a population, as do ancestry, socio-economic background and occupation. Palaeodemography also offers an ideal vehicle to compare and contrast the historical evidence for the biological and social composition of the lowerdeck of the late Georgian R.N. with the skeletal evidence from the three hospital assemblages. The osteological and historical evidence is presented separately, and then compared.

5.2. Osteological evidence

5.2.1. Sex estimation

Thirteen skeletons from Greenwich and one from Haslar were osteologically identified as female. Since they were unlikely to have been seamen or marines they were excluded from the analysis (see Section 4.3.1).

No attempt to assign sex to the child skeleton was made, in accordance with accepted practice (O'Connell 2004). In some older adolescent and young adult skeletons, full sexual maturity had not yet been attained, and sexually dimorphic landmarks showed mixed, or only weakly, male characteristics (possible male). In fully mature adult skeletons with skulls and/or pelves present, male sex was often pronounced. A total of 180 males, 66 probable males, and 17 possible males comprised the combined assemblage (Table 5.1). Sex could not be identified in 21 adult individuals, largely due to the absence or poor preservation of the skull and pelvis.

Table 5.1 *Sex distribution in the skeletal assemblages (N= 300)*

Sex	Haslar	Plymouth	Greenwich	Total
Male	31	75	74	**180**
Probable male	9	32	25	**66**
Possible male	1	15	1	**17**
Subadult unknown	4	12	0	**16**
Adult unknown	4	17	0	**21**
Total	**49**	**151**	**100**	**300**

5.2.2. Age estimation

Osteological age estimation aims to establish the biological age of the skeleton. This age does not always concur with the chronological age (Cox 2000), because factors, such as nutrition, lifestyle and genetic diversity, have an impact on the trajectory of skeletal growth and subsequent degeneration. Unfortunately, there were no named individuals in the three R.N. skeletal assemblages, but general comparisons with age distributions calculated from ship's musters is presented below.

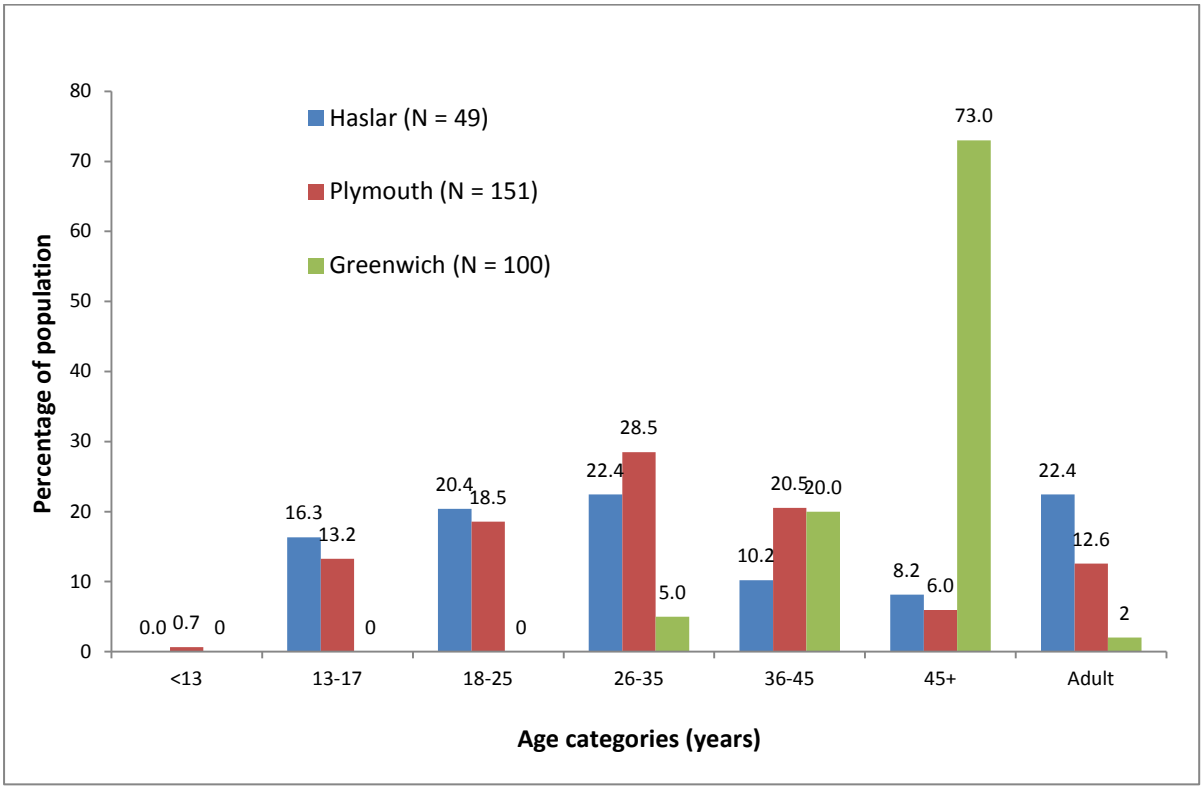
Not altogether surprising for combatants on active service, the majority of Haslar and Plymouth skeletons of known age were younger than 35 years (76.3% and 69.7%, respectively) (Table 5.2; Fig. 5.1). There was one older child of 11-13 years (Plymouth 624) and 20 adolescents (13.2%) in the Plymouth assemblage, and eight Haslar adolescents (16.3%).

Plymouth and Haslar's younger age distribution contrasted sharply with that from Greenwich, where there was a preponderance of older men of >45 years (74.5%). Only 5.1% were aged below 35 years, the remainder aged 35-45 years. Given the propensity of osteological age estimation to underage in the older age categories (Cox 2000), it is probable that even more were older adults. Thus, the Haslar and Plymouth assemblages showed similar, predominantly younger, age distributions, peaking in prime adulthood, whilst the Greenwich assemblage overwhelmingly comprises older adults.

Table 5.2 *Osteological age distribution in the skeletal assemblages (N=300)*

Age range (years)	Haslar (N = 49)	Haslar (%)	Plymouth (N = 151)	Plymouth (%)	Greenwich (N = 100)	Greenwich (%)	Combined (N = 300)	Combined (%)
<13	0	0.0	1	0.7	0	0	1	0.3
13-17	8	16.3	20	13.2	0	0	28	9.3
18-25	10	20.4	28	18.5	0	0	38	12.7
26-35	11	22.4	43	28.5	5	5	59	19.7
36-45	5	10.2	31	20.5	20	20	56	18.7
45+	4	8.2	9	6.0	73	73	86	28.7
Adult	11	22.4	19	12.6	2	2	32	10.7
Totals	**49**	**99.9**	**151**	**100**	**100**	**100**	**300**	**100.1**

Figure 5.1 *Age distribution in the three skeletal assemblages (N = 300).*



5.2.3. Ancestry

Analysis of craniofacial morphology suggested that the seamen and marines were overwhelmingly of Caucasian ancestry (probably European). Inevitably, some European skulls showed occasional or isolated features more typical of African or Far Eastern descent (Fig. 5.2), but, on balance, were European. Individuals showing mixed Caucasian and Mongoloid features associated with facial flattening (such as prominent zygomas) may tentatively suggest Scandinavian or Eastern European ancestry, as such facial flattening becomes progressively more common geographically from

Figure 5.2 *Selected individuals displaying non-Caucasian ancestry in the three R.N. assemblages.*





Left: *Anterior view of the cranium of Haslar 103, which showed African traits.*

Right: *Lateral view of craniotomised cranium of Haslar 103. This skull showed multiple morphological traits indicative of African ancestry.*





Left: *Anterior view of the cranium of Plymouth 757.*

Right: *Lateral view of Plymouth 100.*

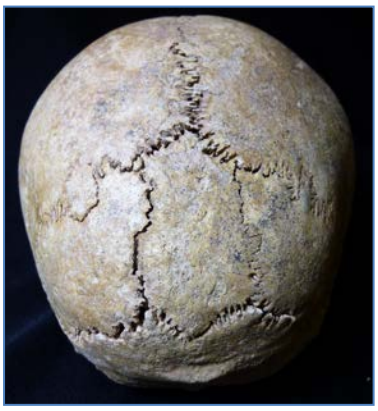
Both individuals showed multiple traits of African ancestry, although some Far Eastern traits were also noted in Plymouth 757.





Left*: Anterior view of the cranium of Greenwich 3029, which displayed traits of both African and Caucasian ancestry.*

Right*: Anterior view of the cranium of Greenwich 3061, which displayed multiple traits of African ancestry.*





Left: *Posterior view of the cranium of Plymouth 523, showing a tripartite Inca bone, Wormian bones and complex suture- lines commonly found in individuals of Far Eastern ancestry.*

Right: *Lateral view of the cranium of Greenwich 3213 showing features of Caucasian and Far Eastern ancestry. This individual also displayed Eagle's Syndrome.*

Western to Eastern Europe (Niskanen 2002), and certainly Swedes, Finns and Prussians are all historically known to have served in the R.N. (see Section 5.3.3).

Inca bones were present in seven R.N. skulls (an anomaly of the occipital bone, in which the upper part is divided by suture/s into two to four separate bones) (Fig. 5.2)- a TPR of 3.6% (N= 193). Five were the complete form, (including two tripartite forms), which is very rare in West Eurasian populations (Hanhara and Ishida 2001). Another six skulls displayed considerable sutural complexity, but only incomplete division of the occipital bone into a separate Inca bone/s. Inca bones are believed to be highly heritable, and occur in high frequencies in populations of Eastern Asian ancestry (such as Inuit, North and South Native Americans) (6-7%) and Tibetan-Nepalese (6.8%), but also in sub-Saharan Africans (5%), with West Africans having a rate as high as 12.5% (*Ibid.*). In Western Europeans, the rate is 1.8-2%. Thus, the R.N rate of 3.6% is higher than the British rate (2%), but lower than the above-mentioned populations. This would support the historical evidence for the eclectic origins of R.N. seamen (see Section 5.3.3), and/or the probably greater gene flow in port towns (whence many seamen originated) than in less internationally connected centres. Interestingly, none of the above skulls displayed African craniometric features, but four did show mixed Caucasian and Mongoloid traits.

There were six individuals, whose facial morphology was strongly associated with African ancestry (Haslar 103 and 303; Plymouth 100, 674 and 757, and Greenwich 3061) and a further four that showed combined African and European features, suggesting more mixed ancestry (Haslar 218; Plymouth 735 and 938; and Greenwich 3029).

5.2.4. Socio-economic background

This section explores the osteological evidence for childhood deprivation, in terms of growth stunting and childhood deficiency diseases, in order to understand the socio-economic background of R.N. seamen and marines. Since child labour was common amongst the poor of late Georgian

England (Roberts and Cox 2003), osteological evidence for strenuous physical activity in youth is also discussed.

(i) Stature estimation

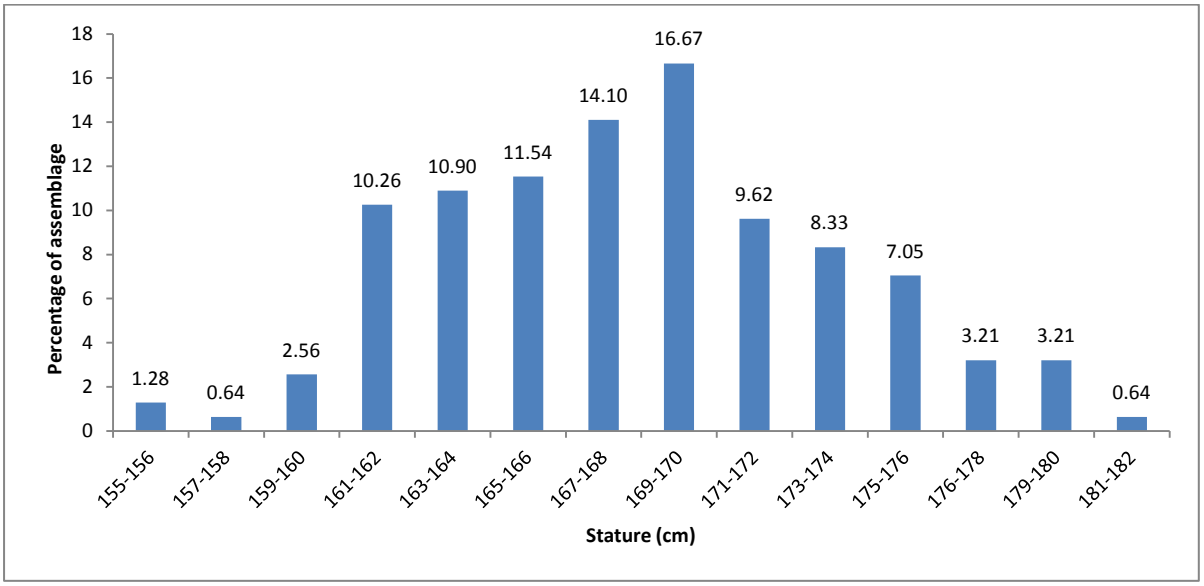
Stature is regarded as one of the most reliable and comparable parameters by which to measure both the general health of individuals in their growing years, and the health and socio-economic well-being of populations (Floud et al. 1990; Larsen 1997; Tanner 1981; Tanner 1992). Attained stature is determined by the complex interplay of inherited and environmental factors (Silventoinen 2003). Although there is a strong genetic influence on an individual's growth and development (including final stature) (Preece 1996), environmental factors, including physical and emotional stressors during childhood and adolescence, may prevent fulfilment of this potential (Jurmain et al. 2009; Lewis 2007; Silventoinen 2003; Tanner 1992). Environmental stressors affecting individuals for extended periods, such as malnutrition and chronic illness (particularly infections), will slow or stop normal growth. Following the stress episode, the individual may experience a period of accelerated growth ('catch-up growth'), which may compensate for this temporarily lost growth (Boersma and Wit 1997). If the stress episode is very severe or prolonged, or if adequate nutrition is not available for catch-up growth, however, the individual will be permanently stunted (Floud et al. 1990; Lewis 2007).

An adaptive response to maximise final stature in chronically disadvantaged individuals is the extension of the growth period into the third and even fourth decade of life (Humphrey 2000; Mays 1998). Since epiphyseal fusion of long bones occurs with termination of longitudinal growth, and osteologically distinguishes adults from subadults, delayed fusion results in the under-ageing of young adults, an over-representation of adolescents, and an under-representation of young adults.

Osteological stature estimation was undertaken on all complete adult long bones of the three R.N. assemblages (Appendix 12). The femur is the most accurate element used in stature estimation (Waldron 1998), and, hence, femoral stature data are presented below. In the combined skeletal

assemblage, left femoral maximum length ranged from 39.2cm to 51.4cm, with a stature range of 155-182cm (5' 1''- 6''), a mean of 168.24± 3.27cm (5' 6¼'') and a median of168cm (5' 6''). The left femora of six individuals showing marked traits of African ancestry produced a slightly lower mean stature of 167.45± 3.94cm (just under 5' 6'').

Figure 5.3 *Stature estimation calculated from left femoral maximum length in the combined skeletal assemblage (N = 156 elements)*



Three subadults showed marked growth stunting, when age estimates from diaphyseal long bone length were compared with male epiphyseal fusion and dental ageing. Plymouth 624 (aged 11-13 years) had the maximum long bone length of a modern nine year old, whilst Plymouth 575 (12-14 years) had that of 9.5 years; and Plymouth 677 (15-17 years) that of an eight year old child. The first suffered chronic maxillary sinusitis and healing scurvy, as well as a healing below-knee amputation, the effects of which probably adversely affected growth in the last few weeks or months of life. However, there were no pathological lesions noted on the other two skeletons to suggest chronic environmental stress.

The final stature of the combined R.N. skeletal assemblage was compared with male stature in 13 contemporary civilian skeletal assemblages from England (Table 5.3). Interestingly, R.N. mean stature was closest to that of other working class contemporaries, but was lowest of all.

Table 5.3 *Comparative male stature estimates from 18th - early 19th century skeletal assemblages in England.*

Sites	Mean male stature (cm)	Male stature range (cm)	Social background	Authors
Combined R.N. assemblages	168	155- 182	working class	This study
Cross Bones burial ground, Southwark, London	169	153- 180	working class	(Brickley et al. 1999)
Baptist burial ground, Kings Lynn	169	153- 181	working class	(Boston 2009)
Baptist burial ground, Poole	169	157- 186	working class	(McKinley 2008)
Quaker burial ground, Kingston-upon-Thames	169	154- 190	middle class	(Bashford and Sibun 2007b)
Quaker burial ground, Kings Lynn	170	160- 179	middle class	(Mahoney-Swales 2009)
Christ Church crypt, Spitalfields, London (femur only)	170	155- 188	middle class	(Molleson et al. 1993)
St Luke's crypt and churchyard, Islington, London	170	155-193	middle and working class	(Boyle et al. 2005)
Newcastle Infirmary burial ground, Newcastle	171	160- 183	working class	(Boulter et al. 1998)
St Martin's churchyard, Birmingham	172	156- 185	mostly working class	(Brickley et al. 2006)
St Peter-le-Bailey churchyard, Oxford	172	161- 186	working class	(Webb 2007)
St George's crypt, Bloomsbury, London (combined femur and tibia only)	172	152- 185	middle class	(Boston et al. 2009)
St Nicholas' crypt, Sevenoaks	173	162- 183	middle class	(Boyle and Keevil 1998)
St Bartholomew's crypt and churchyard, Penn, Wolverhampton	175	145- 185	middle class	(Boyle 2004)

(ii) Skeletal evidence of childhood stress

Several pathological conditions that develop in childhood and adolescence are widely regarded as indicators of physiological stress in the growing years, and by extrapolation, of prevailing adverse socio-economic conditions. These lesions include *cribra orbitalia*, porotic hyperostosis and periostitis (Lewis and Roberts 1997). Childhood deficiency diseases, such as scurvy and rickets, were common in post-medieval Britain, particularly amongst the urban poor (Roberts and Cox 2003), and may also reflect socio-economic hardship. This section briefly discusses the evidence for childhood stress lesions in the R.N. assemblages, and problems in recognition and interpretation of such lesions.

(a) Cribra orbitalia and porotic hyperostosis

Cribra orbitalia and porotic hyperostosis are widely regarded as being indicative of childhood anaemia- traditionally iron deficiency anaemia from dietary deficiency, blood loss from intestinal parasites, haemorrhage or chronic disease, or due to inherited disease, such as thalassaemia (Roberts and Manchester 2005; Stuart-Macadam 1991), but more recently have also been

associated with megaloblastic anaemia from Vitamin B12 and folic acid deficiencies (Walker et al. 2009). Indeed, some researchers (e.g. Ortner 2003) have argued that *cribra orbitalia* and porotic hyperostosis are not characteristic of a specific disease, but are symptoms of several, including rickets, scurvy, osteomyelitis and meningeoma.

Iron is a central component of haemoglobin, the molecule necessary for transportation of oxygen in erythrocytes in the blood. Erythrocytes are produced within the red bone marrow of several bony elements, including the diplőe of the cranial vault. In childhood, the diplőe is particularly important, but becomes a secondary site of erythrocyte production later in life. Low haemoglobin levels in childhood stimulate the diplőe to hypertrophy (Roberts and Manchester 2005). Osteologically, this manifests as thinning and increased porosity of the outer table of the cranial vault and orbits, and cross-sectional thickening of the diplőe (radiographically showing a 'hair-on-end' appearance). These changes are generally restricted to the frontal and anterior parietal bones, and to the roof of the orbits (*Ibid.*).

In the combined R.N. assemblage, orbital lesions were present in 42.33% of all skeletons (Table 5.4), and in 61.06% of skeletons with one or more preserved orbit (Haslar 61.54%; Plymouth 51.81%, and Greenwich 69.77%). Although the prevalence was high, most orbital lesions were slight (Stuart-Macadam (1991) Type 1-2), and were very well-healed, manifesting most commonly as slightly increased micro-porosity, or as vascular channel invaginations in the bone surface of the roofs. Trabecular bone hypertrophy and macro-porosity were only seen in three skeletons with preserved orbits (Stuart-Macadam Type 3).

Bony deposition within the orbits is well recognised feature of subadult (Brickley and Ives 2006; Ortner and Ericksen 1997) and adult scurvy (Geber and Murphy 2012). Indeed, there were very high rates of possible or probable adult scurvy in all three R.N. assemblages, the bulk of which was probably acquired at sea (see Appendix 7 for diagnostic criteria). Macroscopically, distinguishing between increased micro-porosity and vascularity of mild, healed *cribra orbitalia*, and fine, well-

healed, new bone deposition associated with scurvy was highly problematic, and differential diagnosis lies beyond the scope of this study. Probable co-morbidity also complicated diagnosis. What is clear, however, is that no skeletons displayed marked *cribra orbitalia* (Stuart-Macadam 4-5), and milder cases could not be confidently identified as 'classic' *cribra orbitalia* associated with anaemia.

Table 5.4 *Crude prevalence rates (CPR) of pathological lesions associated with deficiency diseases and strenuous physical activity in early life; n= number of lesions.*

	Haslar (N = 49)		**Plymouth (N = 151)**		**Greenwich (N= 100)**		**Combined (N = 300)**	
	n	**CPR**	**n**	**CPR**	**n**	**CPR**	**n**	**CPR**
Orbital lesions	24	48.98	43	28.48	60	60.00	127	42.33
Ectocranial orange-peel porosity	21	42.86	54	35.76	50	50.00	125	41.67
Porotic hyperostosis	3	6.12	3	1.99	8	8.00	14	4.67
Periostitis (single element)	4	8.16	15	9.93	5	5.00	24	8.00
Periostitis(multiple elements)	27	55.10	69	45.70	50	50.00	146	48.67
Rickets	7	14.29	14	9.27	23	23.00	44	14.67
Spondylolysis	3	6.12	7	4.64	6	6.00	16	5.33
Os acromiale	4	8.16	11	7.28	7	7	22	7.33
Osteochondritis dissecans	7	14.29	14	9.27	16	16	37	12.33

One of the most common lesions in the R.N. assemblages was coarse, dense, ectocranial thickening and pitting (resembling the texture of orange peel) (CPR 41.67%), which extended in a broad arch between the temporal lines, from the frontal bone to the nuchal crest (Fig. 5.4). This may be the result of a bony reaction to scorbutic bleeding and pooling beneath the aponeurosis or scalp. This distribution is more extensive than porotic hyperostosis, which usually is restricted to the frontal bone and the anterior aspects of the parietal bones (Roberts and Manchester 2005). The texture and appearance of 'orange-peel porosity' and porotic hyperostosis differs, the latter comprising diplőe thickening, outer table thinning and fine ectocranial foramina (*Ibid.*), whereas 'orange-peel porosity' is coarser and when healed, may appear almost sclerotic. CT-scanning of several Plymouth crania revealed that this orange-peel porosity comprises an additional bony layer overlaying the normal ectocranial surface (Sinnott 2013). This was a very common lesion in the R.N. assemblages (CPR 41.67%) (Table 5.4). The prevalence of orange-peel porosity in skeletons with preserved frontal,

parietal and/or occipital bones was 46.67% in the Haslar (N= 45); 56.84% in the Plymouth (N= 95) and 56.82% in the Greenwich assemblages (N= 88), with a combined assemblage prevalence of 54.82%.

These prevalences were considerably higher than rates for porotic hyperostosis. Only 14 probable cases of porotic hyperostosis (CPR 4.67%) were identified. In skeletons with preserved frontal and parietal bones, rates were 6.12% in the Haslar (N= 49), 3.19% in the Plymouth (N= 94) and 9.09% in the Greenwich assemblages (N= 88), with a combined prevalence of 6.06%. The marked difference between porotic hyperostosis and ectocranial orange-peel porosity prevalences may reflect the different disease processes, which occurred at different times in the



Figure 5.4: *Left: Superior view of the cranium of Plymouth 757, which displayed ectocranial orange-peel porosity on the frontal, parietal and occipital bones, probably associated with scurvy. Note the distinct lateral limit, just within the temporal line. Right: The ectocranial surface of Haslar 324 showing thickening and coarse orange-peel texture of the surface. This individual displayed healing periostitis on multiple elements and endocranial new bone- probable healing scurvy.*

lifecyle (the former being probably due to adult scurvy, whilst the latter, childhood anaemia). However, the layer of new bone over the ectocranial surface in orange-peel porosity may well have overlaid and obscured pre-existing porotic hyperostosis.

(b) Periostitis

Periostitis has also been widely used as an indicator of childhood stress (Lewis and Roberts 1997), and was prolific in the three R.N. assemblages (CPR 8% in skeletons with an isolated element

affected; 48.67% with multiple elements affected). Periostitis is a non-specific inflammatory reaction, and may develop in response to trauma, bleeding, ulceration or infection in close association with, or beneath the periosteum (Adler 2000; Resnick and Niwayama 1995; Weston 2008). Given the high rates of trauma, scurvy, tropical ulcers and other infections in the lowerdeck (Blane 1799; Lind 1753; Lind 1762), a very high periostitis prevalence in the skeletons is not unexpected. In the subadult R.N. skeletons (N= 29), periostitis was active in all but one of the seven cases (CPR 24.14%), with two of these displaying both healed and active lesions. This indicates that most periostitis was recent- probably developing when youngsters were already at sea. Subadult periostitis in the R.N. assemblages was slightly higher than that found in working class children and adolescents in St Martin's churchyard, Birmingham (17.5%) (Brickley et al. 2006). Thus, the high periostitis rate in seaman boys does suggest significant physiological stress, and in the main, this appears to be directly related to their seafaring lifestyle, rather than reflecting earlier insults.

(c) Rickets

Rickets develops in childhood from a deficiency of Vitamin D, principally due to inadequate exposure to ultraviolet rays in sunlight, but has also been associated with a dietary lack of calcium together with genetic, hormonal and other nutritional factors in vulnerable children (Brickley and Ives 2008; Holick 2002; Thacher et al. 2000). In the 17th-19th centuries, rickets was a widespread health problem in the crowded, smoggy cities of industrialising Britain (Steinbock 2003). Its prevalence was particularly high amongst poor urban children, many of whom spent daylight hours labouring indoors in factories and the like. Rickets was identified in the R.N. assemblages primarily from bilateral anterior femoral shaft bowing and medial or lateral bowing of the tibiae and fibulae (using criteria set out by Brickley et al. 2010).

Adolescent rickets was identified in two cases from pronounced anterior angulation of the lower three sacral segments (as described in Aufderheide and Rodriguez-Martin 1998). The crude rickets prevalence in the combined assemblage was 14.67%, with the Greenwich assemblage displaying by



Figure 5.5: *Above: Bilateral lateral femoral shaft bowing of Greenwich 3051 indicative of moderate t marked rickets., Below: Left tibia of Greenwich 3385 showing slight medial bowing of the shaft indicative of slight rickets.*

far the greatest rate (23%). These rates are high compared with the 5-6% CPR for contemporary working class assemblages quoted in Roberts and Cox (2003).

The majority of R.N. cases fell within Brickley *et al.* (2010)'s 'mild' category, and hence, a degree of over-diagnosis or inter-observer error must be considered. Given that sea life was characterised by an outdoor existence, it is unlikely that rickets or osteomalacia developed once children or adults were at sea, although a dietary deficiency of calcium in the naval diet must be considered. Why the Greenwich pensioners should show such a markedly higher rate of lower limb bowing is unclear, but tentatively suggests a more occupationally-related cause. *Genus varus* or bow legs is a recognised condition in modern seamen (Pearce et al. 1996). For example, it was noted in 31% of seamen attending the orthopaedic clinic of the Dreadnought Unit of St Thomas' Hospital, London, between 1989 and 1990 (*Ibid.*). The researchers ascribed this common condition to the effects of the vertical environment and motion of a modern ship and the constrained areas in which seamen worked.

Rather than involving the long bone shafts, however, lateral bowing appeared to be the result of abnormal articulation at the knee joint, with associated joint narrowing, degenerative changes and meniscal damage to the medial compartment. Thus, although the above predisposing occupational factors applied equally to Georgian seamen, lower limb bowing in the two groups are due to very different mechanisms. It is of course possible, but not demonstrated, that the medial bowing so common in the tibiae and fibulae of the Greenwich pensioners was due to buttressing or hypertrophy induced by repetitive activities involving specific muscle groups, and was not rickets at all.

(iii) Strenuous physical activity in childhood and adolescents

In addition to the systemic stresses experience during the growth years, child labour was common in the 18th- and early 19th centuries. The physical effects of strenuous physical workloads on the developing skeleton may manifest in several different bony lesions, including *osteochondritis dissecans*, spondylolysis, Schmorl's nodes and *os acromiale* (Table 5.5- 5.7).

(a) ***Osteochondritis dissecans***

Osteochondritis dissecans develops as the result of repeated micro-trauma or acute trauma to the joint surface following strenuous use of that joint, particularly in childhood and adolescence (Frederico et al. 1990; Smillie 1965; Waldron 2009). It is traditionally associated with convex joint surfaces, most commonly the femoral condyles, but in the R.N. assemblages, several lesions on concave joint surfaces had the appearance of *osteochondritis dissecans,* and were included in this study (Table 5.5). A CPR of 12.33% was present in the combined assemblage. Most commonly affected were the capitulum of the left and right distal humeri (TPR 2.99% and 2.87%, respectively) and the medial condyle of the left distal femur (TPR 2.71%) (Fig. 5.6), followed by the left distal tibia (TPR 1.91%). Given the considerable evidence for ankle trauma, there was surprisingly little talar dome involvement.

Table 5.5 *TPR of osteochondritis dissecans in the skeletal assemblages (n= number of affected elements; N= number of elements observed; d= distal; p= proximal).*

	Haslar			Plymouth			Greenwich			Combined		
Element	**n**	**N**	**TPR**	**n**	**N**	**TPR**	**n**	**N**	**TPR**	**n**	**N**	**TPR**
L humerus (d)	1	23	4.35	4	97	4.12	1	81	1.23	6	201	2.99
R humerus (d)	1	29	3.45	5	103	4.85	0	77	0.00	6	209	2.87
R radius (p)	0	20	0.00	1	91	1.10	0	80	0.00	1	191	0.52
L femur (d)	1	39	2.56	1	90	1.11	4	92	4.35	6	221	2.71
R femur (d)	1	38	2.63	0	94	0.00	0	95	0.00	1	227	0.44
L tibia (p)	0	34	0.00	0	81	0.00	1	91	1.10	1	206	0.49
L tibia (d)	1	30	3.33	1	86	1.16	2	93	2.15	4	209	1.91
R tibia (d)	0	26	0.00	0	85	0.00	3	90	3.33	3	201	1.49
L patella	1	21	4.76	0	72	0.00	1	71	1.41	2	164	0.10
R patella	0	22	0.00	0	72	0.00	1	72	1.39	1	166	0.60
L tarsal	0	199	0.00	0	434	0.00	2	514	0.39	2	1147	0.17
R tarsal	0	183	0.00	2	429	0.47	0	527	0.00	2	1139	0.18
L metatarsal	0	158	0.00	0	359	0.00	1	408	0.25	1	925	0.11
R metatarsal	1	168	0.60	0	356	0.00	0	404	0.00	1	928	0.11
Total	**7**	**990**	**0.71**	**14**	**2449**	**0.57**	**16**	**2695**	**0.59**	**37**	**6134**	**0.60**

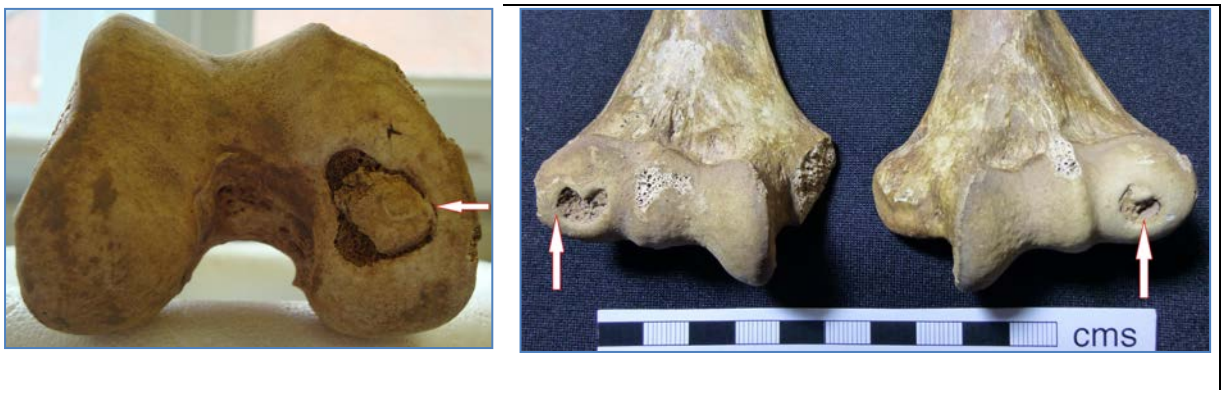


Figure 5.6: *Left: Healed osteochondritis dissecans of the right medial femoral condyle of Haslar 324. This individual also displayed spondylolysis of L5; Right: Healed bilateral osteochondritis dissecans on the capiltulae of the humeri of Plymouth 742.*

Osteochondritis dissecans has been recognised in other maritime assemblages, including the *Mary Rose* (Stirland 2005a) and the *Vasa* (During 1994; During 1997a). Stirland identified eight femoral condylar, unnumbered distal humeral and first metatarsal lesions, whilst one individual from the *Vasa* showed bilateral distal humeral lesions, which During associated with elbow stress induced by

a locked elbow position necessary to operate the whipstaff of the helm. The condition has since been dubbed 'helmsman's elbow' (Capasso et al. 1999).

In an assemblage of 70 male skeletons from a 10th century mass burial pit near Weymouth, Dorset, believed to be executed Viking raiders (Loe et al. 2014), 9.84% of preserved distal humeri displayed *osteochondritis dissecans*, although in this assemblage, rowing and weapon use may have precipitated this lesion as much as steering or sailing. Like the R.N. assemblages, the prevalence of elbow *osteochondritis dissecans* in the Viking raiders was far greater than rates in their knees (2.9%)– in contrast to modern clinical studies in which femoral condylar lesions overwhelmingly predominate (75% of all cases) (Waldron 2009).

(b) **Spondylolysis**

Spondylolysis is another condition that develops in youth, largely as a result of activity-related stress, particularly in flexion and extension of the lumbar spine (Jurmain 1999). Spondylolysis is a cleft defect of the *pars interarticularis* (the segment of bone between the superior and inferior articular facets of the neural arch), resulting in complete or partial separation. This may be bilateral or unilateral. In the overwhelming majority of cases, spondylolysis is located in L5, but examples are known from higher lumbar vertebrae, and occasionally, in the cervical and thoracic spine (Mays 2006; Mays 2007; Merbs 2002). These higher spondylolyses have a greater probability of being congenital, as does anterior slippage of the vertebral body (spondylolisthesis) (Mays 2007).

Most osteological studies agree that spondylolysis is virtual unknown in infants and rare in children, but becomes very much more prevalent in older adolescence and young adulthood. Unlike many other fractures that accumulate with age, spondylolysis rates stabilise, and in some populations even reverse in older age categories (Mays 2006; Merbs 2002). Mays (2006) ascribes this age profile to the changing biomechanical properties of the vertebrae with age. The neural arch does not reach full structural strength until the third decade of life, and is more prone to bending and then fracturing. In

addition, elasticity of the intervertebral discs is greater in younger individuals, allowing greater transmission of shear forces to the intra-articular facet joints. The combination of these properties makes a youthful lumbar vertebra more vulnerable to fracture under stress, particularly when engaged in strenuous physical effort from a standing position with heavy repetitive lumbar spine loading (Mays 2006).

Spondylolysis is occasionally due to acute direct trauma, such as impact from a fall from a height whilst the spine is hyperextended, as occurs when falling backwards (Cope 1988)- a mechanism of injury not improbable in seamen- but most cases are thought to be stress or fatigue fractures associated with strenuous physical activities that involve strain in the lumbosacral region. In Inuit populations, the average crude prevalence of 50% has been attributed to weight-lifting, kayak paddling, wrestling and harpoon throwing in males, and domestic duties, such as food and hide preparation in women, undertaken at ground level whilst bending forwards with the lower limbs straight (Merbs 2002). An inherited component to this prevalence must be considered, however. Indeed, the relationship between possible genetic predisposition and activity remains unclear.



Figure 5.7: *Spondylolysis in L5 of Greenwich 6037*

The Inuit spondylolysis rate is exceedingly high when compared to modern Western populations (5-7%) (Fibiger and Knusel 2005), with the exception of some specialist groups, such as gymnasts, rowers and dancers (Waldron 2009). Sixteen cases (CPR 5.33%) were present in the combined R.N. assemblage (Fig. 5.7, Table 5.4). In other studies of British populations, CPR in adult male skeletons ranged from 3.79% in the Romano-British; 3.64% in Anglo-Saxons; 5.01% in medieval assemblages, to only 1.42% in the post-medieval period (Waldron 1991). It is very uncertain if the small number of selected assemblages is representative of their respective time periods, however. This is most doubtful in the post-medieval period (represented only by the Christ Church Spitalfields crypt assemblage), in which the very low spondylolysis rate probably reflects only a middle-class population not engaged in manual labour, rather than the wider population. Nine cases of spondylolysis were present in the 16th century *Mary Rose* assemblage (Stirland 2005a). No CPR was given, but was either 5% or 10%, depending if only articulated individuals or the complete assemblage was included. Either way, it is very much higher than in Spitalfields. This rate is broadly comparable with the 18th century R.N. assemblage, and with the modern prevalence of 5-6% (Fibiger and Knusel 2005).

(c) Schmorl's nodes

Schmorl's nodes are another vertebral condition thought to develop primarily in youth, and are associated with strenuous activity involving axial loading of the spine in adolescence, when the vertebral end plates of the vertebral bodies are still supple (Resnick and Niwayama 1995). They manifest as depressions in the end plates, and are due to compression of the end plate by herniation of the soft *nucleus pulposa* from the centre of the adjacent intervertebral disc through the *annulus fibrosus* (Faccia and Williams 2008; Resnick and Niwayama 1995). TPR by end plate in the combined assemblage was 18.95% (Table 5.6). These lesions were overwhelmingly located in the lower thoracic and upper lumbar vertebrae. The Schmorl's node TPR was slightly lower than in the Towton soldiers (23.15%) (Coughlan and Holst 2007), but nevertheless was high enough to suggest repetitive

axial loading in many seamen and marines from a young age. Common activities involving axial loading included transferring barrels of water and provisions in and out of the hold during provisioning of the ship and as the need for supplies arose during a voyage (Adkins and Adkins 2008).

Another possible, but unsubstantiated, cause or predisposing factor of Schmorl's node development is scurvy. Spinal involvement, often leading to severe functional impairment, was a feature of scurvy in modern South African Bantu (Seftel et al. 1966), although Schmorl's node development was not specifically investigated. In his *Treatise on the Scurvy*, Lind (1772, 370) quotes the great 17th- century anatomist Thomas Willis, who had observed three or four times in scorbutics:

> *'a crackling of the bones upon moving the joints. Even on turning in bed, by rubbing the bones of the back on each other, a considerable noise was perceived, like the rough handling of a skeleton; which he remarks is an incurable symptom'.*

This crepitus suggests intervertebral disc disease, which might include Schmorl's node development. Aberrant collagen synthesis and osteopaenia in scurvy (Brickley and Ives 2008) may well predispose towards the herniation of intervertebral discs and the development of Schmorl's nodes (McCormick 1954), particularly in physically active individuals, but this hypothesis has not been systematically researched to date. Thus, the high prevalence of Schmorl's nodes in the three R.N. assemblages may indicate youthful loading of the spine, but scorbutic involvement in their development must be considered a possibility too.

Table 5.6 *TPR of Schmorl's nodes (by endplate) in the skeletal assemblages; CV= cervical vertebrae, TV= thoracic vertebrae; LV= lumbar vertebrae; S1= sacral segment 1; n= number of lesions.*

	Haslar			**Plymouth**			**Greenwich**			**Combined**		
	n	**N**	**TPR**	**n**	**N**	**TPR**	**n**	**N**	**TPR**	**n**	**N**	**TPR**
CV	1	397	0.25	2	1054	0.19	4	955	0.42	7	2406	**0.29**
TV	76	235	32.34	596	2004	29.74	526	1635	32.17	1198	3874	**30.92**
LV	32	161	19.88	166	876	18.95	140	675	20.74	338	1712	**19.74**
S1	0	9	0	2	80	2.50	1	77	1.30	3	166	**1.81**
Total	**109**	**802**	**13.59**	**766**	**4014**	**19.08**	**671**	**3342**	**20.08**	**1546**	**8158**	**18.95**

(d) Os acromiale

Os acromiale is a condition in which non-union of the acromial epiphyses persists beyond the age of normal fusion (approximately 21 years (Schaefer et al. 2009)). It is regarded by some as an inherited trait, whilst others believe that the failure of the epiphysis to unite is the result of repetitive overuse of the shoulder, particularly when engaged in overhead arm motions involving abduction and external rotation of the arm (Pecina and Bojanic 1993). Repetitive over-arm activity in the growing years causes laxity of the soft tissue components of the shoulder joint, protecting it from damage during strenuous use. The unfused acromial epiphysis may accommodate a greater range of elevation of the shoulder when the arm is externally rotated to an extreme extent (Knusel 2007).

Overuse from a young age as a result of longbow archery was most famously suggested in the *Mary Rose* assemblage (TPR 12.2%) (Stirland 1987). Similarly, longbow archery and repetitive over-arm actions were suggested as the underlying cause of elevated *os acromiale* rates (TPR 8.6%) in medieval soldiers from the Battle of Towton (1461) (Knusel 2007). The TPR of 10.04% in the combined 18th century R.N. assemblage (Table 5.7), which was slightly lower than in the *Mary Rose* longbowmen, but higher than the Towton soldiers, also showed the slight left-handed dominance of the other groups (Table 5.7). Hauling on ropes, furling sails whilst balancing under the yards, and climbing in the rigging all involved strenuous, loaded, repetitive over-arm actions, and it is thus not surprising that *os acromiale* rates were considerably higher in 18th century seamen than the modern average of 0.05% and 2.7%, cited in Knüsel (2007). This indicates that such activities probably began early in life before the epiphyses had fused.

Table 5.7 *TPR of os acromiale by side in the skeletal assemblages; n = number of lesions observed; N= number of acromia present.*

	Haslar		**Plymouth**		**Greenwich**		**Combined**	
	Left	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
n	2	2	7	4	3	4	12	10
N	10	8	49	57	47	48	106	113
TPR	**20**	**25**	**14.29**	**7.02**	**6.38**	**8.33**	**11.32**	**8.85**

5.3. Historical evidence

5.3.1. Sex

Although a handful of females are recorded as serving as male seamen and marines (e.g. Elizabeth Bowden, Hanna Snell and possibly a William Brown) (Adkins and Adkins 2008), the complete lack of privacy onboard made it highly unlikely that many remained undetected long. Many more went to sea openly as women, but, as they were not regarded as part of the R.N., it is highly unlikely that they were interred in the hospital burial grounds (*Ibid.*). Females documented as being buried here were hospital laundresses and nurses (Haslar Hospital Musters 1792-1824; Newell 1984; Plymouth Hospital Musters 1792-1824).

5.3.2. Age distribution

Sailing a fighting ship was an extremely complex operation, and was dependent on fluid co-ordination of the crew, and the skill and knowledge of individual seamen. A typical seaman of the age had to master several hundred new words describing specific ropes and structures aboard ship, and be so conversant with the many miles of rope rigging that he could unerringly find the right line in the dark, in a storm or in the chaos of battle. He also had to tie at least thirty different types of knots and several splices, understand the complex component operations involved in manoeuvring the ship and in raising anchor, be able to rig all types of tackle, fight with cutlass and firearms, and fire the great guns rapidly and effectively (Lavery 1989). Able seamen were also expected to be competent at steering, heaving the lead, and repairing damaged sail (*Ibid.*). Most able seamen were extremely strong and agile, being capable of running up to 100 feet aloft on ratlines, and out on the yard, balancing on rope harness whilst reefing or furling sails, often in inclement weather and in the dark. Most able were the topmen, mostly young men, who worked high in the rigging. Older and less agile seamen and those with more limited seamanship, worked lower in the rigging or on deck (Adkins and Adkins 2008; Lavery 1989).

Training began early, and children were a general feature of everyday life aboard ship. The Admiralty Regulations stipulated the number of boys of each class to be borne in ships of different size: 13

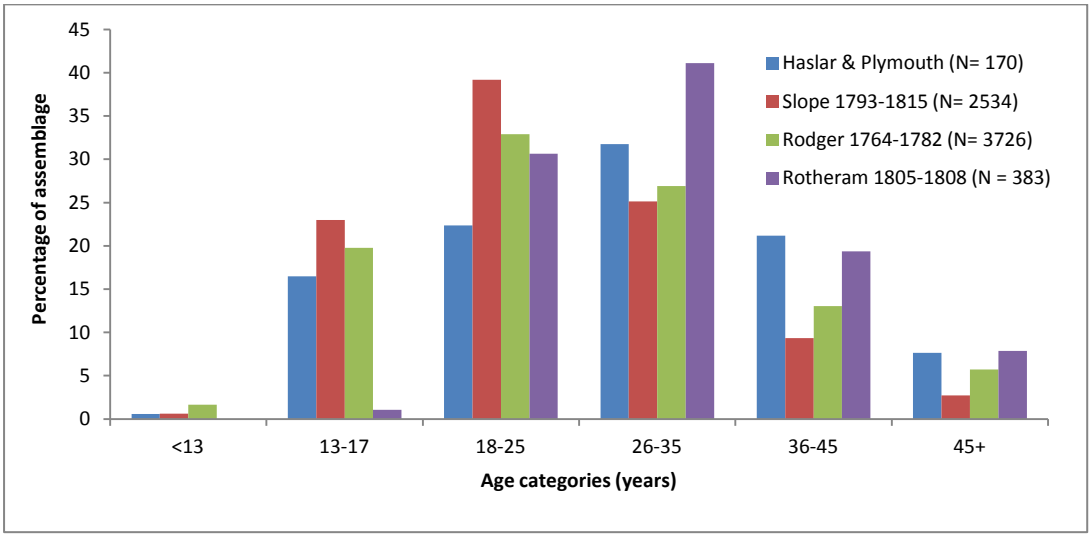
boys second-class (15-17 years) and 19 boys third-class (<15 years) in a first-rate, ten and 14 in a third rate, and six and ten in a frigate (Lavery 1989). Initially, many boys second-class and third- class served as officers' or idlers' servants or apprentices, but increasingly took on seamen's duties with age (Lavery 2004). Although young boys did spend much of the day in play: skylarking in the rigging, playing hide-and-seek on deck, and engaging in often dangerous practical jokes (Rodger 1986), these activities served to familiarise boys with the ship, and built the agility and strength necessary for life as a sailor. Boys messed with adult seamen, each usually under the care of the best seaman of the mess whose task it was to instruct him in such aspects of seamanship as his age allowed (Adkins and Adkins 2008).

'Learning the ropes' took many years and ideally began at a young age so that youthful quickness and strength could be matched by experience and confidence (Rodger 1986). Boys were recruited as young as six years (Rodger 1986). Admiral Collingwood considered the ideal recruitment age to be 14-16 years, however, when boys were strong enough to begin to work hard, but young enough to learn: '*such boys become good seamen: landsmen rarely do for they are confirmed in other habits*' (cited in Lavery 2004, 48). Physician Thomas Trotter (cited in Lincoln 2007, 209) remarked that

> *'The soldier can be perfected in his exercise in a few days, and it little avails what kind of trade he had been employed in: but no person will have the hardihood to contend, that a seaman's duty can be learnt in less than seven years, or after twenty-one years of age. He must be accustomed to it from boyhood; for no adult being can ever be brought to endure the privations, dangers and hardships, which are inseparable from sea-life.'*

Thus, it is not entirely surprising that Rodger (1986) found that in 31 ships during the Seven Years War (1754- 1763), 53% of able seamen and 85% of ordinary seamen were aged 25 years or less.

Figure 5.8 *Age distribution of seamen on active service in the combined Haslar and Plymouth skeletal assemblages, and three historical datasets (Slope(2006), Rodger (1986) and Rotheram (1799-1815)).*



R.N. seamen were 'recruited' from eclectic backgrounds, but, wherever possible, captains took on already experienced seamen '*bred to the sea'* from a young age. Due to the practice of 'turning over' seamen from one ship to the other, average age on first recruitment is impossible to know from ship's musters. However, since the age of each seaman coming aboard was listed, it is possible to construct an age profile of the lowerdeck. Three age profiles from ship's musters are presented in Fig. 5.8. and Table 5.8 (Rodger (1986) for the years 1764-1782; Slope (2006) for 1793-1815, and Rotheram's list (1799-1815) for 1805-1808) and compared with the osteological data from Haslar and Plymouth Hospitals.

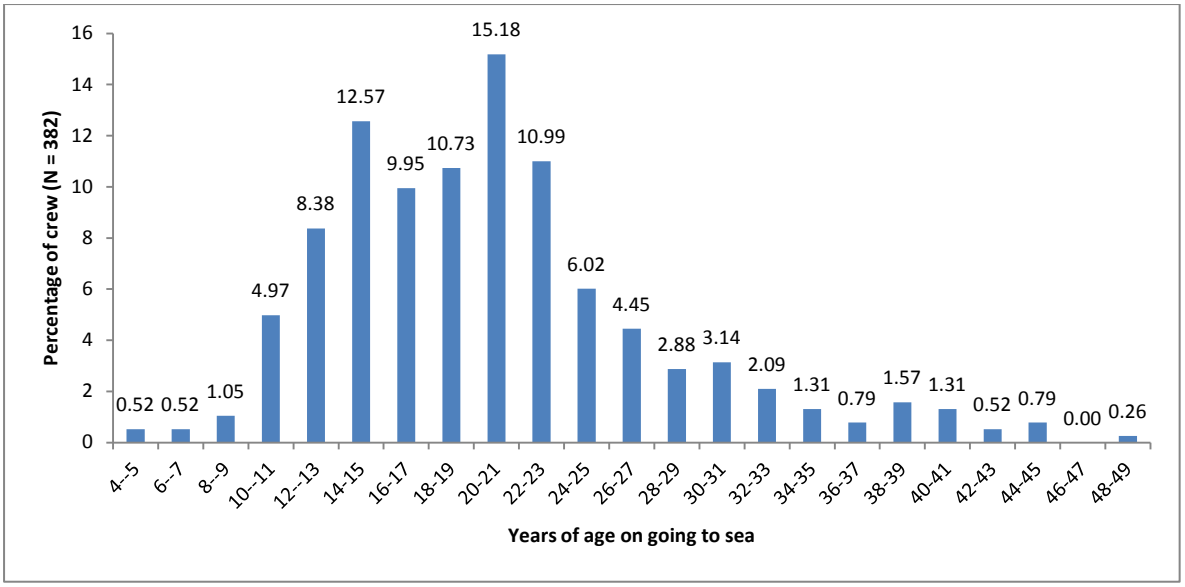
Table 5.8 *Age distribution on active service in the combined Haslar and Plymouth skeletal assemblage and three historical datasets (Slope, Rodger and Rotheram); n= number of individuals, %= percentage of assemblage.*

Age range (years)	**Haslar and Plymouth**		**Slope (1793- 1815)**		**Rodger (1764-1782)**		**Rotheram (1805-1808)**	
	n	**%**	**n**	**%**	**n**	**%**	n	**%**
<13	1	0.6	16	0.6	62	1.66	0	0.00
13-17	28	16.5	582	23.0	736	19.75	4	1.05
18-25	38	22.4	993	39.2	1226	32.90	117	30.63
26-35	54	31.8	637	25.1	1003	26.92	157	41.10
36-45	36	21.2	237	9.4	486	13.04	74	19.37
45+	13	7.6	69	2.7	213	5.72	30	7.85
Totals	**170**	**100.1**	**2534**	**100.0**	**3726**	**99.99**	382	100.00

Slope (2006) and Rodgers' (1986) studies show broadly similar age profiles with a substantial complement of 'boys', a peak in the young adult category, a large component of prime adults and a rapid fall-off in the older age categories. Rotheram's (1799-1815) data is slightly different in having an under-representation of boys (four rather than the 24 stipulated for a third-rater in Admiralty Regulations), a slightly later peak in the prime adult category, and considerably more older seamen. The reason for this older crew profile is unclear, but may reflect an unusual re-manning of the *Bellerophon* following the devastation of the Battle of Trafalgar, in which she lost 27 dead and 123 wounded (Cordingly 2003). It may also reflect the severe shortage of young experienced seamen as the Napoleonic Wars continued, and their replacement with older but unskilled recruits (Adkins and Adkins 2006).

Rotheram's list is exceptional in listing each seaman's age and the number of years he served at sea in the merchant navy and the R.N. From these data it is possible to calculate age at first going to sea, assuming no breaks in service (Fig. 5.9). The youngest was recorded as four years old and the oldest as 48 years. The mean age on going to sea was 20.4 years, with 38% beginning as children or adolescents. The number of years at sea ranged from 0-40 years, with a mean of 7.49 years in the R.N. and 3.18 years in the merchant navy. The high proportion of R.N. to merchant navy years of service reflect the prolonged duration of near-continuous conflict in the Revolutionary and Napoleonic Wars. It probably was not representative of the R.N. in times of peace or during more punctuated conflicts, where proportionally much more time in the merchant navy was probable. Some inaccuracies in seamen's recall are to be expected, particularly if sea service was punctuated by periods on shore. This is the probable explanation in the seaman aged 34 years, who claimed to have spent 30 of them at sea.

Figure 5.9 *Age on going to sea in the seamen of the Bellerophon 1805-1808 (calculated from Rotheram (1799-1815)).*



Marines were also often recruited as 'boys', often as drummers or servants. The officially recommended ratio was one marine boy to every eight men (Donald and Ladd 1982). Minimum age varied but, occasionally, was as low as six years (Blumberg 1979). During the acute manning shortage of 1804, boys were recruited between the ages of 13 and 16 years, or with a minimum height of 5' to 5'2'' (Edwards 2005). The quality of recruits was dependent on national emergency, with taller, more adult recruits preferred in peace-time when the Marine Establishment could afford to be more selective (Blumberg 1979), and over-recruitment of boys and shorter men in a manning crisis. In most marine recruitment posters of the late Georgian period, general health and minimum stature were baseline criteria, rather than age. The age at which a marine was deemed adult (and received full pay and prize money) varied over time. Fifteen year olds were paid a full man's wage for much of the late 18th century (Blumberg 1979), but in 1804, the minimum adult age was set at 17 years (Edwards 2005). Plymouth Hospital burial registers (Stray Park Plymouth Burial Register 1813-1814) record the burial of one marine boy and 12 seamen boys in Stray Park cemetery in those two years.

Older adolescents and young adults were the preferred age of marine recruits, but in times of need the upper age limit was sometimes raised to 30 years (Donald and Ladd 1982). When large numbers of marines were demobilised at the end of the Napoleonic Wars, an age of greater than 40 years was a criterion for discharge, as was being short, infirm or foreign (Blumberg 1979; Donald and Ladd 1982).

Given that the main criteria for admission were long service and severe disability (Newell 1984), it is not unexpected that the Greenwich pensioners were predominantly older adults. A sample of the first 100 entries was taken from Wilcox's (2011) database in the years 1749 (when Goddard's Ground was opened for burial), 1759 and 1763 (the last year recorded in the database) (Tables 5.9 and 5.10). Mean age-on-admission was 62.4 years, 55.2 years and 53.7 years, respectively, with the overwhelming majority admitted when older than 45 years (Figure 5.9).

Table 5.9 *Age distribution of 300 Greenwich pensioners admitted in 1749, 1759 and 1763; calculated from Wilcox (2011); N= number of entries.*

Years of entry	**1749**	**1759**	**1763**	**Combined**	**Combined**
Age category (years)	**N**	**N**	**N**	**Total**	**Percentage**
25-35	1	4	3	8	2.67
36-45	2	6	5	13	4.33
45+	97	90	92	279	93
Total	**100**	**100**	**100**	**300**	**100**

Length of hospital stay varied between one month and 50.7 years (Table 5.10). The mean age-at-death was 71.4 years, 66.1 years and 62.7 years, respectively. The oldest pensioner died aged 112.7 years. Age-at-death in each year was overwhelmingly greater than 45 years (93% of the combined dataset).

Table 5.10 *Age on admission and death, and length of hospital stay in a sample of Greenwich pensioners admitted to the hospital in 1749, 1759 and 1763 (N= 300); calculated from Wilcox (2011).*

Admission year	Mean age on admission (years)	Age range on admission (years)	Length of hospital stay (years)	Range of length of hospital stay (years)	Mean age at death (years)	Age at death range (years)
1749	62.4	29- 80	9.04	0.25- 37.6	71.4	32.8- 106.5
1759	55.2	24-93	10.9	0.08- 50.1	66.1	30- 109.5
1763	53.7	15-70	10.9	0.08- 50.7	62.7	26.7- 112.7

In order to reflect the latter years of Greenwich Hospital, the age-at-death of a sample of 100 Trafalgar veterans who died in the hospital before 1858 was analysed (using Ayshford and Ayshford 2004). In this group, the mean age-at-death was 70.1 years. Thus, although pensioners' mean age-at-death fluctuated over the late Georgian period, no temporal trend was apparent.

Combined length of service in the merchant and R.N.s varied between a few months to greater than 55 years in Greenwich pensioners admitted between 1705 and 1763, with a mean of 19.75 years (Wilcox 2013). This was slightly longer than that of the Trafalgar veteran sample (above), in which sea-service ranged from 3.1 to 42 years, with a mean of 15.7 years (possibly reflecting the greater proportion of non-seamen recruits in this period) (see below).

5.3.3. National origins

'*Place of origin'* entries in ship's musters reveal the very varied geographic origins of R.N. crews. The majority of seamen were English (particularly from coastal counties), followed by Irish, fewer Scots and even fewer Welsh. Often a captain retained a core of followers, which followed him from ship to ship, and many captains preferred those of their native land (Clayton and Craig 2004).

Despite the Admiralty's official prohibition on enlisting foreigners, ship's musters indicate that most R.N. ships carried approximately 10-18% of foreign seamen (Adkins and Adkins 2008; Lavery 1989; Slope 2006). For example, in May 1818, 14% of the *Implacable* were foreign; as was 17% of the crew of the *Warspite* in 1812. Even 8% of the crew of Nelson's flagship the *Victory* at Trafalgar were not British (Lewis 1960b). The *Bellerophon's* crew (1805-1808) comprised English (48%), Irish (24%), Scots (12%), Welsh (7%) and foreigners (8%), including 13 'black' seamen from the West Indies,

Africa and America; white Americans and West Indians; Dutch, Swedes, French, Portuguese, Maltese and Bengali (Cordingly 2003).

Although Americans were theoretically protected from R.N. service, identifying American seamen from Britons was problematic, and many R.N. ships carried a fairly large complement of American seamen, many of whom were illegally impressed. Such impressment was a major source of aggravation between Britain and America, and the seizing of R.N. 'deserters' aboard the USS *Chesapeake* by the *Leopard* on the 22 August 1807 was a significant factor precipitating the War of 1812 (Adkins and Adkins 2006; Rodger 2006).

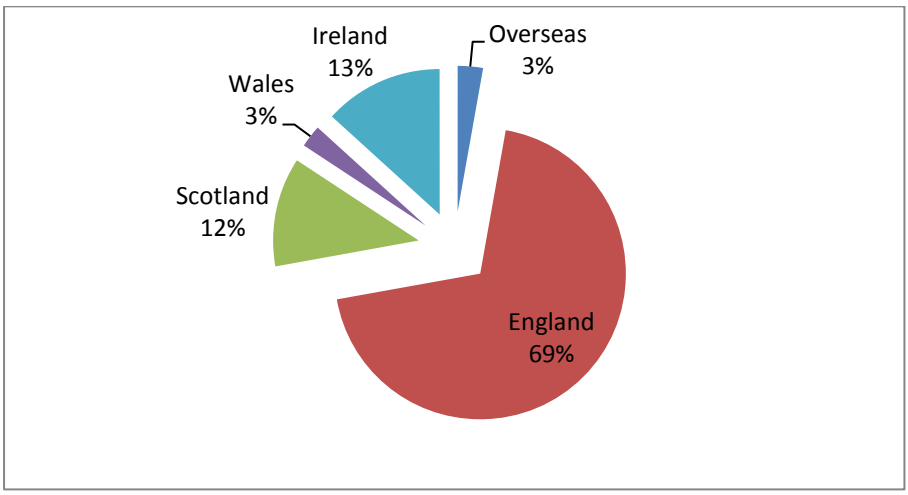
For its time, the Georgian R.N. was remarkably free of institutional racism, offering men of African and Asian descent careers where competence mattered more than colour (Carretta 2003). Most crews included several '*black*' servants and seamen from the West Indies or West Africa, although the term '*black*' was applied widely to non-Europeans. Many were escaped slaves, or were brought on board by their sea officer owners as servants. One such servant was Olaudah Equiano, later a prominent campaigner with Wilberforce for the Abolition of Slavery, who served as a boy aboard the *Roebuck* in 1757 (Equiano 1789). More rarely were seamen from the Indian subcontinent and even the Far East 'recruited', such as the Bengali seaman in the *Bellerophon*. One Greenwich pensioner hailed from Macau (Boston *et al.* 2008).

R.N. 'recruiters' targeted experienced merchant seamen in home ports, many of whom were foreign. Abroad, captains often supplemented their crews with foreign seamen recruited in foreign ports or taken from enemy prizes. A common but unofficial means of obtaining seamen was to commandeer choice seamen from merchant ships at sea. Foreign prisoners-of-war were encouraged to enter the R.N. as an alternative to prison (Adkins and Adkins 2008), and many availed themselves of this opportunity.

In the later Georgian period, the marines very largely comprised Englishmen (75-91%) (Floud et al. 1990). The four main marine headquarters at Chatham, Woolwich, Portsmouth and Plymouth drew in many men from the regional catchment area, and hence, the bulk of marines were from the South and West of England. There was a broadly equal proportion of rural (50.2-58.3%) to urban English recruits (41.6-45.5%), with approximately 10% of the latter hailing from London (*Ibid*). Prohibition against Catholic recruits limited Irish numbers to 4.6-15.6%. The remainder of the corps comprised Scots (2.5-4.8%) and a small proportion of foreigners (*Ibid*.). Foreign nationals included Dutch, Italians, Prussians, Swedes, Danes and even Frenchmen (Donald and Ladd 1982; Edwards 2005). Foreigners (often prisoners-of-war) were frequently recruited in wartime, but were amongst those first to be demobilised when the marine establishment downscaled at the conclusion of a conflict.

The birthplace data on Greenwich in-pensioners in the Wilcox (2011) database sample (Fig. 5.10) indicates that only 3% were foreign: 1.81% Continental European, 0.82% American and 0.16% African. The remainder were overwhelmingly English (69%), Irish (13%), Scottish (12%) and Welsh (3%). The proportion of foreigners was thus much lower in the Greenwich in-pensioner population than in the ship's crews cited above. The obvious explanation is that many foreigners chose to return home after leaving the R.N. rather than to live and die in the hospital. This may also explain the lower proportion of Irish, who could still draw a pension in Ireland. Institutional discrimination

Figure 5.10 *Place of birth of Greenwich in-pensioners in the Wilcox database sample; N = 2,435.*



against foreigners is, of course, possible but, given that it was largely absent afloat, it is unlikely to have been a significant factor.

As Wilcox's database is restricted to hospital admissions between 1705 and 1763, admissions later in the century (e.g. veterans of the Revolutionary and Napoleonic Wars) are not included. Temporal differences between many of the ship's muster rolls cited above, and these earlier in-pensioner population's composition may account for the lower foreign and Irish contingents in the Wilcox sample.

5.3.4. Social origins

R.N. seamen have often been stigmatised in the popular imagination and by some historians as being the 'scum of the earth', the criminal, the desperate and the deprived. Certainly, the Marine Society recruited approximately ten thousand men and boys into the R.N. from the streets of London, and they were often destitute, abandoned children (Floud et al. 1990), but, overall, these comprised only a small proportion of the service (Pietsch 2000). It was not in the interest of the R.N. to recruit the weak, ill or decrepit, and generally such individuals were rejected from receiving ships before joining their ship.

Historical records reveal that most seamen and marines were working class, but there was considerable economic variation within that category, ranging from the homeless and destitute to the modestly comfortable artisan class. Occupations recorded in Rotheram's list indicate that many seamen had been craftsmen before entering the R.N., including several weavers, tailors, house carpenters, shoemakers, cabinet-makers, glassblowers, watchmakers, millers and farmers, as well as tallow chandlers, whitesmiths (tin workers) and miners. There were only 27 unskilled men listed as 'labourers'.

The greatest and most desirable source of 'recruits' were experienced seamen from the merchant navy (Lavery 2010). For example, 45% of the crew of the *Bellerophon* had previously been merchant seamen (Cordingly 2003). There were also several fishermen, lightermen and watermen. Pay in the

merchant navy was generally much better than the R.N., and seamen were not subject to the rigid discipline and punitive punishments of a man-of-war (Lavery 1989), but many merchant seamen fell victim to avaricious financiers, who often grossly under-provisioned and overworked the crew. Living conditions on board were often cramped and filthy. In the slave trade seamen often received worse food and berthing than the valuable slave cargo, and approximately 20% of slavers' crews died from disease in a crossing (Hope 2001). The environmental stress on the growing bodies of many young merchant seamen must have been considerable.

In their detailed analysis of occupational background of the marines, Floud *et. al.* (1990) found a very high proportion of labourers (32-60% of recruits) and textile workers (4.9-15.3%), with a much smaller component of 4.4-6.8% from the building trade, and 0.7-4.6% working with animals. The remainder comprised very small numbers of white collar, commercial and domestic workers.

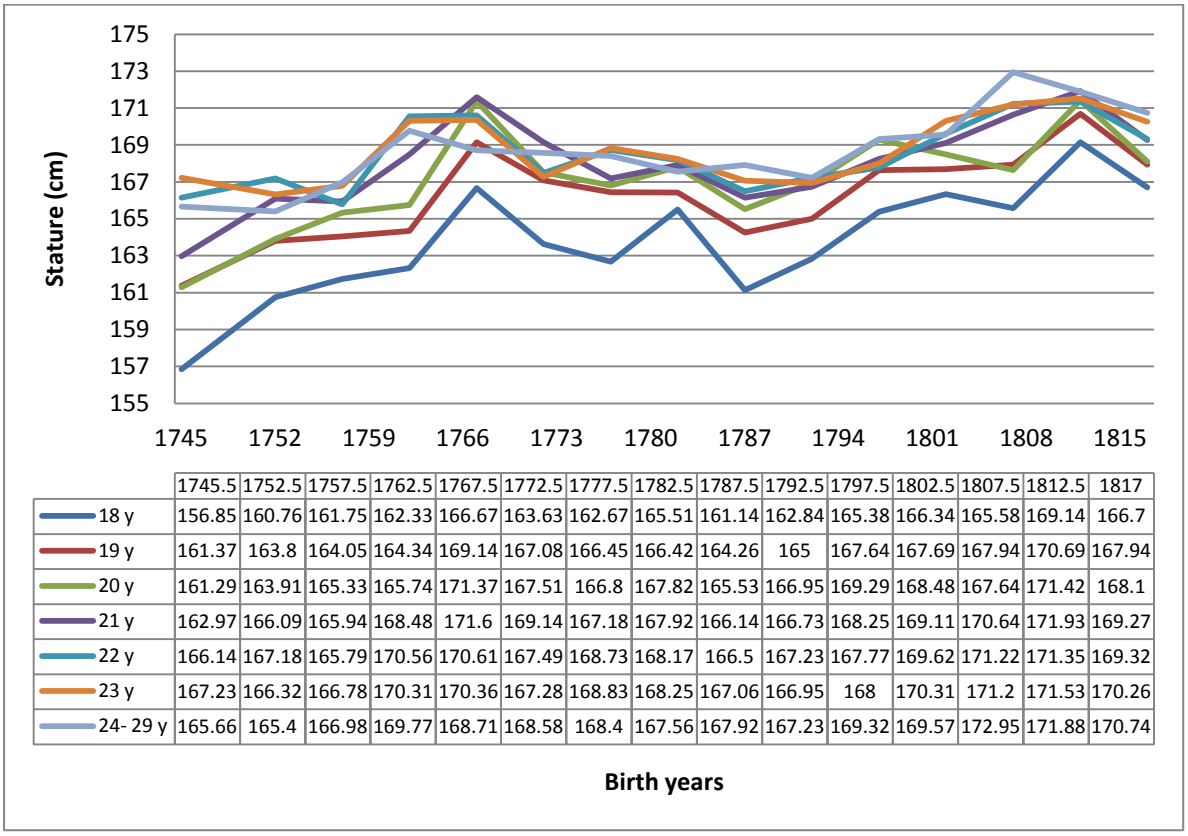
(i) Stature

Marine Description Books routinely record the stature of privates on joining the R.N., which already has been analysed comprehensively (Floud et al. 1990). In contrast, seamen's stature was not routinely recorded in ship's musters, and is far less well understood. Thus, Rotheram's list is particularly valuable in giving the age and stature of the *Bellerophon* seamen.

In their historic analysis of stature in Britain, Floud *et al.* (1990) list the yearly mean stature of marine recruits at ages 18-23 years, and 24-29 years, born between 1747 and 1881. Data contemporary with the three hospital assemblages is presented in Fig. 5.11. There was an overall temporal increase of 5-10 cm in mean height from 1747 to 1817, which is most marked in the youngest two age brackets (156.9cm to 166.7cm, and 161.4cm to 167.9cm). This increase is far from uniform, however, with clear fluctuations over time. There was a marked increase in stature in those born between 1762 and 1767, then a decline by almost 1.5 cm until 1794, when it rose once again in the birth cohorts of 1794 onwards. This may reflect specific temporal episodes of socio-economic stress in the growing years, but equally suggests higher minimum stature requirements for marine

recruitment in times of peace, where the R.N. could afford to be more selective. The latter is highly probable, as these two peaks broadly coincide with the years of peace of 1784-1792 and following the end of the Napoleonic Wars (1815) (if marines were an estimated 20 years of age at recruitment).

Figure 5.11 *Mean marine stature over time, at ages 18- 29 years of age; dates of birth 1745.5- 1817 (data taken from Floud et al. 1990).*



	1745.5	1752.5	1757.5	1762.5	1767.5	1772.5	1777.5	1782.5	1787.5	1792.5	1797.5	1802.5	1807.5	1812.5	1817
18 y	156.85	160.76	161.75	162.33	166.67	163.63	162.67	165.51	161.14	162.84	165.38	166.34	165.58	169.14	166.7
19 y	161.37	163.8	164.05	164.34	169.14	167.08	166.45	166.42	164.26	165	167.64	167.69	167.94	170.69	167.94
20 y	161.29	163.91	165.33	165.74	171.37	167.51	166.8	167.82	165.53	166.95	169.29	168.48	167.64	171.42	168.1
21 y	162.97	166.09	165.94	168.48	171.6	169.14	167.18	167.92	166.14	166.73	168.25	169.11	170.64	171.93	169.27
22 y	166.14	167.18	165.79	170.56	170.61	167.49	168.73	168.17	166.5	167.23	167.77	169.62	171.22	171.35	169.32
23 y	167.23	166.32	166.78	170.31	170.36	167.28	168.83	168.25	167.06	166.95	168	170.31	171.2	171.53	170.26
24- 29 y	165.66	165.4	166.98	169.77	168.71	168.58	168.4	167.56	167.92	167.23	169.32	169.57	172.95	171.88	170.74

Indeed, minimum stature was more often an officially stated marine recruitment criterion than age, but varied over time. For example, in 1773, the height standard was set at 5'4'' (162.6cm), in 1773 at 5'5'' (165.1cm), and in 1793 at 5'6'' (167.6cm) for fully grown men, and in the manning shortages of the Napoleonic wars in 1804 was 5'4'' (162.6cm) (Blumberg 1979; Edwards 2005). In 1761, the diminutive stature of many marines was noted by the enemy, the French at the Battle of Belle Isle referring to the marines as '*le petit grenadiers*' (Smith 1974, 29). In January 1800, Nelson complained about the quality of marines under his command, writing that *'The Marines I believe, will want a very serious inspection: they have no strength and half of them cannot look over the poop hammocks'*

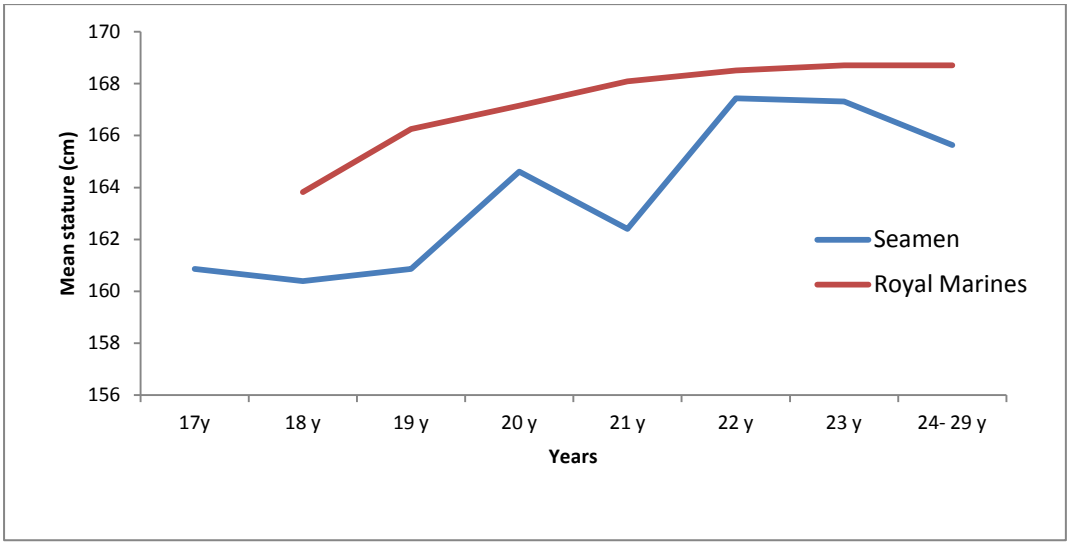
(cited in Edwards 2005, 22). At the conclusion of the Napoleonic Wars, a stature of less than 5' 3½'' (161.3cm) was a criterion for discharge (Donald and Ladd 1982).

Calculations from Floud *et al.*'s (1990) dataset revealed that mean marine stature over the whole time period was 163.8cm (5' 4½'') in 18 year olds; 166.3cm (5' 5½'') in 19 year olds; 167.2cm (5' 5¾'') in 20 year olds; 168.1cm (5' 6'') in 21 year olds; 168.5cm (5' 6⅛'') in 22 year olds, but it then remained static at 168.7cm (5' 6½'') in the 23 year and 24-29 year brackets (Fig. 5.12). Thus, unlike the average cessation of longitudinal growth at 18 years in modern males (Scheuer and Black 1990), the marine recruits continued to grow into their 23rd year. Awareness of delayed growth cessation by marine contemporaries is suggested by the 1793 standard height on recruitment set at

- 5'4'' (162.6cm) for growing lads
- 5'5'' (165.4cm) for men aged 20 to 30 years
- 5'6'' (164.6cm) for men 30-38 years (Donald and Ladd 1982).

Indeed, this would suggest that many potential recruits were still growing beyond 30 years.

Figure 5.12 *Mean stature of seamen and of marine recruits aged 17-29 years; marine data taken from Floud et al. 1990; seamen data calculated from Rotheram (1805-1808).*



Rotheram's list gives a detailed 'snapshot' of growth patterning in 382 seamen aboard the *Bellerophon* (1805-1808). How representative these stature data is of other crews or of seamen in earlier decades is unknown. Unlike marines, minimum stature was not a criterion in the recruitment of seamen. Hence, mean seamen's stature is unlikely to show the same institutionally driven temporal fluctuations. However, land-based seamen recruits would have been vulnerable to similar general socio-economic pressures of the age that afflicted many marine recruits and civilians. The late Georgian English working classes were experiencing considerable social upheaval and hardship in the wake of rapid industrialisation and urbanization of the Industrial Revolution, and rural poverty and dislocation following the Enclosures Acts (1750-1860) (Erickson 1996). In addition to these general social trends, disruptions in trade as a result of the Revolutionary and Napoleonic Wars and several harvest failures resulted in food shortages and rising prices (the worst years being 1795, 1800 and 1812) (Nicholas and Steckel 2009). Thus, young men born after 1780 would have suffered at least one of these 'hunger years' before achieving their final height.

Floud *et. al's* marine dataset numbered 5,000 entries per decade. Rotheram's list of 194 entries, aged 17-29 years, was much smaller. In the latter, no boys below the age of 15 years were listed, and stature in the younger age brackets (17 to 19 years) was restricted to two or three entries each, making the dataset statistically questionable (Table 5.11). As discussed above, this dearth of boys is highly unusual aboard a R.N. ship of this era (Rodger 1986). Nevertheless, stature in the youngest four age brackets are considerably lower than in the 23 year and 24-29 year categories, which suggests continued growth into the 23rd year of life (Fig. 5.12). Unlike the marine growth curve, this was not a smooth trend, however, but fluctuated suddenly downwards in the 21 year age bracket. Again, this anomaly may be the consequence of a small dataset. Final mean stature appeared to have been achieved by 21 years with little difference in values between the 22 and 23 year categories (167.4cm and 167.3cm, respectively). There is, however, an inexplicable drop to 165.6cm in the much larger 24-29 year bracket. This age cohort would have been born between 1785 and 1786, dates that coincide with the temporal dip in stature of the marine recruits (Fig. 5.12) and

hence, may represent very time-specific deleterious socio-economic conditions, which affected growth and final stature of both groups.

The pattern of deferred final stature attainment until 23 years in both seamen and marines concurs closely with British army recruits of this period (Floud et al. 1990), as well as 11,303 English and Irish male convicts transported to Australia between 1817 and 1840 (Nicholas and Steckel 2009). All three groups were drawn from the working classes. Like the marines, mean final stature in Australian convicts aged >24 years fluctuated over time, but overall stature measured 5' 5¾'' (167.cm) in English convicts and 5'6'' (167.7cm) in Irish, with urban populations in both groups being considerably shorter than their rural counterparts (*Ibid.*).

Table 5.11 *Stature measurements of seamen and marines in age brackets 17 to 29 years (marine data taken from Floud et al. (1990); seamen data calculated from Rotheram (1805-1808)).*

Years	Seamen (N)	Seamen (cm)	Marines (cm)
17y	**3**	160.86	-
18 y	**2**	160.40	163.82
19 y	**3**	160.86	166.25
20 y	**9**	164.62	167.15
21 y	**12**	162.41	168.09
22 y	**27**	167.44	168.51
23 y	**25**	167.31	168.71
24-29 y	**113**	165.63	168.71
Total	**194**	**165.66**	**167.32**

What is not immediately apparent is why the mean stature of seamen of the *Bellerophon* in all age categories was lower than that of the marines, with a difference in final mean stature in the 23 year age bracket of 1.4cm, and in the 24-29 years age bracket of more than three cm. This difference could not be tested statistically using a *t*-test, however, as the standard deviation of Floud *et. al.*'s data was unknown. Marines and seamen consumed the same diet and were exposed to the same disease loads, yet a marine's everyday workload (much of it sentry duty) would have been less physically demanding than a seaman's daily activities. However, the seamen's final stature was also slightly lower than male convicts to Australia and British army recruits. The reason for this deficit is difficult to determine. A considerable proportion of seamen joined the R.N. in their growing years,

and should have benefited from the relatively better sanitary conditions and regular and generous rations of carbohydrate and protein (an estimated 5,000 calories-a-day). This intake was far in excess of most contemporary working men (MacDonald 2004). Indeed, as one observer noted

> '*poor boys thin and meagre and helpless coming into the navy who have formerly lived hard... having everything in a plentiful manner at sea they thrive extraordinarily, beyond what one can image, and shoot up to be men on a sudden, after a prodigious manner.'*
>
> (cited in Harland 2005, 68).

The type and amount of work expected of young boys in the R.N. did not appear unduly onerous by the standards of the day, with allowance made for their youth. Admiral Collingwood's statement above would imply, however, that older adolescents were expected to shoulder a full adult workload, which may well have had deleterious effects on their growth and final stature. In addition, exposure to common 'sea diseases' may also have adversely affected growth. Overwork and under-nutrition were common realities for many merchant seamen (Hope 2001; MacDonald 2004), and many were probably of reduced stature as a result. It is also possible in some seamen that extreme deprivation in early childhood before going to sea resulted in such severe stunting that catch-up growth in the R.N and delayed growth cessation could not entirely compensate for those early years. The stature of landsmen coming into the R.N. as physiologically mature adults reflects the social conditions from whence they were drawn.

5.4. Discussion

In this chapter, the biological and social composition of the lowerdeck of the late Georgian R.N. has been explored separately using osteological and historical evidence. This section compares the results from the two datasets, and suggests explanations for any differences.

5.4.1. Age distribution

Historical evidence of the age composition of the lowerdeck in both the Seven Years War (Rodger 1986) and French Revolutionary and Napoleonic Wars (Slope 2006) indicates that by far the greatest proportion of the lowerdeck was aged below 25 years, the peak age being the early 20s. The

Bellerophon seamen in 1805-1808 (Rotheram 1799-1815) showed a slightly older age distribution, one much more similar to the osteological age profile of the combined Haslar and Plymouth skeletal assemblages.

Thus would invite several interpretations and methodological criticisms:

1. The osteological age profile more closely reflects that of the *Bellerophon* because the skeletons chronologically dated to the latter half of the Napoleonic Wars, rather than to earlier time periods when crews were younger.
2. The skeletons represent the biological 'failures'- those who had died in the hospitals. Thus, prime adults were more susceptible to falling ill or getting injured than adolescents and young adults, or died in greater numbers when they did. Young adults either were not admitted to the hospitals in fewer numbers, or better survived their hospital stay.
3. The prime and mature adult patients treated in the hospitals represent better survivors than those youngsters who died at sea, as they had at least survived the voyage to the hospital, even though they died.
4. Osteological age estimation systematically over-aged young adults, and hence they were under-represented, whilst prime adults were over-represented.
5. The skeletal and/or historical assemblages presented here were not representative of the R.N. of the period.
6. Many seamen were illiterate and did not recall their age accurately. Hence, ages recorded in ship's musters and Rotheram's list are inaccurate.

The above hypotheses are now examined in the light of the information that is available.

1. Unfortunately, burials could only be broadly dated to the years that the burial grounds in which they lay were in use. Only one Haslar and one Plymouth skeleton were associated with dateable artefacts, providing *terminus post-quems* of 1793 and 1796, respectively.

2 and 3. The question of survivorship is complex, and there has been insufficient historical research on the age composition of sick and hurt men aboard ship to properly understand the age distribution of those who fell ill and died on board, and those who recovered or were discharged to hospital. The exception is Slope's (2006) study of four frigate crews (1793-1815). He found that the mean on-board mortality of the combined crews over those 22 years was 35%. Adolescents were the least likely (16%) to be medically treated but, when they were, 44% died aboard. Young adults were by far the largest age cohort aboard ship, and comprised 41% of the sick list. They constituted 34% of those who died on board. There were numerically fewer prime adult seamen in the crews, and fewer of these were medically treated (24% of the sick list), and 35% of those treated died aboard. Slope found that proportionally more older crewmen were treated, but had a very much lower mortality of 15%.

Sick and hurt seamen recovered aboard or were invalided out- '*discharged unserviceable'* or were sent to naval hospital ships or hospitals for further treatment. Unfortunately, Slope does not distinguish between these two groups. An average of 28% returned to their ships following treatment, presumably recovered. The highest proportion of those invalided was prime adults (31%), followed by young adults (28%), mature adults (17%), older adults (15%) and adolescents (9%). Interestingly, this general profile more closely reflects the skeletal age distribution from Haslar and Plymouth than it does of the ship's crews in Rodger and Slopes' studies. This tentatively suggests that the age of the combined burial assemblage reflects that of hospital patients, and that each age category had a fairly equal chance of survival once in hospital.

4. Methodological problems of osteological age estimation are well recognised, and mainly constitute under-ageing skeletons in the mature and older age categories (Cox 2000). The use of Bayesian statistics has been used to reduce these methodological problems (Aykroyd et al. 1999), but lies beyond the scope of this study. The under-representation of young adults and over-representation of prime adults in the R.N. assemblages suggests over-ageing of young adults. Given

the pattern of prolonged longitudinal growth in seamen and marine populations evident from historical sources, resulting in delayed epiphyseal fusion until 21-22 years, an over-representation of adolescents and an under-representation of young adults were expected. Instead of this expected, pattern, there was an over-representation of men in the 25-35 year age bracket.

5. Temporal fluctuations in recruitment affected the age composition of ships' companies, particularly at the height of the Napoleonic Wars when the manning crisis was most acute. This may explain the *Bellerophon's* slightly older age distribution. The much larger samples and the long time spans covered by Rodger and Slope's studies, which showed a similar younger age profile, make it more probable that these profiles rather than the *Bellerophon*'s, better represent the age distribution of the long durēe of the late Georgian R.N.

The skeletal assemblages may only be broadly dated to the late Georgian period. The sample size of 170 is generally regarded as statistically valid, but undoubtedly a larger sample would have been preferable.

6. Accurate recall of age in this time period is a common problem encountered by genealogists, where errors of as much as five years are common (Hey 1993). Although individual seamen's age recall may well have been slightly inaccurate, there was no institutional incentive to exaggerate or underplay their true age. It is thus highly improbable that systematic skewing was present in the large historical datasets, and thus individual ageing errors are unlikely to affect the overall pattern.

It is most probable that the disparity in age distribution between Rodger and Slope's ship's crews and the skeletal assemblage is the result of differential survivorship in the different age categories, with a higher proportion of prime adults being invalided and sent to Haslar and Plymouth Hospitals, where they subsequently died, than occurred in the young adult category.

The historical and osteological age-at-death distributions of the Greenwich pensioners generally concur that the majority of pensioners were aged over 45 years when they died. In the historical

assemblage this comprised 93% of the total sample, but in the osteological assemblage only 74.5% of known aged skeletons. The remainder were aged 26-35 years (5.1%) and 36-45 years (20.4%). If the historical age-at-death distribution is assumed to be correct, under-ageing in the 36-45 year category of the skeletal assemblage is apparent. The tendency to under-age skeletons in more mature age brackets is a well recognised methodological problem in osteology (Cox 2000), and appears to be present in this study.

5.4.2. Nationality

Although it is impossible to determine nationality from skeletal remains, 10 individuals in the combined osteological assemblage (3.3%) were identified as having fairly direct sub-Saharan African ancestry. Mongoloid traits were not strongly expressed, and were mixed with Caucasian features, and probably do not indicate a close Far-Eastern or Native American ancestry. The higher incidence of non-Caucasian traits, such as Inca bones, however, does suggest greater gene flow in port towns, whence many seamen originated, than in other British populations (Hanhara and Ishida 2001). The overwhelming majority of skulls showed clear Caucasian, probably European ancestry. Carbon and nitrogen stable isotope analysis of a sample of 50 Haslar and 50 Plymouth Hospital skeletons of this study indicated that most seamen had consumed foodstuffs predominantly obtained from temperate zones, but at least one Caucasian individual and one individual of African descent were identified as having a mixed C3 and C4 diet (Roberts et al. 2012). These values compared closely with east coast colonial American and West Indian slave diets of the time (Pfeiffer and Williamson 1991; Schroeder et al. 2009).

It is well recognised in historical sources, such as ships' musters and illustrations, that 'black' sailors were a regular component of ships' companies. In the *Bellerophon,* 13 seamen were described as having '*negro*' or '*sambo*' complexions (3.4%). Thus, the proportions of African seamen in the *Bellerophon* compared very closely to that of the skeletal assemblages. This suggested that either there was no racial discrimination in obtaining admission to the hospitals, and if correct that the same proportion of 'black' seamen died in the hospitals as European seamen and marines. Given

that 'black' seamen do not appear to be discriminated against in the R.N. on the basis of their colour, equal access to medical treatment is not entirely surprising.

5.4.3. Socio-economic background

The osteological and historical evidence for the socio-economic backgrounds of seamen and marines was investigated using some directly comparable data, such as stature, and other more diverse sources.

(i) Stature

Mean final stature of the skeletal assemblages was calculated as 168.2± 3.94cm (5' 6± 1⅓''). Historical analysis indicates that the mean final stature of marines was 168.7cm (5' 6⅓''), and that of the *Bellerophon* seamen was 165.6cm (5' 5''). In both, the growth period was extended into the 23rd year. Unfortunately, it was archaeologically and osteologically impossible to distinguish between marines and seamen, but, given that marines comprised 15-20% of the lowerdeck, it is assumed that they constitute a similar proportion of the skeletal sample and stature estimates.

The mean osteological stature was slightly higher than historically recorded final statures of both marines and seamen, but fell within the osteological stature range about the mean of ±3.27cm (using maximum femoral length). When stature difference between the two assemblages was tested using the *t*-test, however, they were statistically significantly different (*t*= 5.012, critical value 2.58, p= 0.01). The reason for this difference is unclear, but may lie in measurement errors, or in temporal changes in stature height over the late 18th- to early 19th- century (see above).

The R.N. skeletal assemblages were shorter than 12 other contemporaneous assemblages. This is also true that historically documented stature in seamen compared with other working class groups (Nicholas and Steckel 2009). This difference was less pronounced in marines.

(ii) Indicators of early physiological stress

It is historically accepted that the majority of seamen and marines came from the working classes. Rotherham's list shows that the overwhelming majority of seamen who had not been 'bred to the sea' from childhood were skilled craftsmen. A much higher proportion of marines were listed as labourers.

Childhood health is often used as a proxy for the general health of a population. Unfortunately, due to co-morbidities and subsequent disease processes, probably contracted in sea service (e.g. scurvy and infection), several pathological lesions normally associated with childhood stress could not be equated with childhood stress. Others, such as porotic hyperostosis, may have originally present, but were overlaid by later disease processes (e.g. the ectocranial orange-peel porosity of adult scurvy). Where they were they tended to be mild.

It was not in the R.N.'s interest to recruit physically broken down men, and selection for the young and healthy was a deliberate aim of pressgangs and recruiting officers wherever possible (Adkins and Adkins 2008). Thus, it is not surprising that there were very few osteological examples of severe childhood deprivation in the R.N. skeletons. The exceptions are the severely stunted subadults from Plymouth, who may well have been Marine Society boys, or similarly deprived youngsters.

Sea service generally began young, with 38% of the *Bellerophon* seamen becoming seamen as subadults. This may have been even higher if most crews' age distributions more nearly resembled those of Slope (2006) and Rodger (1986). Thus, it is not surprising that high rates of lesions associated with strenuous activity in childhood and adolescence were present in the skeletal assemblages. More pronounced involvement of the upper limb is consistent with an occupation that involved strenuous repetitive upper limb activities, such as pulling on ropes, handling the sails and the like. Interestingly, youthful flexion-extension loading of the lower spine was not suggested by the low spondylolysis rate, although the relationship of activity patterns with the development of spondylolysis is complicated by probable genetic predisposition or congenital weakness in the

development of this condition (Merbs 2002). Schmorl's node prevalence was high, but conclusions regarding occupational activity patterns must be tempered by consideration of the possible involvement of scurvy in their development and generally contested aetiology for these vertebral end plate lesions.

5.5. Conclusion

Although it was not possible to directly compare data in all sections of this chapter, the overall impression from both the osteological and historical datasets is that the lowerdeck comprised largely young men, who undoubtedly worked at a physically demanding occupation from a young age. Seamen and marines' exposure to marked environmental stressors in the growing years manifests in prolonged longitudinal growth until at least 21-22 years, and despite, this extended growth period, the final stature of seamen was still lower than that of marines and of land-based working class contemporaries.

Osteological interpretation of childhood stress markers was complicated by co-morbidities and subsequent disease processes, but rates of *osteochondritis dissecans* and *os acromiale* do support the historical data that many seamen began their maritime careers in childhood or adolescence. This early exposure to sea-life was essential for seamen to master the complexities of sailing a fighting ship whilst still in their physical prime, and to adapt their minds and bodies to a perilous and demanding existence.

6. Results: trauma

6.1. Introduction

The principal aim of this thesis is to compare osteological trauma patterning with trauma cases recorded in contemporary documentary sources from these hospitals. This chapter presents the data on which these comparisons are based. The results of the osteological analysis of bone trauma in the R.N. skeletons is presented first, and followed by the historical evidence for trauma from the Haslar and Plymouth Hospital Musters and the Entry Books of Greenwich Hospital.

Fracture prevalence and distribution throughout the skeleton is osteologically quantified, and the fracture types described. This is a necessary stage in determining the more common mechanisms of injury and probable aetiology of these fractures, many which probably were incurred at sea. In addition, bony changes consistent with joint trauma (such as dislocation and labral tears) are described. Unless otherwise stated, all photographs in this chapter were taken by the author.

6.2. Osteological evidence of trauma

6.2.1. Trauma prevalence and distribution

The number and range of fracture types in the three R.N. assemblages was considerable. A total of 926 lesions were unambiguously identified as fractures in the combined assemblage, a mean of 3.09 fractures per skeleton and a true prevalence rate (TPR) of 2.92% (Table 6.1). In the Greenwich skeletons, many well-aligned fractures in an advanced stage of remodelling (probably incurred many years or decades before death) were difficult to recognise, even with the aid of radiography. In other cases, fractures were suspected but poor bone preservation or incompleteness prevented a confident diagnosis. Such ambiguous lesions (numbering approximately 80) were not included in the dataset described below. Thus, the numbers given here are a conservative quantification of the fractures present.

Overall fracture numbers differed between the hospitals, with a very high proportion of the fractures (68.35%) identified in the Greenwich assemblage (n= 633), considerably less (25.59%) in the Plymouth (n= 237), and the remainder in the smallest assemblage of Haslar (n= 56). Fractures

per capita numbered 6.33 in the Greenwich pensioners, but were much lower in the Plymouth assemblage (1.57 *per capita*), and even lower in the Haslar assemblage (1.14 fractures *per capita*). Statistically, there was a significant difference between the CPR of fractures in the Greenwich assemblage and that of Haslar (two tailed t-test: t value 7.51, t critical value 2.58, p= 0.01) and Plymouth assemblages (two tailed t-test: t value 5.77, t critical value 2.58, p= 0.01). However, CPRs were not significantly different between CPR of the Haslar and Plymouth assemblages (two tailed t-test: t value 0.97, t critical value 2.58, p= 0.01).

The TPR of all fractures in each of the three assemblages broadly followed the *per capita* pattern, in that the Greenwich assemblage showed by far the highest rate (4.6%), followed by the Plymouth assemblage (1.57%), and then by Haslar (1.03%).

The TPRs indicate that nasal bones were by far the most frequently fractured elements (left 51.38%, right 48.31%), followed by the right ilium (16.25%), the vomer (14.67%), the left ilium (13.93%) and the maxillae (left 10.14%, right 8.78%). Of the major long bones, the highest TPR was in the right tibia (7.69%), followed by left tibia (7.2%), the right fibula (7.31%), the right humerus (6.15%), the left fibula (5.93%), the right ulna (4.15%) and the right radius (3.49%). Least frequently fractured were the right femur (2.06%), and then the left humerus (2.43%), left radius (2.53%), left ulna (2.53%) and left femur (3.29%). There was no significant side dominance in major long bone fractures (56 left, 70 right) (chi-squared=1.34; df=1, critical value 6.63, p= 0.001). Side dominance was more evident in the upper limb bone fractures (18 left, 31 right), but was not statistically significant (chi-squared= 2.93; df=1; critical value 6.63, p= 0.01).

The advanced stage of healing of most fractures, high fracture rate per skeleton, and advanced age of the Greenwich skeletons made it impossible to confidently attribute multiple lesions to a single traumatic incident, as fractures may well have been unrelated, and acquired incrementally over a lifetime. More probable associations between fractures in a skeleton (given probable mechanisms of injury) are described below, but remain largely unsubstantiated.

Table 6.1 *Fractures by element (TPR) in the skeletal assemblages; N= 300 skeletons, n= 926 fractures; L= left; R= right*

	Haslar (n= 56)	Plymouth (n= 237)	Greenwich (n= 633)	Combined (n= 926)			
Elements	**TPR (%)**	**TPR (%)**	**TPR (%)**	**Fractures**	**Total elements**	**TPR (%)**	**CPR (%)**
L temporal	2.44	1.15	3.41	5	216	2.31	1.67
R temporal	0	0	0	0	215	0	0
L parietal	2.22	2.2	5.68	8	224	3.57	2.67
R parietal	0	4.44	4.6	8	220	3.64	2.67
L maxilla	2.5	1.23	22.09	21	207	10.14	7
R maxilla	5.13	1.23	20	18	205	8.8	6
L nasal	15.79	33.33	65.28	56	109	51.38	18.67
R nasal	10.53	38.89	59.26	57	118	48.31	19
L sphenoid	0	0	1.18	1	177	0.56	0.33
R sphenoid	0	0	3.49	3	179	1.68	1
L zygoma	3.23	0	3.66	4	180	2.22	1.33
R zygoma	3.33	0	3.23	4	188	2.13	1.33
Mandible	7.32	1.12	2.3	6	217	2.76	2
Frontal	0	6.52	11.36	16	223	7.17	5.33
Occipital	2.22	1.08	0	2	226	0.88	0.67
Vomer	0	28.57	18.37	11	75	14.67	3.67
Hyoid	4	0	0	1	71	1.41	0.33
Sternum	0	2.56	1.79	3	149	2.01	1
L scapula	5.71	1.88	4.76	8	225	3.56	2.67
R scapula	0	1.86	6.9	8	227	3.52	2.67
L clavicle	0	0.96	8.43	8	222	3.6	2.67
R clavicle	0	1.85	4.82	6	226	2.65	2
L ribs	1.49	1.73	9.6	93	2095	4.44	31
R ribs	1.06	2.55	9.6	107	2108	5.1	35.67
Cervical vertebrae	0.38	0	0.35	3	1420	0.21	1
Thoracic vertebrae	0.25	1.05	1.71	31	2591	1.2	10.2
Lumbar vertebrae	0	0.58	2.3	15	1138	1.32	5
Sacrum	0	0	0.29	1	805	0.12	0.33
Coccyx	0	0	10.53	2	57	3.51	0.67
L ilium	7.32	10.19	20	34	244	13.93	11.33
L ischium	0	0	0	0	224	0	0
L pubis	0	0	0	0	133	0	0
R ilium	9.52	12.75	22	39	240	16.25	13
R ischium	0	0	0	0	220	0	0
R pubis	0	0	0	0	125	0	0
L humerus	0	1.79	4.4	6	247	2.43	2

	Haslar (n= 56)	Plymouth (n= 237)	Greenwich (n= 633)	Combined (n= 926)			
Elements	**TPR (%)**	**TPR (%)**	**TPR (%)**	**Fractures**	**Total elements**	**TPR (%)**	**CPR (%)**
R humerus	4.65	3.67	9.78	15	244	6.15	5
L radius	2.44	0	4.3	6	238	2.53	2
R radius	2.44	1.85	4.4	8	229	3.49	2.67
L ulna	0	0.97	4.3	6	237	2.53	2
R ulna	4.88	1.89	4.26	8	241	4.15	2.67
L carpals	1.8	0	0.5	4	877	0.5	0.67
R carpals	1.6	0	1.3	7	910	0.77	2.33
L metacarpals	3.03	0.97	2.3	21	1121	1.9	7
R metacarpals	0.79	3.63	5.41	38	1295	2.93	12.67
L hand phalanges	0	0.15	0.67	6	1488	0.4	2
R hand phalanges	0.49	0.15	0.31	4	1547	0.26	1.33
L femur	2.38	1.83	5.26	8	243	3.29	2.67
R femur	0	0	5.15	5	243	2.06	1.67
L tibia	4.76	1.98	13.98	17	236	7.2	5.67
R tibia	2.33	5	13.19	18	234	7.69	6
L fibula	0	1.06	11.24	13	219	5.93	4.33
R fibula	0	2.13	15.48	16	219	7.31	5.33
L patella	0	2.78	4.23	5	164	3.05	1.67
R patella	0	2.73	5.56	6	167	3.59	2
L tarsals	0.5	3.46	3.97	36	1137	3.17	12
R tarsals	1.09	3.26	3.42	34	1139	2.99	11.33
L metatarsals	0	1.11	3.92	20	925	2.16	6.67
R metatarsals	0	0.56	1.73	9	928	0.97	3
L foot phalanges	0	1.53	2	12	833	1.44	4
R foot phalanges	0	1.84	2.87	17	827	2.06	5.67
L pedal sesamoid	0	11.11	0	1	36	2.78	0.33
R pedal sesamoid	0	12.5	0	1	34	2.94	0.33
Total	**1.03**	**1.57**	**4.6**	**926**	**31757**	**2.92%**	**3**
Fractures per skeleton							
All elements	**1.14**	**1.57**	**6.33**	**926**			**3.09**

6.2.2. Fracture by body part

In order later to facilitate comparisons between trauma distributions in the osteological and historical datasets, this section describes fractures grouped by body part, dividing the body into the same regions described in the Hospital Musters (Table 6.3). These include head (cranial vault, facial region and mandible), chest (ribs and sternum), back and neck (hyoid and vertebrae), shoulder (proximal humerus, clavicle and scapula), arm (humeral shaft, ulnar and radial shafts and distal epiphyses), elbow (olecranon, distal humerus and radial head and neck), hand (carpals, metacarpals and hand phalanges), hip (ilium, ischium and pubis), thigh (femoral head, neck and shaft), knee (femoral condyles, tibial plateau and patella), leg (tibial and fibular shafts and proximal fibula), ankle (distal tibia and fibula and talar dome), and foot (tarsals, metatarsals, pedal sesamoids and phalanges). There were no wrist injuries listed in the musters, so it is assumed that such injuries were described as arm or hand fractures. Thus, in the sections below, distal radial and ulnar fractures were grouped with arm fractures, whilst carpal fractures were grouped under hand fractures. The skeletal components comprising each body part are presented in the relevant sections below.

Although fractures were distributed diffusely throughout the skeleton, TPRs indicate that certain elements and body areas suffered more skeletal trauma than others (Table 6.2, Figs 6.1 and 6.2). In the combined assemblage, the facial region was most affected (TPR 13.63%), followed by the hip (7.76%), the chest (4.66%), the leg (3.3%) and the ankle (2.8%). Least affected were the back (0.87%), the elbow (1.16%), the hand (1.18%), the arm (1.92%) and the foot (2.23%). Fracture types were also very varied, indicating a wide range of probable mechanisms of injury. These are outlined below.

Table 6.2 *Fractures by body part in the skeletal assemblage; n= number of fractures, N= number of parts of elements present, TPR= true prevalence rate, CPR= crude prevalence rate.*

	Haslar			Plymouth			Greenwich			Combined				
Element	**n**	**N**	**TPR (%)**	**n**	**N**	**TPR (%)**	**n**	**N**	**TPR (%)**	**n**	**N**	**TPR (%)**	**CPR (%)**	**% of all fractures**
head	3	325	0.92	14	657	2.13	26	698	3.72	43	1680	2.56	14.33	4.64
face	13	238	5.46	18	426	4.23	146	635	22.99	177	1299	13.63	59	19.11
chest	7	567	1.23	49	2273	2.16	147	1512	9.72	203	4352	4.66	67.67	21.92
back	3	976	0.31	17	2760	0.62	33	2346	1.41	53	6082	0.87	17.67	5.72
shoulder	3	216	1.39	8	621	1.29	28	498	5.62	39	1335	2.92	13	4.21
arm	4	251	1.59	6	642	0.93	14	356	3.93	24	1249	1.92	8	2.59
elbow	2	156	1.28	4	565	0.71	8	488	1.64	14	1209	1.16	4.67	1.51
hand	10	921	1.09	21	2950	0.71	48	2831	1.7	79	6702	1.18	26.33	8.53
hip	4	196	2.04	25	489	5.11	39	191	20.47	68	876	7.76	22.67	7.34
thigh	1	83	1.2	2	214	0.93	10	192	5.21	13	489	2.66	4.33	1.4
knee	2	184	1.09	5	503	0.99	16	513	3.12	23	1200	1.92	7.67	2.48
leg	1	167	0.6	8	389	2.06	21	352	5.97	30	908	3.3	10	3.24
ankle	0	182	0	6	339	1.77	23	516	4.46	29	1037	2.8	9.67	3.13
foot	3	988	0.3	54	2248	2.31	74	2639	2.8	131	5875	2.23	43.67	14.15
Total	**56**	**5450**	**1.03**	**237**	**15076**	**1.57**	**633**	**13767**	**4.6**	**926**	**34293**	**2.70**		**100**

Figure 6.1 *True prevalence rate in the combined skeletal assemblage (n =926).*

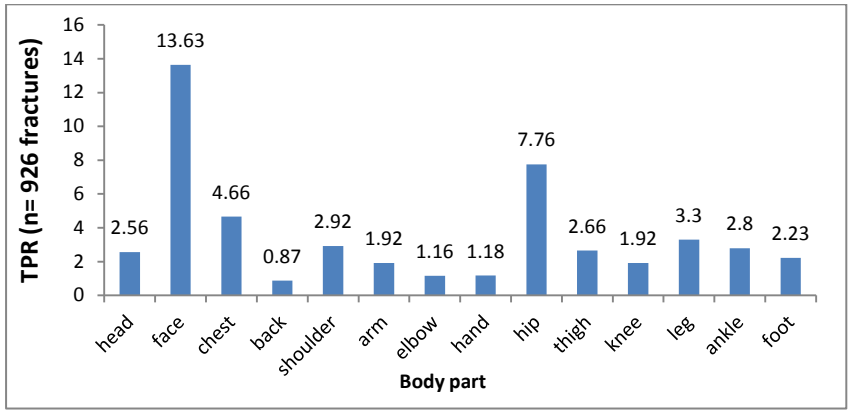
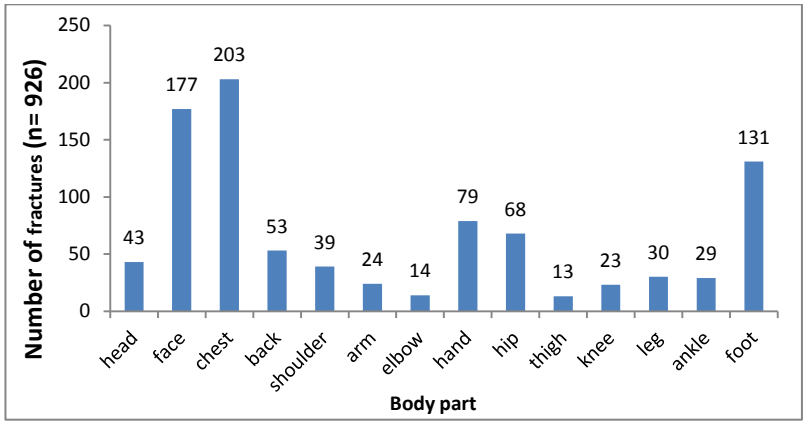


Figure 6.2 *Number of fractures in the combined skeletal assemblage by body part (n = 926).*



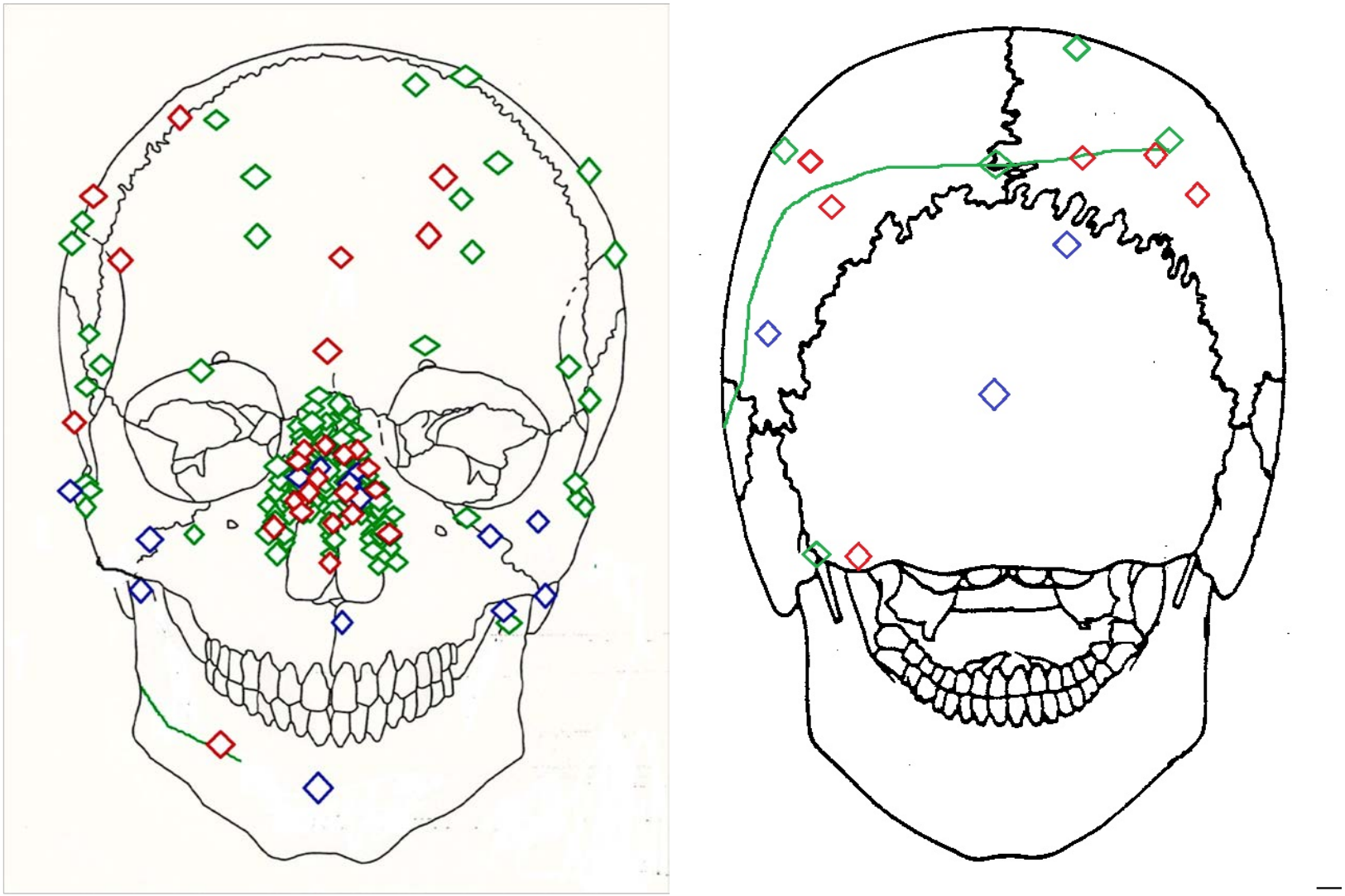


Figure 6.3 *Anterior and posterior views of the skull showing fracture distribution in the skeletal assemblages (Haslar in blue, Plymouth in red, Greenwich in green).*

(i) Cranial vault fractures

Forty-three cranial vault fractures (including frontal, parietal, temporal, occipital and sphenoid bones) were identified in the combined assemblage (TPR 2.56%) (Table 6.3), of which 24 (including frontal and occipital bones) were located on the left, and 19 on the right side. However, this difference was not significance (chi-squared= 0.37; critical value 6.64, p= 0.01). Clear clustering was not identified in any one area of the cranial vault (Fig. 6.3), with the possible exception of the left frontal bone, but this was not convincing.

Table 6.3 *Cranial vault fractures in the skeletal assemblages by element affected, L = left, R = right. TPR is given in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
L temporal	1/ 41 (2.4%)	1/ 87 (1.2%)	3/88 (3.4%)	5/ 216 (2.31%)
R temporal	0/ 42 (0%)	0/ 85 (0%)	0/88 (0%)	0/ 215 (0%)
L parietal	1/ 45 (2.2%)	2/ 91 (2.2%)	5/88 (5.7%)	8/ 224 (3.6%)
R parietal	0/ 43 (0%)	4/ 90 (4.4%)	4 / 87 (4.6%)	8/ 220 (3.6%)
L sphenoid	0/ 36 (0%)	0/ 56 (0%)	1/ 85 (1.2%)	1/ 177 (0.6%)
R sphenoid	0/ 30 (0%)	0/ 63 (0%)	3/ 86 (3.5%)	3/ 179 (1.7%)
Frontal	0/ 43 (0%)	6/ 92 (6.5%)	10/ 88 (11.4%)	16/223 (7.2%)
Occipital	1/ 45 (2.2%)	1/ 93 (1.1%)	0/ 88 0%)	2/ 226 (0.9%)
Total	**3/ 325 (0.92%)**	**14/ 657 (2.1%)**	**26/ 698 (3.7%)**	**43/ 1680 (2.6%)**

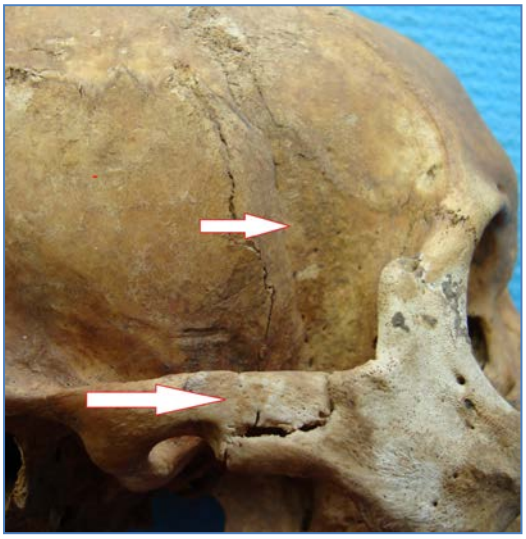


Figure 6.4 *Posterior view of the cranium of Greenwich 3151 showing a depressed cranial fracture of the posterior parietal bones (arrow).*

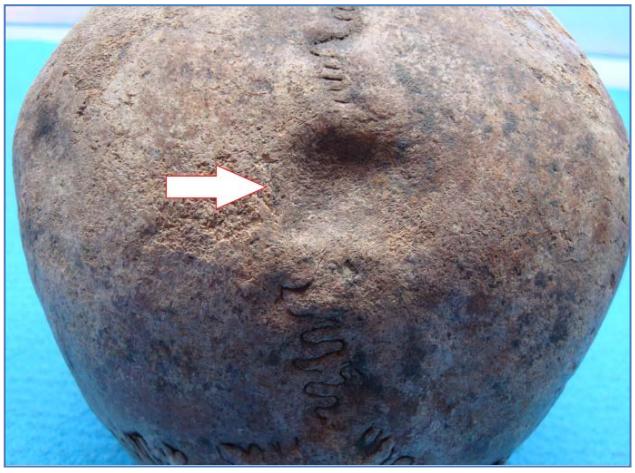


Figure 6.5 *Right lateral view of the cranium of Greenwich 3019 showing well-healed vertical depressed fracture of the greater wing of the sphenoid (smaller arrow) and frontal bone, and a fractured zygomatic arch (larger arrow). This cranium displayed multiple nasal and maxillary fractures*

The vast majority of depressed cranial vault lesions were slight and well-healed, manifested as an ectocranial depression of the outer table and probably the underlying diploë, but did not involve the inner table (Fig. 6.4). Most were circular or round, but one right parietal depressed fracture was linear (suggesting blunt force trauma with an implement such as a length of lead pipe, beam or spar). Three Greenwich crania (3019, 3103 and 3241) displayed a vertically-orientated depressed fracture of the right greater wing of the sphenoid and frontal bone, and associated zygomatic arch fractures (Fig. 6.5), indicative of blunt force trauma to the side of the head and face.

Two full-thickness cranial vault lesions may well have been the result of projectile trauma. The occipital bone of young adult Plymouth 651 was penetrated by a circular hole 7mm in diameter (Fig. 6.6). The shape and dimensions suggest projectile trauma from a pistol ball (British naval issue being a calibre of 6.2mm), although no lead scatter was identified with radiography. Two radiating fractures indicate that considerable kinetic energy was released on impact, as does the bevelling of the inner table.

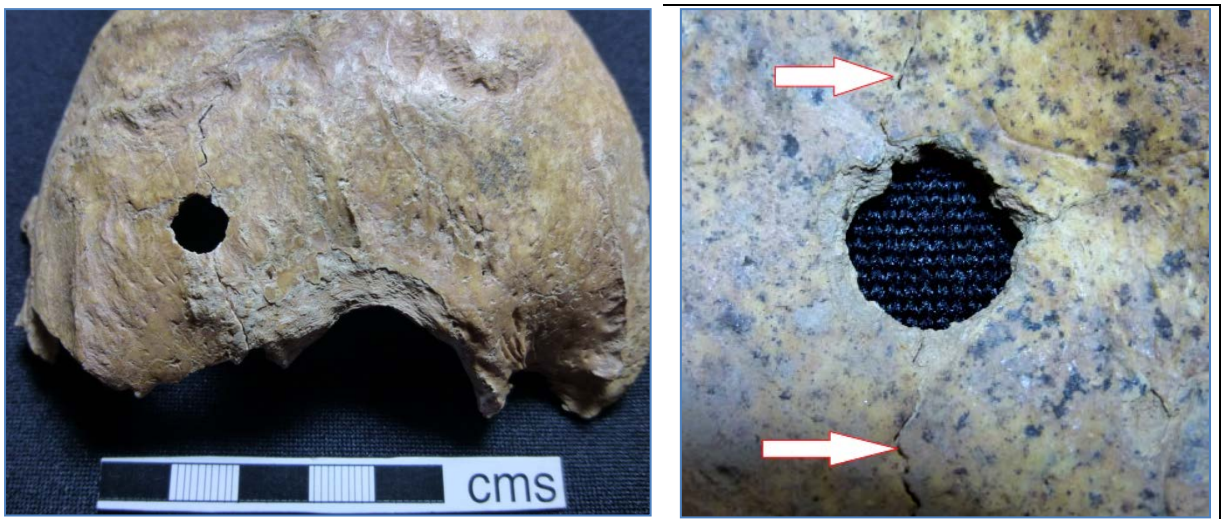


Figure 6.6 *Left: Ectocranial view of probable projectile trauma of the occipital bone of Plymouth 651, with radiating fractures. Right: Endocranial view showing internal bevelling and radiating fractures (arrows).*

The cranium was incomplete, and no exit wound was identified in the surviving bone. The lesion appeared to be perimortem as the edges were sharp, and no remodelling was macroscopically evident. The location so close to the *foramen magnum* indicates that either the shot was directed

upwards from a lower vantage point, or that the victim had his head and neck flexed when he was shot from behind.

The second penetrating injury of the cranial vault was present in the occipital bone of prime adult Haslar 002. The lesion was broadly triangular, with maximum dimensions of 22mm x 21mm (Fig. 6.7). Considerable force on impact is implied by the full-thickness ribbon-like radiating fractures and diastasis of the lambdoid suture.

The implement responsible for the above lesion is problematic to identify, but one possibility is the spiked poll of a boarding axe or tomahawk, which is of appropriate dimensions and has a triangular cross-sectional morphology (Fig. 6.8). Another is an obliquely directed low-velocity projectile, such as spent grapeshot or a musket-ball grazing the back of the head, creating a so-called keyhole fracture. This is supported by unequal bevelling of the inner table, which was pronounced superiorly, but minimal inferiorly (features consistent entry and exit wounds of a keyhole fracture) (Ortner 2008).

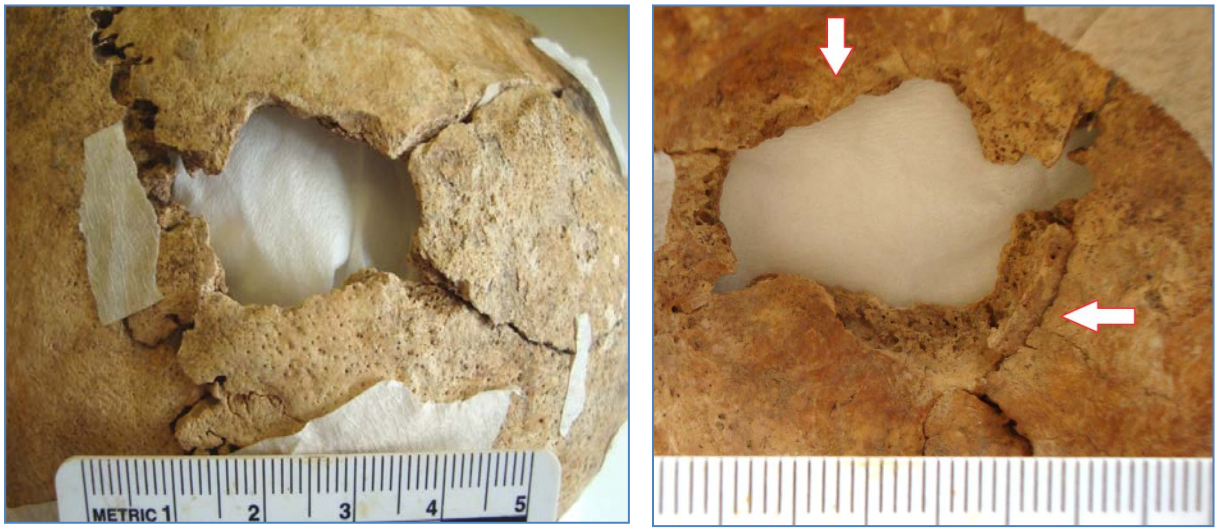


Figure 6.7 *Ectocranial view of penetrating injury of the occipital bone of Haslar 002 with radiating fractures, early healing and possible surgical intervention. Right: Endocranial view of penetrating injury of the occipital bone of Haslar 002, showing internal bevelling (arrows).*

Bevelling of the ectocranial aspect of the lesion is less clear, however, as interpretation is complicated by taphonomic alteration (with the loss of a fragment of the superior margin) and



Figure 6.8 *Late 18th century American Navy tomahawks showing the spiked poll. The French, Spanish and British Navies used similar axes in battle to clear away fallen rigging and, when driven into the wooden sides of an enemy vessel, provided a foothold for boarders. They could also be thrown or wielded. (Photo courtesy of Wolfe 2005, p. 15).*

possible surgical modification of the wound edges (probably bone splinter removal). Thus, the aetiology of this injury remains unclear. Slight smoothing of the wound edges indicated several weeks' healing. There was no exit wound elsewhere in the cranium, nor endocranial new bone deposition to suggest secondary infection or intracranial haemorrhage.

Sharp force trauma of the cranium was limited to two examples (Plymouth 844 and Greenwich 3269). In the former, the anterior aspect of the right parietal bone displayed a short linear straight-edged shallow cut (20.7mm x 9.3mm) into the outer table and diploë, indicative of a superficial slicing blade injury. Smooth wound edges indicated advanced healing.

In Greenwich 3269, a 170mm narrow, linear depression in the outer table, measuring 2-3mm wide, extended in a straight line obliquely across the posterior right parietal bone, across the left posterior parietal bone, and then angled inferiorly, terminating in the squamous part of the left temporal bone (Fig. 6.9). The walls of the lesion were smooth and shallow (*c.* 1-2mm deep), and did not appear to penetrate the diploë. The injury is consistent with well-healed, fairly superficial sharp force trauma, such as a long slash with a thin blade (such as a sword, bayonet or pike) across the



Figure 6.9 *Left lateral view of the cranium of Greenwich 3269 showing the superficial linear sharp force trauma extending across the left parietal and temporal bones (arrow).*

back of the head. The weight of the weapon caused inbending of the outer table and a radiating fracture.

An unusual cranial fracture seen in Greenwich 6151 was the complete, healed fracture of the left styloid process where it joins the petrous bone. Part of the process had been lost port-mortem, and the surviving fragment was 28mm in length. The complete right styloid process was 51mm long. Thus, this individual had Eagle's Syndrome, reportedly a rare condition in which the styloid process is longer than 30mm (Raina et al. 2009). Although the full length of the left styloid process of Greenwich 6151 is unknown, it may well have been of similar length to the right, and this length made it more vulnerable to fracture. Interestingly, eight other skeletons of the combined assemblage had Eagle's Syndrome (15.8% of individuals with surviving processes) (Fig. 4.3, 5.10 and 5.11).



Figure 6.10 *Elongated stolid process of Haslar 007 (arrow) indicative of Eagle's Syndrome.*



Figure 6.11 *Left lateral view of the cranium of Greenwich 3035 showing the elongated styloid process (arrow) of Eagle Syndrome.*

(ii) Facial fractures

The face was the most fractured body region in the combined assemblage- a total of 177 fractures (TPR 13.63%, CPR 59%) (Table 6.4). This high prevalence was largely due to the large number of nasal bone fractures (left 51.38%; right 48.31%), principally in the Greenwich skeletons (left 65.28%; right 59.26%). No significant side dominance was present in either the nasal or maxillary bones (chi-squared (former)= 0.04, (latter)= 0.1, critical value 6.64, p= 0.01).

Most nasal fractures comprised comminution and depression of the distal part, and/or transverse or oblique fractures of the nasal bridge. Both nasal bones were commonly involved in a single individual and, although there was only a slight left-sided numerical dominance, the extent of injury was generally more marked on that side. Seventeen frontal processes of the left maxilla and 16 right processes were associated with nasal fractures, where the force of the blow had

Table 6.4 *Facial fractures in the skeletal assemblages (n= 177); L= left, R= right, TPR are in brackets.*

Face	**Haslar**	**Plymouth**	**Greenwich**	Combined
L maxilla	1/ 40 (2.5%)	1/ 81 (1.2%)	19/ 86 (22.1%)	21/207 (10.1%)
R maxilla	2/ 39 (5.1%)	1/ 81 (1.2%)	15/ 85 (17.7%)	18/ 205 (8.8%)
L nasal	3/ 19 (15.8%)	6/ 18 (33.3%)	47/ 72 (65.3%)	56/ 109 (51.4%)
R nasal	2/ 19 (10.5%)	7/ 18 (38.9%)	48/ 81 (59.3%)	57/ 118 (48.3%)
L zygoma	1/ 31 (3.2%)	0/ 67 (0%)	3/ 83 (3.7%)	4/ 180 (2.2%)
R zygoma	1/ 30 (3.3%)	0/ 65 (0%)	3/ 93 (3.2%)	4/ 188 (2.1%)
Mandible	3/ 41 (7.3%)	1/ 7 (1.1%)	2/ 87 (2.3%)	6/ 217 (2.8%)
Vomer	0/ 19 (0%)	2/ 7 (28.6%)	9/49 (18.4%)	11/ 75 (14.7%)
Total	**13/238 (5.5%)**	**18/ 426 (4.2%)**	**146/ 635 (23%)**	**177/1299 (13.6%)**

extended onto adjoining elements. Like the nasal bones, the extent of injury was more marked on the left maxilla, suggesting the sweep- through of a blow by a right-handed assailant facing the 'victim' (Figs 6.12 and 6.13).



Figure 6.12 *Healed fracture of the frontal process of the left maxilla and comminuted fracture of left nasal bone of Greenwich 3057.*



Figure 6.13 *Healed fracture of the frontal process of the left maxilla and comminuted fracture of left nasal bone of Greenwich 1572.*

Recognition of vomer fractures was complicated by poor bone preservation and obscured views, and was probably much higher than the 11 cases (TPR 14.67%) reported here. This is particularly likely given the extent of deviation of the nasal bridge from the midline in many nasal injures (Figs 6.14 and 6.15).



Figure 6.14 *Gross right deviation of the nasal bridge of Greenwich 3103 associated with healed fractures of the nasal bones and frontal processes of the maxillae.*



Figure 6.15 *Right deviation of the nasal bridge following fractures to both nasal bones, the frontal processes of the maxillae and the vomer of Greenwich 3019-healed.*





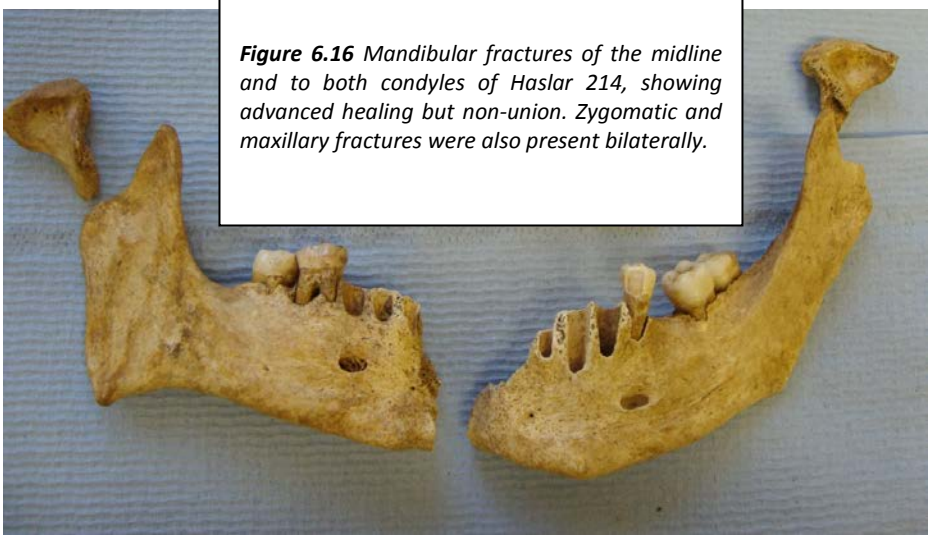


Figure 6.16 *Mandibular fractures of the midline and to both condyles of Haslar 214, showing advanced healing but non-union. Zygomatic and maxillary fractures were also present bilaterally.*

Prime adult Haslar 214 displayed 15 healed but un-united fractures, including multiple facial fractures: of the left and right mandibular condyles, the midline of the maxilla and the mandible (Fig. 6.16), the left and right maxillae close to the zygomatic suture, and between the right malar bone and zygomatic arch, a right crush fracture of the glenoid fossa of the right temporo-mandibular joint and also a fractured hyoid bone. Advanced fracture healing indicates that this individual survived his extensive injuries for months.

A further three mandibular fractures were identified in the combined assemblage (TPR 2.76%): a healing but un-united, osteomyelitic fracture of the right body (Plymouth 633); a healed, united left condylar fracture (Greenwich 3272), and sharp force trauma of the right body and mandibular ramus of older adult Greenwich 3032 (Fig. 6.17). The first two appear to be blunt force trauma, but the last injury was caused by a vertical inferiorly directed blow by a heavy blade (e.g. a cutlass), which severed the right zygoma and incompletely bisected the right mandibular ramus. Loss of molars on that side was probably due to this blow, and the morphology of the left condyle was greatly altered and reduced.



Figure 6.17 *Vertically directed sharp force trauma that penetrated the right mandibular body of Greenwich 3032. Extreme atrophy of the right ramus and condyle are present. Insert: Mandibular lesion showing the longitudinal cut-mark, loss of the gonial angle, ante-mortem tooth loss, advanced healing and abscess formation.*

A small puncture wound of the left maxilla of mature adult Greenwich 3272 was unusual in displaying evidence of active healing, the lesion being surrounded by a halo of grey woven bone on both the anterior and posterior aspects (Fig. 6.18). The wound edges were still sharp, indicating that healing was not advanced at the time of death. The small dimensions and broadly triangular shape is consistent with a puncture wound with a pointed object, such as the tip of a knife. Active healing makes it probable that the injury occurred after leaving the R.N., probably whilst an in-pensioner of Greenwich Hospital.



Figure 6.18 *Puncture wound of left maxilla of Greenwich 3272 (arrow) showing minimal remodelling. The lesion is surrounded by grey new bone.*

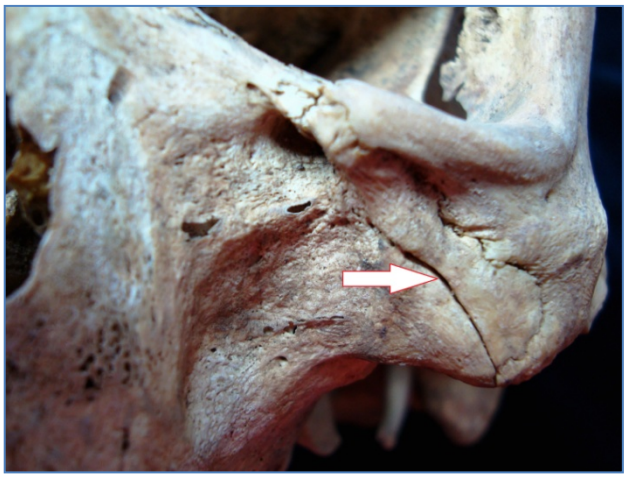


Figure 6.19 *Healed linear fracture of the left maxilla of Greenwich 3103 (arrow).*

The anterior blow to the left maxilla of Greenwich 3103 resulted in a full-thickness fracture that separated the infero-lateral floor of the orbit and the zygoma from the rest of the orbital structures, also fracturing more laterally on the zygomatic arch, and superiorly at the zygomatico-frontal suture (Fig. 6.17). Damage to, or even loss of the eye, was highly likely. The straightness of the maxillary fracture makes it probable that the blow was made by a heavy blade, but the other parts had broken under referred force. This individual displayed several blunt force fractures of the upper face (Fig. 6.14).

(iii) Chest fractures

Chest fractures in the combined assemblage comprised three sternal body fractures (TPR 2.0%), 93 left rib and 107 right rib fractures (TPR left 4.4%, right 5.1%) (Table 6.5). Side dominance in rib fractures was not statistically significant (chi-squared= 0.85; critical value 6.64, p= 0.01).

Table 6.5 *Sternal and rib fractures in the skeletal assemblages, L= left, R = right, TPR is presented in brackets.*

Chest	Haslar	Plymouth	Greenwich	Combined
Sternum	0/ 15 (0%)	2/ 78 (2.6%)	1/ 56 (1.8%)	3/ 149 (2.0%)
L ribs	4/268 (1.5%)	19/ 1098 (1.7%)	70/ 729 (9.6%)	93/ 2095 (4.4%)
R ribs	3/284 (1.1%)	28/ 1097 (2.6%)	76/ 727 (10.5%)	107/ 2108 (5.1%)
Total	**7/ 567 (1.2%)**	**49/ 2273 (2.2%)**	**146/ 1456 (10%)**	**203/ 4352 (4.7%)**

In Plymouth 757, the right inferior margin of the sternal body had been lost to penetrating trauma (probably by the sharp point of a small blade or a splinter), which had removed a small area of the margin. Smooth dense new bone along the wound edge and on the posterior aspect of the body indicated advanced remodelling (Fig. 6.20).

The anterior aspect of the lowest sternal segment of Plymouth 909 displayed a shallow linear lesion, which penetrated the cortical bone to the depth of 1-2 mm (Fig. 6.21). It extended obliquely in a supero-medial direction from the left lateral margin, terminating in a point 14mm from the margin. The straight near-vertical medial edge and more oblique straight lateral edge support the interpretation of sharp force trauma, that was probably directed from below and to the side, in the case of an up-thrust knife stroke that grazed the sternum and then was retracted. Healing was advanced.



Figure 6.20 *Posterior aspect of the sternal body of Plymouth 757 showing a sharp force traumatic lesion (arrow).*



Figure 6.21 *Sharp force trauma to anterior aspect of the sternal body of Plymouth 909 (arrow).*

A well-healed transverse fracture of the sternum of Greenwich 3269 was evident from smooth callus formation on the visceral surface of the first sternal segment. The anterior aspect was too poorly preserved to observe the fracture. There was no displacement of the fractured segments. This was probably blunt force trauma, such as a direct anterior blow to the chest.

Rib fractures constituted 22% of all fractures in the combined assemblage (n= 200). The number of rib fractures per skeleton ranged between 0 and 15 (Greenwich 3241). In many cases, multiple fractures on adjacent ribs were vertically aligned suggesting that a single traumatic episode was responsible for multiple fractures. This was particularly apparent in posteriorly located fractures, suggesting that the individual had suffered a direct posterior blow.

The vast majority of rib fractures were transverse, which had united without marked mal-alignment. A left 12th rib fracture in Greenwich 3229 was an exception, in that healing was still active at the time of death, and union of the fractured segments had not been achieved. This older adult male also displayed *spina bifida occulta*, and the incomplete left neural arch of the first sacral segment had been completely fractured. It too showed active new bone remodelling and non-union, and it is probably that this sacral injury was caused by the same posterior blow that caused the rib fracture.

Due to post-mortem fragmentation and incompleteness, it was impossible to determine the precise location of fractures on many of the ribs, or indeed to identify which ribs were affected. Fracture location on the rib could be identified in 95 cases in the combined assemblage (47.5% of all rib fractures). Anteriorly located rib fractures comprise 20% (n = 19), whilst 30.5% (n = 29) were laterally located (at the angle of the rib) and 49.5% (n= 47) were posterior. The last affected predominantly in the mid- to lower thoracic ribs, probably due to the protective effect of the overlying scapulae on more superior ribs. Anteriorly and laterally located fractures show a more varied distribution with greater numbers in the mid- to upper thoracic rib cage.

(iv) Back and neck trauma

Fifty-three neck and back fractures were present in the combined assemblage (TPR 0.9%) These numbers did not include the 16 spondylolysis cases described in Chapter 5, nor seven vertebral bodies that had collapsed as a result of spinal tuberculosis (Pott's spine) in Greenwich 3098. These exclusions were made as this study specifically explores evidence for trauma rather than pathologically induced fractures (in the case of the Pott's spine). Although trauma has been implicated in the development of spondylolysis, the influence of a congenital or inherited predisposition (Fibiger and Knusel 2005) has precluded it from being included in the fracture rates below.

Table 6.6 *Back and neck fractures of a total number of elements present in the three skeletal assemblages; TPR is presented in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
Cervical vertebrae	1/265 (0.4%)	0/ 584 (0%)	2/ 571 (0.4%)	3/1420 (0.2%)
Thoracic vertebrae	1/404 (0.3%)	14/ 1243 (1.1%)	16/ 944 (1.7%)	31/ 2591 (1.2%)
Lumbar vertebrae	0/175 (0%)	3/520 (0.6%)	12/ 520 (2.3%)	15/ 1138 (1.3%)
Sacrum	0/ 94 (0%)	0/ 371 (0%)	1/ 340 (0.3%)	1/ 805 (0.1%)
Coccyx	0/13 (0%)	0/ 25 (0%)	2/ 19 (10.5%)	2/ 57 (3.5%)
Hyoid	1/ 25 (4%)	0/ 17 (0%)	0/ 29 (0%)	1/ 71 (1.4%)
Total	**6/ 976 (0.6%)**	**23/ 2760 (0.8%)**	**24/ 2346 (1%)**	**53/ 6082 (0.9%)**

Fractures that were included in this study comprised three cervical fractures (TPR 0.2%), 31 thoracic vertebral fractures (TPR 1.2%), 15 lumbar fractures (TPR 1.3%), one sacral fracture (0.1%), two coccygeal fractures (3.5%) and one hyoid fracture (1.4%) (Table 6.6).

Two of the cervical vertebral fractures involved the neural arches of cervical vertebrae 3 and 4 (C3 and C4) (Greenwich 3243). The third was a crush injury to the spinous process of C7 (Haslar 114), which suggested a direct posterior blow to the process.

There were 31 thoracic vertebral fractures: eight located in the upper six thoracic vertebrae (T1-6), and 23 in the lower six (T7-12). In the former, two involved the vertebral bodies) and six, the spinous processes. Two healed united 'clay-shoveller's' fractures of T1 were present (HAS 219 and Greenwich 3098) (Fig. 6.22). Clay shoveller's fractures of the spinous process of C7 and T1 are avulsion fractures from repeated contraction of the *Rhomboid* and *Trapezius* muscles (such as during prolonged shovelling) (Knusel et al. 1996), or acutely through sudden hyperflexion or hyper-extension of the neck on impact in high energy trauma (Zmurko et al. 2003).

The remaining spinous process fractures were healed transverse fractures of T3, 4 and 6. Like the many posterior rib fractures of these R.N. assemblages, these were probably the result of a direct posterior blow to the posterior chest region. T1 of Greenwich 3144 (Fig. 6.23) displayed a fracture crossing the body on all aspects, effectively demarcating the anterior third from the rest of the body. The fracture was incomplete, however. This fracture is characteristic of a hyperflexion avulsion fracture (Maat 2000), but may also be avulsion during retraction of the scapula, and contraction of the M. Rhomboid major (Knusel et al. 1996).

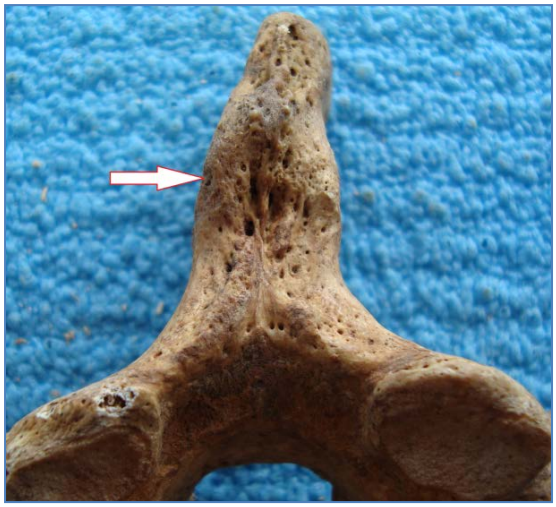


Figure 6.22 *Inferior aspect of the spinous process of T1 of Greenwich 3098 showing the well-healed united fracture of the spinous process (arrow).*

Lower thoracic vertebral fractures (T7-12) comprised 23 body fractures. Vertical crush fractures were present in 11 vertebral bodies, including five adjacent bodies of Plymouth 674, which had ankylosed. Anterior wedging of the bodies was present in 12 fractures, resulting in slight to severe kyphoses. The most marked kyphosis was present in the vertebral column of Greenwich 3241, in which anterior wedge fractures of T8, T12 and L1, and burst fractures with vertical crushing of L3 and L5, were present (Fig. 6.23). This older adult skeleton displayed 43 fractures- many consistent with a fall onto an outstretched lower limb. Such burst fractures occur when the force on

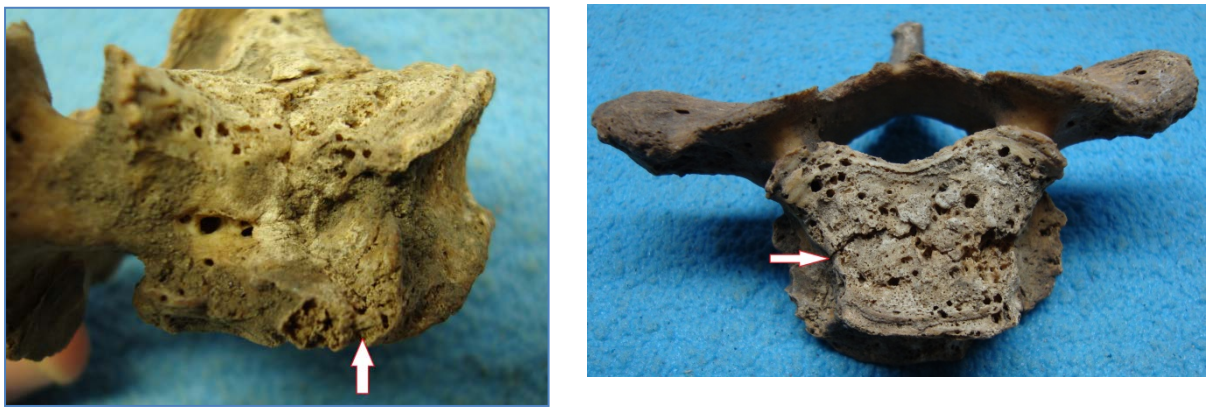


Figure 6.23 *Left: Right lateral view of the body of T1 of Greenwich 3144 showing the healed fracture line (arrow) crossing the vertical height of the body; Right: Fracture crossing the superior end plate (arrow).*

impact transfers through the lower limbs and pelves to the vertebrae (Scalea et al. 1986). Similarly, in Greenwich 3208, crush fractures of the calcanei, distal tibiae and fibulae (probably a feet-first

landing) were associated with a crush fracture of L1 with marked anterior wedging (Fig. 6.24), and possible fracturing of T12.



Figure 6.24 *Inferior end plate of L1 of Greenwich 3208 showing a burst fracture. Marginal osteophyosis of the anterior margin had developed in response to marked wedging of the body.*

In Greenwich 910, there was spondylolysis of L3, but also a neural arch fracture (not spondylolysis) of L5. Similarly, in Greenwich 6094 L4 showed spondylolysis, but L3 and L5 showed fractured neural arches, but not at the *pars interarticularis* as is characteristic of spondylolysis (Mays 2006; Mays 2007; Merbs 2002). One cleft first sacral segment was fractured (Greenwich 3229, described above). Two coccygeal fractures were recognised not by ankylosis, but by mal-alignment with the fifth sacral segment (Greenwich 3105 and 3202).

The only hyoid bone fracture was present in Haslar 214, and was probably fractured at the same time that this individual fractured so many facial and limb bones. One of the horns of this element had been completely fractured and remained ununited. Hyoid fractures are strongly suggestive of strangulation (Ubelaker 1997), but have also been associated with high level falls, with neck muscle bleeds and hyoid bone fractures found in 33% of falls from more than 10 m in one modern study (Turk and Tsokos 2004).

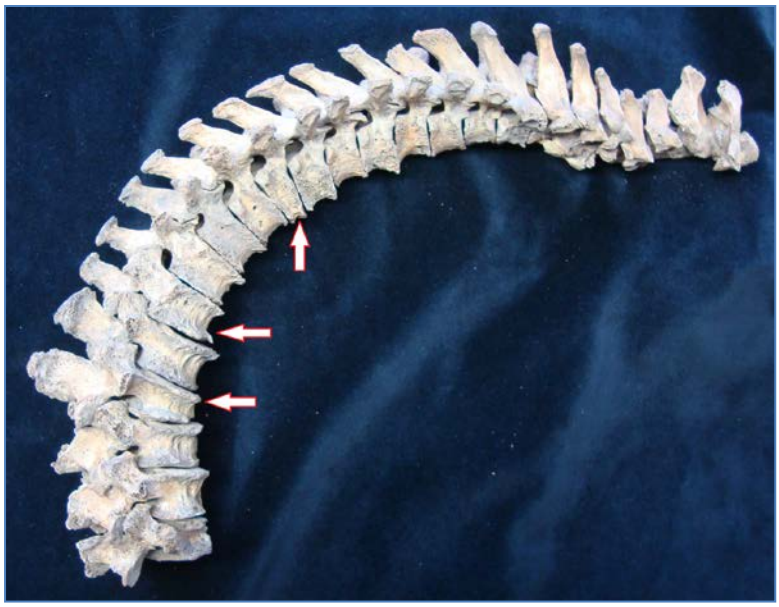




Figure 6.25 Left: *Marked kyphosis of the vertebral column of Greenwich 3241, due to anterior wedging of the vertebral bodies of T8, T12 and L2 (arrows).*
Below: L3 and 5 of Greenwich 3241 showing burst fractures and vertical crushing (arrows).

(v) Shoulder trauma

The shoulder joint is a shallow, unstable joint and is particularly vulnerable to injury through rotator cuff muscle tearing, fracture and/or dislocation. Thirty-nine fractures affected the shoulder joint in the combined assemblage (TPR 12.33%) (Table 6.7): 16 scapular (TPR left 3.56%, right 3.52%), 14 clavicular (TPR left 3.6%, right 2.65%) and nine proximal humeral fractures (TPR left 0.94%, right 3.17%). A total of 18 left and 21 right shoulder fractures were present. However, side dominance was not significant (chi-squared= 0.10, critical value 6.64, p= 0 0.01).

These fractures involved subluxation and superior impingement in nine cases (Table 6.8), and there were two luxations of the glenohumeral joint. Marked rotator cuff muscle enthesopathies on the greater and lesser tubercles of the humeri were almost always associated with bony shoulder trauma, but quantification lies beyond the scope of this study. Similarly, costoclavicular syndesmoses of the medial clavicle were very common.

Table 6.7 *Fractures of the shoulder region in the skeletal assemblages; L= left, R = right. TPR is given in brackets.*

Elements	HAS	Plym	KWK	Combined
L scapula	2/ 35 (5.7%)	2/ 106 (1.9%)	4/ 84 (4..8%)	8/ 225 (3.6%)
R scapula	0/ 33 (0%)	2/ 107 (1.9%)	6/ 87 (6.9%)	8/227 (3.5%)
L clavicle	0/ 35 (0%)	1/ 104 (1%)	7/83 (8.4%)	8/222 (3.6%)
R clavicle	0/ 35 (0%)	2/ 108 (1.9%)	4/ 83 (4.8%)	6/226 (2.7%)
L humerus proximal	0/ 38 (0%)	0/ 96 (0%)	2/ 80 (2.5%)	2/214 (0.9%)
R humerus proximal	1/ 40 (2.5%)	1/ 100 (1%)	5/81 (6.2%)	7/227 (3.2%)
Total	**3/ 216 (1.4%)**	**8/621 (1.3%)**	**28/ 498 (5.6%)**	**39/1335 (2.9%)**

Chronic anterior luxation of the glenohumeral joint was present in Greenwich 3159 (Figs 6.26 and 6.27). The proximal humerus had been anteriorly dislocated and driven between the ribcage and the scapula, fracturing right ribs 2 to 4. The humeral neck and tubercles were severely crushed and malformed. Unfortunately, much of the head had suffered taphonomic destruction. Considerable remodelling made fracture interpretation problematic, and radiology revealed only extensive crushing and remodelling. A large vertical spur of ossified soft tissue (probably *myostosis ossificans traumatica* of the *M. biceps brachii*) stabilized the new joint anteriorly (Fig. 6.26). Bony remodelling to accommodate altered articulation of the new joint surface was present on the coranoid process and the anatomical neck of the humerus. A concave pseudo-joint surface had developed on the anterior neck of the scapula, which articulated with the displaced humeral head (Fig. 6.27). The right acromium displayed *os acromiale* with extensive remodelling of the epiphyseal surface. It is uncertain if the aetiology was developmental or traumatic, but it was certainly unilateral. The mechanism of shoulder injury was probably an indirect high-energy impact, such as a lateral or backwards fall onto the abducted upper limb (Norris 1992). The extent of the remodelling and lack of disuse atrophy indicates that this older adult continued to use his right arm ‘after a fashion’.



Figure 6.26 *Right proximal humerus of luxated shoulder joint of Greenwich 3159 showing fractured tubercles and new joint surface, myostosis ossificans traumatica (arrow), which formed anterior margin of a pseudoarticulation with the scapular neck.*



Figure 6.27 *Anterior aspect of right scapula of Greenwich 3159 showing the pseudoarticular surface (arrow) on the scapular neck (anterior luxation).*

Plymouth 661 also showed multiple right shoulder fractures and anterior dislocation, including an impacted humeral head, in which antero-posterior crushing had resulted in a flattened fusiform shape (Fig. 6.29). Extensive bony rugosity and porosity of the tubercles indicated extensive rotator cuff damage, and a possible Hill-Sachs lesion was present. The anterior margin of the glenoid cavity had been lost, and a new articular surface had formed on the anterior neck (Fig. 6.28). This surface was continuous with, but obliquely angled to the original glenoid joint surface. A vertical line of eburnation on this surface corresponded with a similar band of eburnation on the flattened humeral head. Bony extension of the humeral joint surface was present superiorly, indicated abnormal superior articulation, possibly with the coracoid process (although this had not survived). The humeral joint surface also showed extensive marginal osteophytosis. The right scapular spine had been fractured (a healed fully united transverse fracture), suggesting that a direct posterior blow was responsible for the shoulder trauma, rather than being an indirect abduction injury. There was no macroscopic disuse atrophy of the upper limb.



Figure 6.28 *Anterior aspect of the right scapula of Plymouth 661 with anterior dislocation and eburnation (horizontal arrow), and a transverse fracture of the acromial process (vertical arrow).*



Figure 6.29 *Antero-posterior compression of right humeral head of Plymouth 661, showing flattening and eburnation (arrow).*

Hill-Sachs lesions of the proximal humeral head and neck and Bankart's fractures of the antero-inferior margin of the glenoid cavity are pathognomonic of anterior shoulder dislocation, and are usually the only osteological evidence for acute subluxation (Rockwood and Wilth 1996). Glenoid cavity fractures are almost always due to the impact of the humeral head, most commonly of the antero-inferior margin (a Bankart fracture) (Kirtland et al. 1988; Petrovecki et al. 2008). Due to complex anatomy of the shoulder joint, fractures of these parts often result in muscle tearing and shoulder dislocation. Avulsion fractures of the labrum also occasionally occur (*Ibid.*), and are osteologically visible if paralabral cysts develop (see below).

Hill-Sachs lesions were present on the posterior aspect of the left proximal humerus of Greenwich 3253, the right humerus of Greenwich 3628, and probably Plymouth 661 (indicative of an anterior dislocation). Greenwich 3148 displayed a reverse Hill-Sachs on the anterior humeral neck, indicative of acute posterior subluxation (Fig. 6.30) (Miles 2000). Greenwich 3628 and probably also Plymouth 661 displayed both a Hill-Sach's and Bankart's fracture, but a Bankart's fracture was noted without an obvious Hill-Sachs lesion in Greenwich 3268 (Fig. 6.31). The presence is likely in Greenwich 3162,

where a large extension of the joint surface beyond the normal antero-inferior margin was presumably the result of localised marginal damage.

Chronic superior subluxation, or more correctly, humeral impingement, was identified in five Greenwich skeletons: four right and one left-sided. These changes were bilateral in Greenwich 3253. Abnormal articulation of the superior aspect of the humeral head with the inferior surface of the acromium (Fig. 6.32) was identified by large sclerotic, sometimes eburnated articular surfaces on both elements. Marked rotator cuff damage was present in all cases.



Figure 6.30 *Reverse Hill-Sachs lesion on the left proximal humerus of Greenwich 3148 (arrow). The flattened smooth area immediately anterior to the lesion indicates chronic subluxation or impingement.*



Figure 6.31 *Bankart's fracture of the anterior glenoid rim of the left scapula of Greenwich 3268.*

Table 6.8. *Summary of shoulder luxations and subluxations in the combined assemblage (n = 11); L = left; R = right; MC= metacarpal.*

Skeleton	Type of dislocation	Hill-Sach's lesion	Bankart's fracture	Scapular neck articular surface	Acromial articular facet	Humeral articular facet	Eburnation	Rotator cuff entheseophytes	Other associated trauma
Greenwich 3103	R superior impingement	-	-	-	R	R	R glenoid margin	marked	Para-labral cysts; L clavicle fracture
Greenwich 3106	R superior impingement	-	-	-	R	R	R greater tubercle, R acromion	marked	Nil
Greenwich 3148	L posterior subluxation	L	-	-	not preserved	L	-	marked	Nil
Greenwich 3159	R anterior luxation	-	-	R anterior	-	-	-	marked	R greater & lesser tubercles & head fractures; R acromial fracture; *myostosis ossificans traumatica* of possibly *of M. bicep brachii*; R rib 2-5 fractures; : R clavicular fracture
Greenwich 3162	R anterior/ inferior subluxation	-	probable R	-	-	not preserved	greater tubercle	marked	R para-labral cyst; glenoid *osteochondritis dissecans*; R ulnar styloid fracture
Greenwich 3211	L anterior subluxation	L	-	-	not preserved	-	-	marked	L scapular body fracture
Greenwich 3218	R anterior subluxation	R	-	-	-	-	-	marked	Granular bony deposits on R glenoid joint surface- possible haemarthrosis; R *os acromiale*; possible scapular body fracture
Greenwich 3253	L & R superior impingement	L	-	-	L & R	L & R	L & R acromial process; L & R tubercles porous & sclerotic	marked	nil
Greenwich 3268	R anterior subluxation & superior impingement	-	R	-	R	R	-	marked	L Colles' fracture & L MC5 fracture; L & R acromio-clavicular joints osteoarthritis
Greenwich 3628	R anterior subluxation	R	R	-	-	uncertain	-	marked	R clavicle possible fracture
Plymouth 661	R anterior luxation	Probable R	probable R	R anterior	-	-	R humeral head & glenoid cavity	marked	R acromial fracture

Soft-tissue damage of the labrum of the right shoulder joint is suggested by the presence of at least three large smooth-walled cyst-like lesions on the inferior joint surface and posterior margin of the glenoid cavity of Greenwich 3103 (Fig. 6.33), and a single, less convincing cyst on the posterior margin of the right glenoid cavity of Greenwich 3162. Differential diagnosis of other pathological conditions causing marginal smooth-walled lytic lesions was made (e.g. tuberculosis and gout) but this is an unusual location for such conditions, and there was no evidence of these diseases elsewhere on the two skeletons. Similar lesions were present in the joint surface margins and juxta-articular region of the acetabula (discussed below).

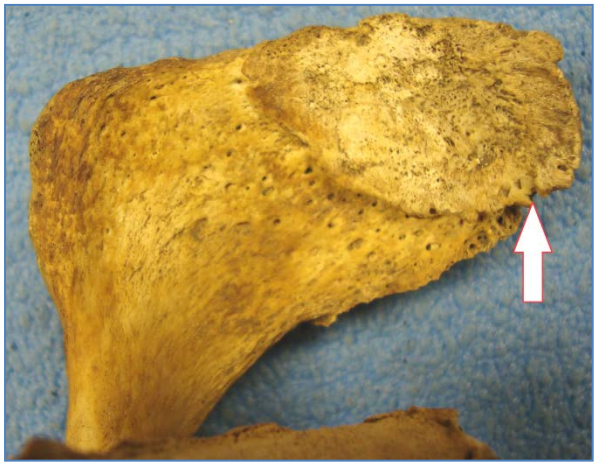


Figure 6.32 *Inferior aspect of the right acromium of Greenwich 3253 showing the large sclerotic articular surface (arrow) indicative of superior humeral impingement.*

There were seven fractures of the scapular body, including both crush fractures to its lateral margin and blade, and two healed penetrating injuries of the left scapular blades (Plymouth 906 and 910) (Fig. 6.34). A healed fracture of the lateral margin of the left scapular body of Greenwich 3241 just inferior to the neck was present, whilst irregular crushing of the blade was present in Haslar 221, Plymouth 661, Greenwich 3101 and 3211. The latter was probably due to direct impact.

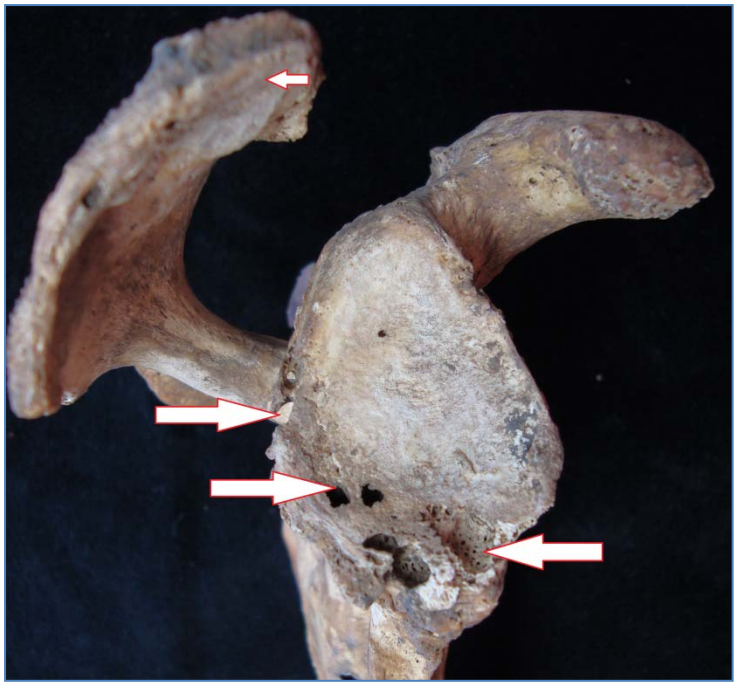


Figure 6.33 *Right scapula of Greenwich 3103 showing multiple probable para-labral cysts in the glenoid joint surface and margin (large arrows) and a large acromial articular surface associated with superior impingement of the humeral head (small arrow).*

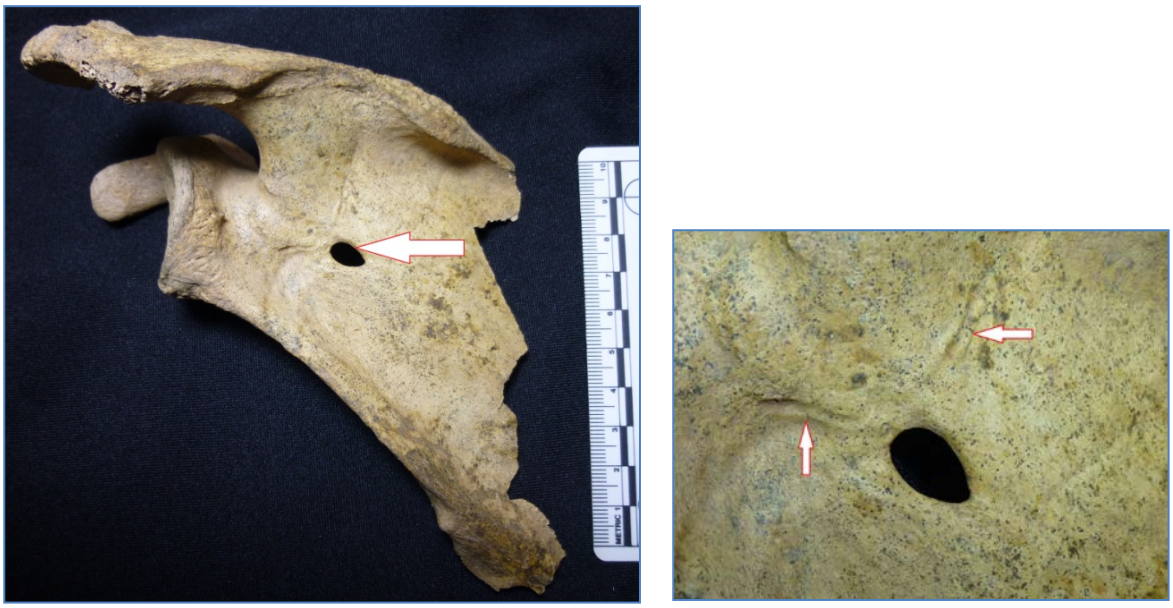


Figure 6.34 *Left: Well-healed penetrating trauma of the left scapular body of Plymouth 910 (arrow). Right: Close-up of the same lesions showing well-healed fracture lines radiating from the injury (arrows).*

Although the smooth margins of the penetrating lesions in Plymouth 906 and 910 might argue for a developmental anomaly (e.g. when soft tissue becomes trapped in the developing blade), rather than a traumatic lesion, the associated evidence for slight crushing and new bone deposition, favours the latter interpretation (Fig. 6.34, inset). 'Weapons' causing these injuries would probably have had a narrow pointed tip, such as a knife, pike or woody splinter.

Greenwich 3421 has a well-healed, well aligned fracture of the surgical neck of the right proximal humerus. This individual also displayed right clavicular, Colles' and ulnar styloid fractures, suggesting indirect trauma from a fall onto an outstretched hand.

A very different injury to the proximal humerus of Haslar 009 was sharp force trauma, manifesting as a straight-sided wedge-shaped lesion (21mm x 10mm maximum x 14mm deep), extending from the lesser tubercle into the head and proximal joint surface (Fig. 6.35). A heavy blade, such as a sword or even a cleaver or tomahawk, might have inflicted such a blow. Brown discolouration and inward folding of the cortex of the posterior wound margin suggests trauma to 'green' bone. The lack of macroscopic evidence for healing indicates perimortem trauma. Unfortunately, taphonomic processes had destroyed much of the anterior wound margin. The only other pathological lesions seen on the skeleton were widespread active periostitis, the distribution of which was typical of scurvy (see Appendix 7).

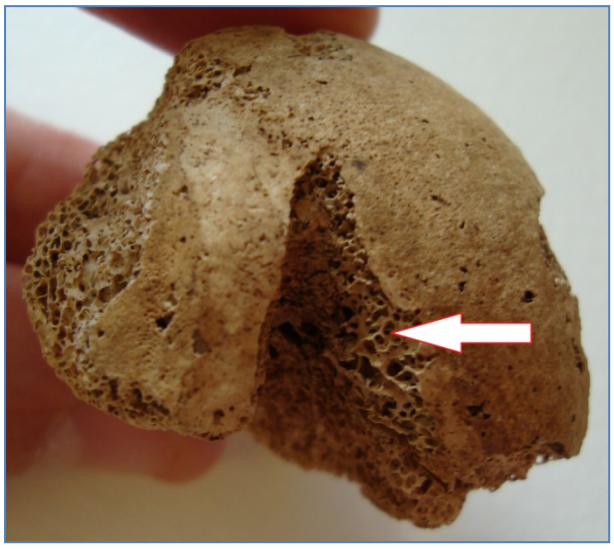


Figure 6.35 *Wedge-shaped sharp force trauma of the right humeral head and neck of Haslar 009 (arrow). Post-mortem damage is apparent on the anterior margin of the lesion (arrow).*

Eight left and six right clavicular fractures were present in the combined assemblage (TPR left 3.6%, right 2.65%). Most lesions were located in the lateral half of the element, close to or beyond the conoid tubercle. Mal-alignment was common, but union had occurred in all but one case. This exception, the left clavicle of Greenwich 6103, had been fractured 85-90mm from the sternal end

(Fig. 6.36). There was non-union of the fractured parts, with extensive bony deposition and some sclerosis along the fracture line of the proximal fragment to suggest a pseudoarthrosis. Unfortunately, the corresponding fractured laterall surface was too damaged to be certain. Abnormal flattening of the lateral clavicle and extensive osteophytosis and eburnation of the acromioclavicular joint suggests an abnormal acromioclavicular articulation, but the lack of disuse atrophy in the left upper limb indicates that the individual continued to use the damaged shoulder and arm. The underlying first rib was also fractured, but had united and was well-healed at the time of death.



Figure 6.36 *Left clavicle of Greenwich 6103 showing non-union and remodelling of the fractured bone with possible pseudarthrosis. Bony changes to the lateral joint surface (to the right of the photograph) suggests acromioclavicular dislocation.*

(vi) Arm fractures

Although the hospital musters distinguished between the thigh and the lower leg, no such distinction was made between the upper arm and forearm. Hence, 'arm fractures' in this group included those affecting the humerus, radius and ulna. Twenty-four arm fractures (TPR 1.92%) were present in the combined assemblage, including six humeral shaft fractures, two radial shaft fractures, nine distal radial fractures, one ulnar shaft fracture, and six ulnar styloid fractures (Table 6.9). There were 17 right and seven left fractures, but side dominance was not statistically significant (chi-squared= 3.38; critical value 6.64, p= 0.01).

Table 6.9. *Fracture prevalence in arm bones of the three assemblages and combined assemblage; TPR for each part of an element is given in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
L humerus shaft	0/ 44 (0%)	1/ 112 (0.9%)	0/91 (0%)	1/ 247 (0.4%)
R humerus shaft	1/ 43 (2.3%)	2/ 109 (1.8%)	2/92 (2.2%)	5/ 244 (2.1%)
L radius shaft	1/ 41 (2.4%)	0/ 104 (0%)	1/93 (1.1%)	2/ 238 (0.8%)
L radius distal	0/21 (0%)	0/ 82 (0%)	3/79 (3.8%)	3/ 182 (1.6%)
R radius shaft	0/ 41 (0%)	0/ 108 (0%)	0/ 80 (0%)	0/ 229 (0%)
R radius distal	1/24 (4.2%)	1/ 86 (1.2%)	4/ 78 (5.1%)	6/ 188 (3.2%)
L ulna shaft	0/41 (0%)	0/ 103 (0%)	0/ 93 (0%)	0/ 237 (0%)
L ulna distal	0/ 19 (0%)	0/ 59 (0%)	1/69 (1.5%)	1/ 147 (0.7%)
R ulna shaft	0/ 41 (0%)	0/ 106 (0%)	1/94 (1.1%)	1/ 241 (0.4%)
R ulna distal	1/15 (6.7%)	2/ 28 (7.1%)	2/ 70 (2.9%)	5/ 113 (4.4%)
Total	**4/251 (1.59%)**	**6/ 642 (0.93%)**	**14/356 (3.93%)**	**24/1249 (1.92%)**

Five of the six humeral shaft fractures manifested as abnormal unilateral bowing of the shaft. In one case (Plymouth 633), there was also shortening of the element by 9mm, and slight torsion of the humeral head (Fig. 6.37). The minimum shaft circumference was 5mm greater on the right than the left humerus, and cortical defects at the *M. latisimus dorsi* and *M. pectoralis major* insertion sites were pronounced. The fracture type was unclear as remodelling was advanced and no fracture lines could be discerned radiographically. Probable fracture types are greenstick, spiral or oblique fractures of childhood.



Figure 6.37 *Right humeral shaft of Greenwich 633 showing bowing and shortening of the element. The left humerus is normal.*

The distal humeral shaft fracture of Haslar 214 displays very different features. This was a

comminuted fracture with non-union and extreme mal-alignment, such that the distal part was angled medially at approximately right angles to the proximal part. A large callus had developed on the anterior aspect of the distal segment, holding within it a large shard of comminuted bone (Fig. 6.36). This callus acted as the anterior part of a pseudarthrosis, which articulated with the proximal portion of the fractured bone. Considerable new bone deposition had formed a concave 'articular surface' for the distal part, and widespread sclerosis was present. The fractures showed advanced remodelling but with some ongoing new bone formation- presumably in response to continued fracture instability. This individual had suffered multiple ununited injuries to the face and limbs.



Figure 6.38 *Top: Right humerus of Haslar 214 showing gross mal-alignment of a comminuted fracture of the distal shaft. Lower left: Posterior aspect of distal portion showing the sclerotic 'articular surface' of the pseudarthrosis (arrow) and the bony outgrowth of the callus anteriorly, against which the proximal part rested. Lower right: Anterior aspect of proximal portion of the fractured shaft showing advanced remodelling. This comprised the proximal component of the pseudarthrosis.*

There were two left radial and one right ulnar shaft fractures in the combined assemblage. Like the right humerus of HAS 214, the left proximal radial shaft of this skeleton displayed a non-united

fracture, located 94mm from the proximal and 151mm from the distal ends (Fig. 6.39). The fractured surfaces showed advanced healing with obliteration of the marrow cavity. Although a short spur of bone had developed on the proximal fragment (containing a bone shard), there was no osteological evidence to suggest pseudoarthrosis formation, however. Conversely, the slightly atrophied ends tentatively suggest localised neurological or vascular damage to structures supplying the bone. As the right ulna was intact, and would effectively have anatomically splinted the radius, lack of union may well be the consequence of localised neurovascular damage. There were two carpal fractures (a necrotic scaphoid bone and possibly a capitate) in the same limb.



Figure 6.39 *Non-union of a fracture of the left proximal radial shaft of HAS 214.*

In contrast to the above, the only other radial shaft fracture (Greenwich 6063) was healed, united and very well aligned, indicating effective reduction and immobilisation.

The only ulnar shaft fracture in the combined assemblage was an oblique fracture of the right mid-to-distal shaft of Greenwich 3107 (Fig. 6.40). The shaft was very well-aligned and remodelling appeared complete. This may indeed be a true parry fracture as the only other fracture of this limb was an avulsion fracture of the styloid process of the third metacarpal. The long oblique angle of the fracture, however, is less typical of a parry fracture (Galloway 1999). Alignment was very good, indicating effective reduction and immobilisation.

In older adult Greenwich 3151, no fractures of the left radial and ulnar shafts were observed macroscopically or radiologically but moderate lateral bowing of the shafts and shortening of the elements were present (Fig. 6.41). The maximum length of the left radius was 10mm shorter than



Figure 6.40 *Above: Lateral view of right ulnar shaft fracture of Greenwich 3107. Below: Anterior view of the same element showing well-healed oblique fracture.*



Figure 6.41 *Lateral bowing and shortening of the left radius and ulna of Greenwich 3151. The right radius and ulna are normal.*

the right, and the radial head diameter was 1.7mm smaller. Maximum length of the left ulna was 14mm shorter than the right. Limb shortening suggests that both injuries were incurred whilst the individual was still growing. The lack of observable fracture lines (probably greenstick fractures) may be due to extensive remodelling over many decades. Alternatively, these bony changes may be tubular bowing, a permanent deformation of a shaft under stress, which may occur in more pliable

subadult bone (Glencross and Stuart-Macadam 1998). Element shortening and the unilaterality make it improbable that this bowing was the result of infantile rickets.

the right, and the radial head diameter was 1.7mm smaller. Maximum length of the left ulna was 14mm shorter than the right. Limb shortening suggests that both injuries were incurred whilst the

Nine distal radial and six distal ulnar fractures were present in the combined assemblage. Of the former, six were of the right element, and three were of the left, and, of the latter, one was left and five were right. Five distal radial fractures were Colles' fractures of the metaphysis (Fig. 6.42). Four distal radial fractures involved the distal joint surface and were classified as a Barton's, a volar Barton's, a Chauffeur's fracture and a possible die-punch fracture (Galloway 1999; Glencross and Stuart-Macadam 1998), although advanced remodelling did complicate classification.

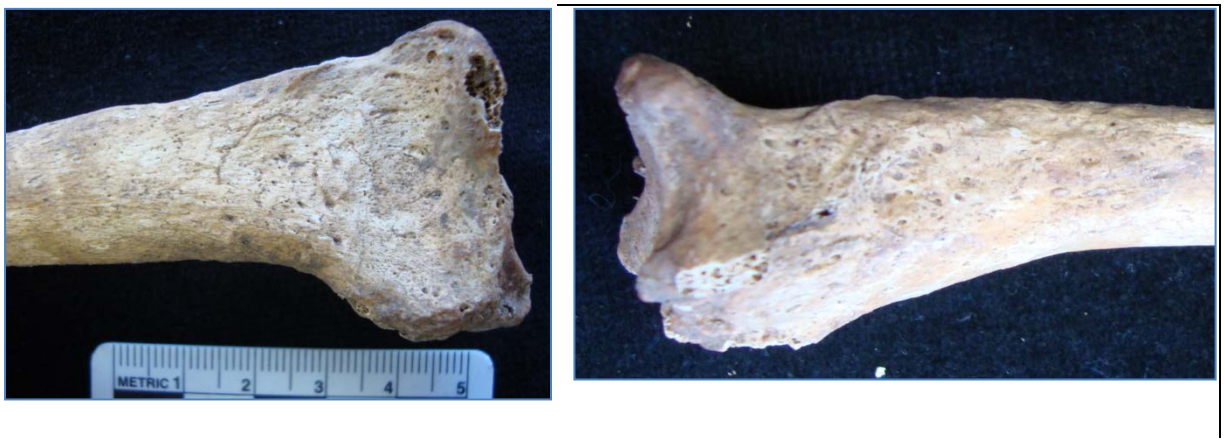


Figure 6.42 *Left: Anterior view of healed Colles' fracture of the right distal radius of Greenwich 3241. Right: Lateral view of the same fracture showing posterior displacement of the distal part (inferior on the image).*

Distal radial fractures were associated with ulnar styloid process fractures in six cases. All distal ulnar fractures involved the styloid process, and were often associated with osteophytosis and porosity of the joint surface, and, in several cases, with eburnation.

Distal ulnar and radial injuries were bilateral in Greenwich 3044 and 3241. In Greenwich 3162 and 3268, right distal radius and ulnar fractures were associated with right shoulder subluxation, whilst Greenwich 3044 displayed a right clavicular fracture and three right metacarpal fractures as well as

secondary osteoarthritis associated with the right Colles' and ulnar styloid process fractures. Multiple bilateral upper limb bones were fractured in Greenwich 3241 -(see Chapter 7).

(vii) Elbow trauma

Fourteen fractures of the elbow joint were present in the combined assemblage (TPR 1.2%): six of the distal humeral metaphysis and epiphyses (TPR left 1.5%, right 1.4%), two right radial head fractures (TPR 1.1%) and six olecranon process fractures (TPR left 1.9%, right 1%) (Table 6.10). Seven fractures were left and seven right-sided.

Table 6.10. *Elbow fractures in the three skeletal assemblages and combined assemblage; TPR is presented in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
L humerus distal	0/ 23 (0%)	1/ 97 (1%)	2/ 81 (2.5%)	3/201 (1.5%)
R humerus distal	0/ 29 (0%)	1/ 103 (1%)	2/ 77 (2.6%)	3/209 (1.4%)
L radial head	0/ 15 (0%)	0/ 85 (0%)	0/ 84 (0%)	0/184 (0%)
R radial head	1/20 (5%)	1/ 91 (1.1%)	0/ 80 (0%)	2/ 191 (1.1%)
L olecranon	0/ 37 (0%)	1/ 92 (1.1%)	3/ 84 (3.6%)	4/213 (1.9%)
R olecranon	1/ 32 (3.1%)	0/ 97 (0%)	1/ 82 (1.2%)	2/211 (1%)
Total	**2/ 156 (1.3%)**	**4/ 565 (0.7%)**	**8/ 488 (1.6%)**	**14/1209 (1.2%)**

With the exception of Plymouth 881 (Fig. 6.44), the distal humeral fractures were all very well-healed low transcolumn fractures of the metaphysis, probably incurred during childhood or adolescence before the epiphysis had fused. All fractures were associated with moderate to marked marginal osteophytosis.



Figure 6.43 *Well-healed probable transcolumn fracture of the right distal humerus of Plymouth 835 (large arrow), with marginal osteophytosis. Osteochondritis dissecans is present on the capitulum (small arrow).*

The left humeral capitulum of older adolescent Plymouth 881 showed marked depression and irregularity of the anterior joint surface consistent with crushing. Unfortunately, the corresponding radius had not survived. There was an incomplete probable oblique fracture of the olecranon process joint surface, but this was very superficial. What were very clear, however, were three discrete smooth-walled lesions on the joint surface and margin of the coronoid process (Fig. 6.45). As with the para-labral cysts in the glenoid cavity of Greenwich 3103, these cyst-like lesions occurred in the absence of tubercular or gouty lesions elsewhere on the skeleton. The latter disease is highly unlikely in one so young. It is more probable that these lesions formed in response to elbow trauma (possibly involving synovial fluid infiltration beneath the cartilage and into the bone of the joint surface).



Figure 6.44 *Left distal humerus of Plymouth 881 showing healed crushing of the capitulum (arrow).*



Figure 6.45 *Left ulnar joint surface of Plymouth 881 showing three large healed cyst-like lesions on the coronoid process (arrows).*

The left metaphysis of Greenwich 6019 displayed a large, oval smooth-walled depression (15mm x 8.6mm) in the anterior surface immediately proximal to the capitulum joint surface (Fig. 6.46). Much of the interior of the depression had been infilled with the smooth dense new bone of long-standing lesion. Although the aetiology of this lesion is unclear, crushing projectile trauma (such as a musket-ball or grapeshot fragment) may have caused this lesion.



Figure 6.46 *Anterior view of the distal left humerus of Greenwich 6019 showing possible healed projectile trauma to the metaphysis (arrows). Inset: Close-up of the lesion (arrow).*

All the proximal ulnar fractures involved the olecranon process: two incomplete transverse fractures (Plymouth 881 and Greenwich 6149), one ununited transverse impacted fracture (Haslar 214), one comminuted fracture in which some fragments had united whilst others had not (Greenwich 3144) (Fig. 6.47), and two ununited transverse fractures (Greenwich 1565 and 6151) (Fig. 6.48).



Figure 6.47 *Comminuted fracture of the right olecranon process of Greenwich 3144 with union of one fragment (upwards arrow) and non-union of another (downwards arrow).*

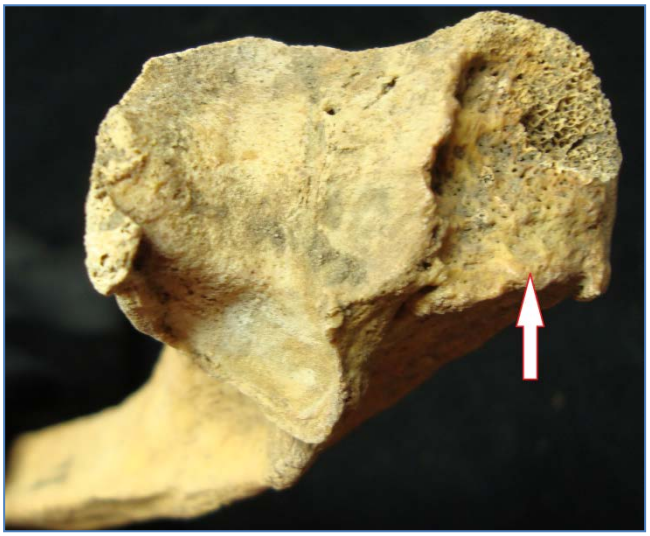


Figure 6.48 *Non-union of a well-healed transverse fracture surface (arrow) of the olecranon process of Greenwich 1565.*

Only two right proximal radial fractures were identified: a probable wedge fracture of the radial head and neck of Haslar 214, and an impaction of the head of Plymouth 835. The former was associated with considerable right upper limb trauma, including a grossly malaligned humerus (see above) and an ununited olecranon process fracture. The radial head fracture of Plymouth 835 was associated with a distal humeral fracture and *osteochondritis dissecans* of the corresponding capitulum.

(viii) Hand fractures

There were 79 hand bone fractures in the combined assemblage (TPR 1.1%): 21 left and 38 right metacarpal fractures (TPR left 1.9%, right 2.9%), seven right carpal fractures (TPR 0.8%), four left carpal fractures (TPR 0.5%), five left phalanges (TPR 0.4%) and four right phalanges (0.3%) (Table 6.11). There were 30 left and 49 right hand fractures. Side dominance was statistically significant at a 95%, but not at a 99% confidence level (chi-squared 4.1, critical value 3.84 at p= 0.05; and 6.64 at p= 0.01).

Table 6.11 *Hand bone fractures in the skeletal assemblages (n = 79), L= left, right= right, TPR are in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
L carpals	2/ 111 (1.8%)	0/ 376 (0%)	2/ 390 (0.5%)	4/ 877 (0.5%)
R carpals	2/ 125 (1.6%)	0/ 394 (0%)	5/ 391 (1.3%)	7/910 (0.8%)
L metacarpals	4/132 (4%)	4/ 411 (1%)	13/ 391 (3.32%)	21/ 934 (2.24%)
R metacarpals	1/ 127 (0.8%)	15/ 413 (3.6%)	22/ 406 (5.4%)	38/ 946 (4.02%)
L hand phalanges	0/220 (0%)	1/ 669 (0.2%)	4/ 599 (0.67%)	5/ 1488 (0.34%)
R hand phalanges	1/ 206 (0.5%)	1/ 687 (0.2%)	2/ 654 (0.3%)	4/ 1547 (0.3%)
Total	**10/ 921 (1.1%)**	**21/ 2950 (0.71%)**	**48/ 2831 (1.70%)**	**79/6702 (1.18%)**

Metacarpal fractures constituted 75% of all hand bone fractures (n= 59)- 21 left and 38 right sided. Side dominance was statistically significant (chi-squared 7.71, critical value 6.63, p= 0.01). The first metacarpal (MC1) fractures suffered the greatest number of fractures (9 left, 21 right), followed by the third metacarpal (MC3) (5 left, 11 right) (Table 6.12). Bennett's fractures accounted for 20 MC1 fractures (Fig 6.49 and 6.50): six left and 14 right.

Table 6.12. *Number of metacarpal fractures in the skeletal assemblages (n = 58), MC = metacarpal.*

	Haslar			Plymouth			Greenwich			Combined		
Element	**Left**	**Right**	**Total**	**Left**	**Right**	**Total**	**Left**	**Right**	**Total**	**Left**	**Right**	**Total**
MC1	3	0	3	1	13	14	5	8	13	9	21	30
MC2	0	0	0	0	0	0	1	2	3	1	2	3
MC3	1	1	2	0	2	2	4	8	12	5	11	16
MC4	0	0	0	1	0	1	1	2	3	2	2	4
MC5	0	0	0	2	0	2	1	2	3	3	2	5
Total	**4**	**1**	**5**	**4**	**15**	**19**	**13**	**22**	**34**	**20**	**38**	**58**



Figure 6.49 *Right MC1 of Plymouth 581 showing a healing Bennett's fracture of the proximal joint surface (large arrow) and woven bone on the metaphysis (small arrow). Inset: The proximal joint surface showing on-going healing of the same Bennett's fracture (arrow).*



Figure 6.50 *The MC1s of Plymouth 727 showing a healed shaft fracture with shortening of the left element, and a healed Bennett's fracture of the right.*

The remainder of MC1 fractures were united shaft fractures (Fig. 6.50), often involving dorsal bowing of the shaft and shortening of the element, and one head and neck crush fracture.

Five of the 16 MC3 fractures were left, and 11 right-sided. With the exception of one head and neck crush fracture (Greenwich 3208), these were avulsion fractures of the styloid process. However, an absent styloid process may be a developmental anomaly or variant. Thus, only those fractures with clear fracture lines or remodelling were included in the fracture numbers. Incomplete fractures (n= 8) were identified by a fracture line crossing the proximal joint surface, separating the styloid process from the rest of the element, but with the styloid still attached. Complete severance was present in seven styloid processes -the exposed trabeculae of the fractured surface gradually infilling with smoother more dense bone (Fig. 6.51).



Figure 6.51 Avulsion of the styloid process of the right MC3 of Greenwich 3515 (arrow) with remodelling.



Figure 6.52 Well-healed probable spiral fracture of the right fifth metacarpal shaft of Plymouth 590, with abnormal palmar angulation of the proximal part.

The remaining metacarpal fractures were shaft fractures and two neck fractures. All were healed and united, although overlap and bowing of the shafts were sometimes present (Fig. 6.52). These included three MC2, four MC4 and five MC5 fractures.

Seven right carpal fractures included two chip or avulsion fractures of the lunate, two ununited scaphoid bone fractures with extensive eburnation, one incomplete hamate and one pisiform

fracture, and one trapezium saddle joint fracture associated with a Bennett's fracture. Four left carpal fractures (TPR 0.5%) comprised a necrotic ununited scaphoid bone fracture of Haslar 214, a lunate chip fracture, and two trapezium saddle joint fractures (Fig. 6.53). Phalangeal fractures comprised the remainder of hand fractures. These were largely crush fractures of the proximal or distal epiphyses.



Figure 6.53 *Carpal fractures: (a) complete ununited fracture of the right scaphoid bone of Greenwich 6082 with marked eburnation, (b) Incomplete fracture of the right hamate of Greenwich 3261 (arrow), (c) chip or avulsion fracture of the left lunate of Haslar 303 (arrow), (d) incomplete fracture of the saddle joint of the trapezium of Greenwich 6089 (arrow).(b)- (d) all healed.*

(ix) Hip trauma

The hip, pelvic, innominate bone or os coxae comprises the ilium, ischium and pubis, which, in males, fuse at the acetabulum in late adolescence between 14 and 18 years of age (Schaefer et al. 2009). With a single exception of probable projectile trauma to the right iliac blade of Plymouth 633,

pelvic trauma in the three R.N. assemblages was located in the acetabulum. These traumatic injuries included acetabular rim fractures, impaction fractures of the joint surface, and acetabular flange lesions. In many individuals these injuries were linked. As the acetabulum is composed of all three above-mentioned pelvic bones, fractures to this part are listed separately (Table 6.13).

Table 6.13 *Fractures of the innominate bones of the skeletal assemblages. TPR is given in brackets.*

L pelvis	**Haslar**	**Plymouth**	**Greenwich**	**Combined**
L ilium	0/ 41 (0 %)	0/ 108 (0%)	0/ 95 (0%)	0/ 244 (0%)
L ischium	0/ 38 (0%)	0/ 99 (0%)	0/ 87 (0%)	0/ 224 (0%)
L pubis	0/ 18 (0%)	0/ 49 (0%)	0/ 66 (0%)	0/ 133 (0%)
L acetabulum	3/ 41 (7.32%)	12/ 108 (10.19%)	19/ 95 (20%)	33/ 244 (13.52%)
Total	**3/ 138 (2.17%)**	**12/ 256 (4.69%)**	**19/ 248 (7.66%)**	**34/601 (5.66%)**
R pelvis	**Haslar**	**Plymouth**	**Greenwich**	**Combined**
R ilium	0/ 42 (0%)	1/ 102 (0.98%)	0/ 96 (0%)	1/ 240 (0.42%)
R ischium	0/ 37 (0%)	0/ 90 (0%)	0/ 93 (0%)	0/ 220 (0%)
R pubis	0/ 20 (0%)	0/ 41 (0%)	0/ 64 (0%)	0/ 125 (0%)
R acetabulum	4/ 42 (9.52%)	12/ 102 (11.77%)	22/ 96 (22.92%)	38/ 240 (15.83%)
Total	**4/ 99 (4.04%)**	**13/ 233 (5.58%)**	**22/ 253 (8.70%)**	**39/ 585 (6.67%)**

There were five left and three right acetabular rim fractures (TPR left 2.10%, right 1.25%). These fractures were located in the anterior column of the pelvis, predominantly of the antero-superior rim (Figs 6.56 and 6.57), but with two located posterior to the anterior inferior iliac crest (i.e. the supero-posterior rim). Small bone fragments from the rim had been detached in these lesions, with the loss of the normal smooth margin, leaving this section of the margin less defined. The most common acetabular fracture was an impaction lesion of the joint surface: present in 28 left and 35 right acetabula (TPR 13.52%, right 15.83%). However, there was no statistically significant side dominance (chi-squared 2.29; critical value 6.64, p= 0.01).

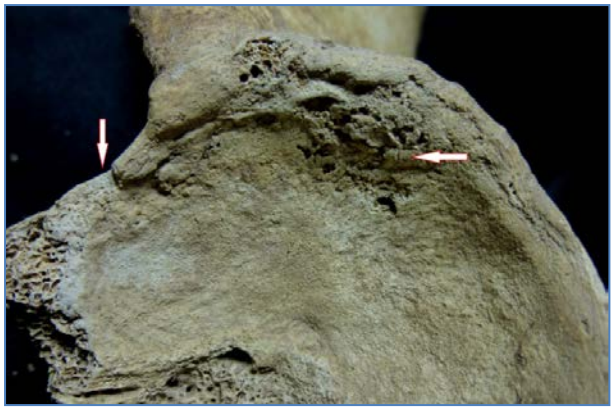


Figure 6.54 *Healed antero-superior rim fracture of the left acetabulum of Plymouth 727 (vertical arrow) and an impaction lesion of the joint surface (horizontal arrow).*

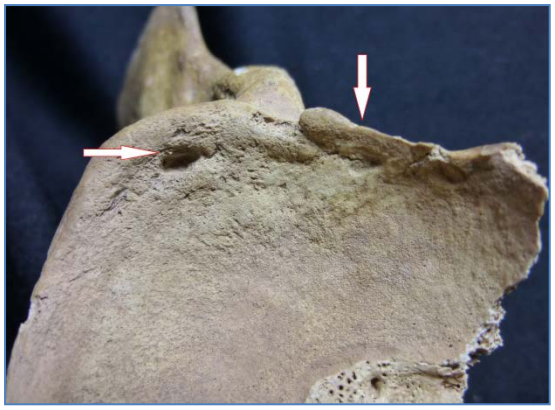


Figure 6.55 *Healed antero-superior rim fracture of the right acetubulum of Plymouth 927 (vertical arrow). A cyst is present on the postero-superior joint surface (horizontal arrow).*

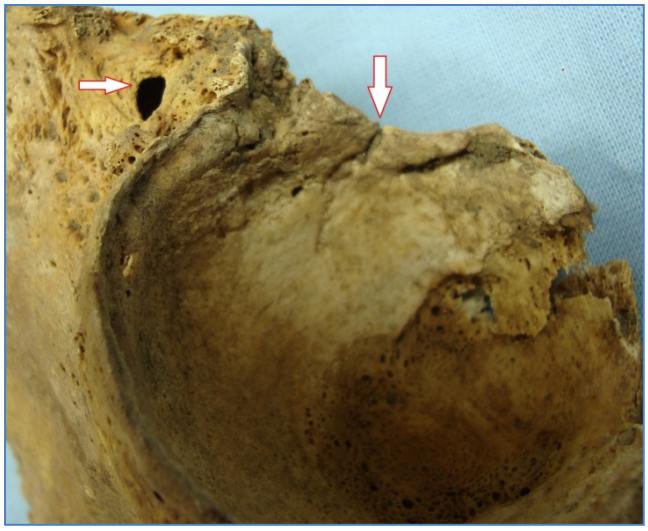


Figure 6.56 *Right antero-superior rim fracture (vertical arrow), slight compression to the joint surface and development of a supra-acetabular cyst in the ilium of Greenwich 3051 (horizontal arrow).*

Without exception, these lesions were located in the supero-posterior aspect of the joint surface just inferior to the joint margin. Lesions manifested as discrete areas of irregular, porous or sclerotic plaques on the joint surface. Increased porosity (localised hypervascularity) and subchondral cysts were often present. In many cases, the lesion was depressed relative to the surrounding joint surface, and tiny multi-directional fracture lines were sometimes observed. It appears that such lesions involve a very specifically located, localised crushing of the joint surface, probably the result of impaction of the femoral head on the acetabular joint surface when landing from a jump or fall with flexed knees.

Although these lesions might be mistaken for degenerate joint changes, they frequently occurred in younger individuals, and in most cases in the absence of other degenerative joint changes (such as marginal osteophytosis or eburnation). There were no associated femoral head lesions, of either a traumatic or degenerative aetiology. Acetabular impaction lesions were often associated with distal tibial and/or fibular fractures, reinforcing the hypothesis that these lesions formed as a result of referred impact of landing on the feet.



Figure 6.57 *Left acetabulum of Greenwich 3068 showing the localised depression and increased porosity of a healed impaction lesion (vertical arrow), and flattening and extension of the joint surface- a flange lesion (horizontal arrow). Note the wide, flat socket morphology.*

Although acetabular dimensions were not formally measured in this study, a very large proportion of skeletons had unusually wide, shallow acetabula when compared with terrestrial assemblages. The consequence of this flattening and a fairly blunt joint margin or rim is a tendency to slight superior subluxation of the femoral head. Osteologically, this was identified by the extension of the normal smooth, dense articular surface onto the rim, or superiorly beyond it to form an acetabular flange lesion (Figs 6.58- 6.61). Ten left and eight right flange lesions were identified in the combined assemblage (TPR 4.10%, right 3.33%). These lesions were located on the superior aspect of the rim, as were many rim fractures, or adjacent to joint surface impaction lesions, and may well have developed in association with or as a consequence of this trauma.



Figure 6.58 *Left acetabulum of Plymouth 757 showing flattening and remodelling of the superior rim consistent with a developing flange lesion.*

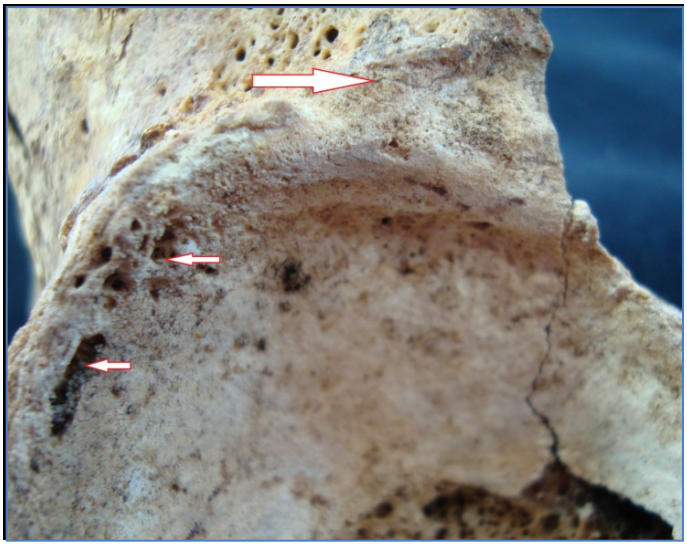


Figure 6.59 *Right acetabulum of Greenwich 6037 showing an anterior flange lesion (large arrow) and cyst formation on the joint surface and rim.*



Figure 6.60 *Right acetabulum of Greenwich 6003 showing an acetabular flange lesion of the superior rim (arrow).*

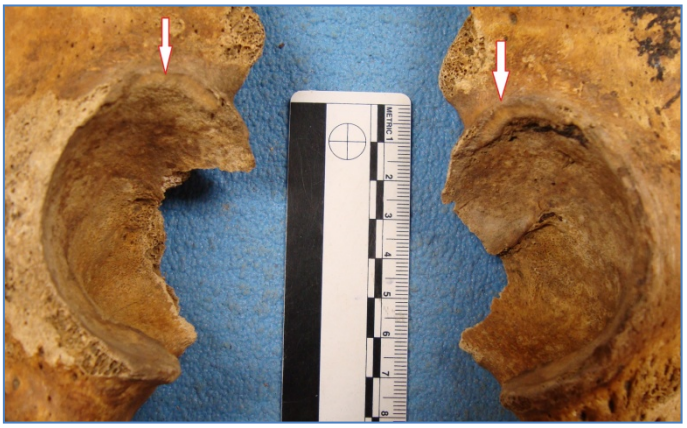


Figure 6.61 *Bilateral acetabular flange lesions on the acetabular rims of Greenwich 3187 (arrows).*

Supra-acetabular cysts are another pathological change that has been strongly associated with trauma to the hip joint, particularly labral tears (Mays 2005). These lesions were present in three left and three right pelves of the combined assemblage (TPR left 1.23%, right 2.08%) (Figs 6.56, 6.62 and 6.63). When developed, they are smooth-walled, broadly circular lesions penetrating the cortical bone and underlying trabecular bone of the ilium in and beyond the joint margin (predominantly juxta-articular). The largest supra-acetabular cyst on the posterior aspect of the right ilium of Greenwich 3039 was 25mm in diameter and 20mm deep (Fig. 6.63). Smaller multiple lesions were

more common, with several acetabula displaying large cysts of the joint surface just within the supero-posterior margin, of the rim itself (some with full thickness penetration), and the juxta-articular area.

In every case, cyst formation was associated with a rim fracture, joint surface impaction lesion and/ or flange lesion, strengthening the probability of a linked traumatic aetiology. Like the cyst formation in the glenoid cavity and right elbow joint described above, these lesions probably developed through incursion of synovial fluid beneath the labrum, cartilage and bony joint surface into the underlying trabecular bone.



Figure 6.62 *Posterior aspect of the right ilium of Greenwich 3051 showing two large supracetabular cysts beyond the acetabular rim (arrows).*



Figure 6.63 *Right pelvis of Greenwich 3039 showing a large supra-acetabular cyst (arrow).*

The right ilium of Plymouth 633 displayed a very different lesion in the centre of the anterior aspect of the blade, which may be the result of projectile trauma (Fig. 6.62). The cortical bone had been penetrating revealing the trabecular bone beneath. The lesion had a sinuous, somewhat lobed margin, areas of which showed smoothing suggestive of early wound healing (*c.* 22mm in diameter). Slight post-mortem damage hindered interpretation. There was no discernible remodelling of the underlying trabecular bone. The size and shape of the lesion is consistent with penetration by a deformed musket-ball or grapeshot, which presumably had been surgically removed. There was no

lead scatter on the radiograph, however. The skeleton also displayed an unhealed right femoral amputation, a mandibular fracture with osteolomyelitis, and fine perimortem cutmarks on the left ilium.



Figure 6.64 *Left: Healing probable projectile trauma of the right iliac blade of Plymouth 633 (arrow). Right: Close-up of lesion. The two depressed post-depositional lesions are canid puncture marks.*

(ix) Thigh fractures

Thigh fractures present in the combined assemblage comprised five fractures of the proximal femur and six femoral shaft fractures (Table 6.14). There was slight left-sided dominance, with seven fractures being left, and four right (TPR left 2.88%, right 1.65%).

Table 6.14 *Femoral fractures in the combined assemblage, L= left, R= right, TPR is in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
L femur proximal	0/ 39 (0%)	1/ 109 (0.92%)	1/ 93 (1.08%)	2/ 241 (0.83%)
L femur shaft	1/ 42 (2.38%)	1/ 106 (0.94%)	3/ 95 (3.16%)	5/ 243 (2.06%)
R femur proximal	0/ 39 (0%)	0/ 94 (0%)	3/ 97 (3.09%)	3/230 (1.3%)
R femur shaft	0/ 41 (0%)	0/ 105 (0%)	1/ 97 (1.03%)	1/ 243 (0.41%)
Total	**1/ 83 (1.2%)**	**2/ 214 (0.93%)**	**8/ 192 (4.17%)**	**11/ 489 (2.25%)**

Proximal femoral fractures comprised well-healed impaction fractures of the neck of older adults Greenwich 3016 (Fig. 6.65) and Greenwich 3032 (Fig. 6.68), two fractures involving posterior crushing of the intertrochanteric crest (Plymouth 910 and Greenwich 3103) (Fig. 6.67), and one complete right inter-trochanteric impaction fracture of Greenwich 3241, which resulted in element

shortening by 30mm and abnormal external rotation of approximately 45° of the distal part (Fig. 6.67).



Figure 6.65 *Healed right neck of femur fracture in Greenwich 3016 (arrow).*

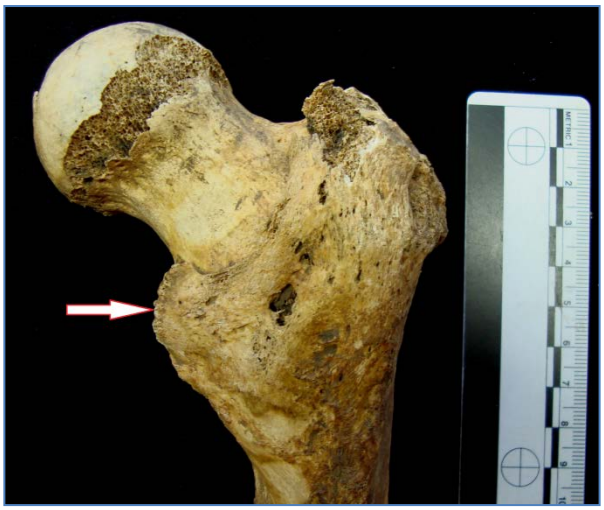


Figure 6.66 *Impaction of the right intertrochanteric crest of Greenwich 3103 (arrow).*

Today, neck of femur fractures are most commonly associated with falls from a standing height in older, osteoporotic women, but are not uncommon in males older than 70 years (Van Staa et al. 2001). The only fractures recorded in older adult Greenwich 3016 were a right femoral neck fracture and a L1 wedge fracture- both commonly associated with osteoporosis. Thus, these may well be age-related fractures.

The fractured left femoral neck of Greenwich 3032 may also be a consequence of bone demineralisation, but in this case, extreme osteopaenia was a probably a sequelae of earlier trauma (Fig. 6.68). It is possible, of course, that the neck of femur fracture preceded the femoral atrophy, and, nerve damage associated with this injury was, indeed, its cause. However, co-existing marked osteopaenia of the left innominate bone would strongly suggest a less localised neuromuscular trauma- probably central or spinal nerve damage. This individual had also sustained severe sharp force trauma to the right side of the face (Fig. 6.17), and, although no cranial vault fracture was noted, injury to the right side of the brain may well have accompanied the facial trauma, resulting in

neurological impairment of the contralateral lower limb. There were no vertebral pathological changes to support a spinal aetiology.



Figure 6.67 *Healed intertrochanteric impaction fracture of the right femur of Greenwich 3241 (arrow) with shortening of the element and external rotation of the distal part. The left femur is normal.*



Figure 6.68 *Healed left neck of femur fracture in Greenwich 3032 (arrow), and extreme atrophy and osteopaenia of the element. The right femur was normal.*

This osteopaenic aetiology does not apply to the other proximal fractures, which are either probably direct impaction fractures from a forceful posterior blow (Plymouth 910 also displayed a fractured L5 neural arch and perforation of the left scapular body) or, in the cases of Greenwich 3104 and 3241, fractures occurred in concert with several other fractures indicative of a high velocity fall onto an outstretched lower limb.

There were four left and one right femoral shaft fractures in the combined assemblage. Greenwich 3229 suffered bilateral transverse or slight oblique fractures of the mid- and distal shafts (Fig. 6.69)- quite possibly incurred in a single traumatic episode, such as a slightly angled blow across both lower limbs. Both femora showed an overlap of the broken ends of 40mm on the left and 70mm on the right, causing unequal final lengths of the elements. Radiography also revealed an anterior angulation of approximately 20° of the proximal part relative to the distal part, but only slight external rotation of the distal part. There was also slight external rotation in the right femur. Displacement and overlap of the broken parts was more lateral, with little malalignment in the sagittal plane. Large cloacae in the callus and medullar resorption associated with both fractures indicated secondary osteomyelitis, and suggested compound fractures. In both elements, the callus had completely remodelled, and hence, the infection was not active at the time of death.



Figure 6.69 *Bilateral femoral shaft fractures of Greenwich 3229 showing overlap, shortening and external rotation of the distal parts. A cloaca indicates osteomyelitis of the right femur (arrow). Photo courtesy of Oxford Archaeology.*

Haslar 214 displayed non-union of a comminuted fracture of the left femoral mid-shaft. Smoothing of the broken fragments indicated that the injury occurred several weeks or even months before death (Fig. 6.70), but union had not been achieved (in keeping with healing but non-union of several facial and upper limb fractures described above). Several bone fragments of the comminuted or butterfly fracture were missing- either not excavated or had resorbed before death. The excavation

photograph of Haslar 214 *in situ* in the grave shows the extreme instability of the fracture (Fig. 6.71). There is considerable overlap of the broken parts and marked shortening of the left limb relative



Figure 6.70 *Healing but un-united comminuted or butterfly fracture of the left femoral shaft of Haslar 214.*



Figure 6.71 *Excavation photo of the lower limbs of Haslar 214 in situ. Note the marked overlap of the left femoral shaft fracture, shortening of the limb and extreme rotation of the distal part. Photo courtesy of Peter Masters of Cranfield University.*

to the right. There is also extreme rotation of the distal part, such that the distal femur lies almost at right angles to its original alignment (although some excavation disturbance here is probable). Most convincing is the extremely abnormal anatomical position of the distal tibia and fibula, which appear to have been rotated through 180°, such that their posterior aspects were now facing anteriorly and

the fibula was now medial to the tibia. It is to be hoped, for the sake of this unfortunate man, that such rotation occurred after death during laying out of the corpse, but such extreme overlap and rotation may well reflect the gross instability of the fracture, and the forceful contraction of the *M. quadriceps femoris* at the time of injury (Knusel and Goggel 1993).

A less dramatic, well-healed and united fracture was a very well-healed proximal-to-midshaft oblique fracture of the left femur of Plymouth 868, recognised from abnormal posterior angulation of the distal shaft relative to the proximal part. There was no overlap. The poorly preserved left distal femoral shaft showed a very well-healed transverse fracture with anterior angulation of the fractured parts and overlap. The right femoral shaft of Greenwich 6037 showed unilateral medio-lateral and antero-posterior bowing and marked enthesophyte formation on the posterior proximal shaft. The fracture line was not clear due to advanced remodelling, but the absence of overlap and shortening suggests an incomplete fracture (e.g. a greenstick fracture).

The only evidence for sharp force trauma of the femur was present in a fragment of disarticulated femoral shaft, and, as such, was not included in the fracture counts. At least four slices of cortical bone had been removed from that part of the anterior shaft by repeated oblique blows from a heavy curved blade, such as a French cutlass (Fremont-Barnes 2008) (Fig. 6.72). In addition, at least three other isolated cut-marks were present on different aspects of the shaft fragment, suggesting that the individual was a moving target during the assault. Slight smoothing of the margins of the lesions indicates that the patient had survived some days or weeks after the injury. No woven bone was present to indicate inflammation/ infection.



Figure 6.72 *Disarticulated femoral fragment showing a series of oblique cuts on the anterior shaft, made by a heavy blade. Smoothing of the surface and margins indicated healing. Note the isolated cut-mark to the right and above.*

(x) Knee trauma

There were 21 well-healed fractures of the knee region (TPR 1.75%): 11 patellar fractures, two femoral condylar fractures and eight proximal tibial fractures (Table 6.15).

Table 6.15 Fractures to the knees of the combined assemblage, L= left, R= right, TPR is in brackets.

Elements	Haslar	Plymouth	Greenwich	Combined
L patella	0/ 21 (0%)	2/ 72 (2.78%)	3/ 71 (4.23%)	5/ 164 (3.05%)
R patella	0/22 (0%)	2/ 73 (2.73%)	4/ 72 (5.56%)	6/ 167 (3.59%)
L femur distal	0/ 36 (0%)	0/ 90 (0%)	1/ 92 (1.09%)	1/ 218 (0.46%)
R femur distal	0/ 38 (0%)	0/ 95 (0%)	1/ 95 (1.05%)	1/ 228 (0.44%)
L tibia proximal	1/ 34 (2.94%)	0/ 81 (0%)	3/ 91 (3.23%)	4/ 205 (1.95%)
R tibia proximal	1/ 33 (3.03%)	0/ 92 (0%)	3/ 92 (3.26%)	4/ 217 (1.84%)
Total	**2/ 184 (1.09%)**	**4/ 503 (0.78%)**	**15/ 513 (2.92%)**	**21/ 1200 (1.75%)**

The left tibial condyle of Haslar 214 showed crushing of the medial condyle. Similarly, the left femoral and tibial joint surfaces of Greenwich 3229 showed crushing, and subsequent remodelling (Figs 6.73 and 6.74). Several near-vertical fracture lines were present centrally on the anterior aspect of the femoral joint surface, and a depressed area of the joint surface superiorly suggests compression by the patella. The patella was not present. It is probable that this is due to taphonomic processes (including non-recovery during excavation), but a patellectomy for severe crushing must be considered. Slightly raised plaques of new bone were located on the medial femoral joint surface– possibly remodelling following fracture. The corresponding proximal medial tibial joint

surface showed considerable postero-lateral crushing. A fracture line on the lateral condylar surface followed the medial margin of that surface. Marginal osteophytosis was present, suggesting joint stress and instability, possibly even dislocation. Such crush fractures may have resulted from referred impaction or from a direct anterior blow to the knee. The latter is more probable given that this individual had also sustained bilateral compound femoral shaft fractures (see above), quite possibly at the same time as the knee injury, and no lower leg or foot fractures were present to suggest a fall onto that limb.



Figure 6.73 *Left femoral condyle of Greenwich 3229 showing crushing of the joint surface with fracture lines (arrow), new bone deposition and probable patella crushing superiorly.*



Figure 6.74 *Left tibial plateau of Greenwich 3229 showing crushing of the medial condyle (vertical arrow) and a fracture line on the lateral condyle (horizontal arrow).*

There were fractures of the right femur and patella of Greenwich 3151 (Figs 6.75 and 6.76) and chronic lateral displacement of the patella. Just within the medial margin on the anterior aspect of the medial condylar surface of the femur was an area of roughening and irregularity consistent with localised crushing of the joint surface and subsequent bony remodelling.



Figure 6.75 *Joint surface of the right patella of Greenwich 3151 showing fractures of the lateral and inferior margins (arrows) and eburnation of the lateral joint surface.*



Figure 6.76 *The anterior aspect of the distal right femur of Greenwich 3151 showing a healed fracture of the medial condyle (horizontal arrow) and eburnation of the lateral condyle (vertical arrow).*

The latter was continuous with moderate to marked marginal osteophytosis. Much of the anterior joint surface of the lateral condyle was eburnated. This corresponded with eburnation of the lateral joint surface of the right patella. This suggests chronic lateral displacement of the patella. The lateral and infero- lateral patellar margins immediately adjacent to this eburnation had been fractured, leaving an irregular but well-healed edge. On the medial patellar joint surface, a raised roughened area of healed new bone corresponded with the femoral fracture.

The right patella of Greenwich 6063 showed sheering of the lateral aspect of the joint surface, with displacement of that fractured part medially onto the normal joint surface, creating a large protrusion (Fig. 6.75), not dissimilar to *osteochondritis dissecans*. Extensive marginal osteophytosis was present at the superior pole and a bony facet had developed along the infero-medial margin. The former articulated with a large 'flange' of extensive osteophyte formation on the superior margin of the distal femoral joint surface (Fig. 6.78). This remodelling suggests superior

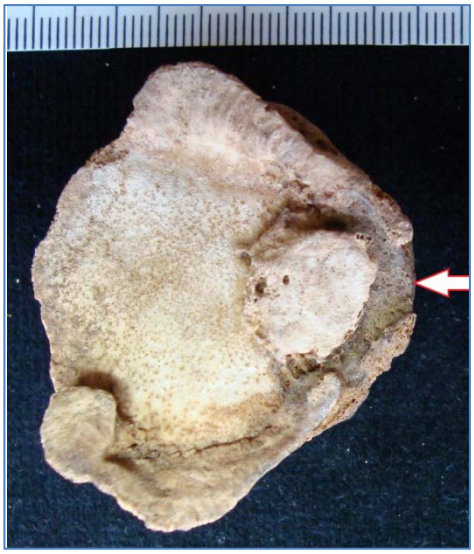


Figure 6.77 *Joint surface of right patella of Greenwich 6063 showing detachment of a section of the joint surface and re-attachment medially (arrow). Marked superior marginal osteophytosis is present.*



Figure 6.78 *Distal right femur of Greenwich 6063 showing extensive osteophytosis of the superior margin of the condyle (arrow), and a small articular surface for the patellar protrusion.*









Figure 6.79 *Upper left: Incomplete fracture of the joint surface of the right patella of Greenwich 6053; Upper right: Crush fracture to the joint surface of the left patella of Greenwich 3274; Lower left: Complete fracture of the lower pole of the right patella of Plymouth 551; Lower right: Large complete fracture of the left patella of Plymouth 960 (arrow).*

displacement of the patella, possibly due to patellar ligament rupture and/or damage to the supra-patellar bursa.

Patellar fractures included three incomplete crush fractures of the joint surface - probably the result of a direct anterior blow to the knee (Fig. 6.79). The remainder were complete fractures in which a large section of the patella had separated. Distinction between a vastus notch or emarginated patella and a curvilinear fracture was made on the basis of ongoing healing in the cases of Plymouth 907 and 960 (Fig. 6.79). The most probable aetiology of a complete fracture of the lower pole of Plymouth 551 (Fig. 6.79) is a substantial avulsion of the patellar ligament.

Greenwich 3143, 3168 and 3177 displayed fractures of the posterior joint surface and margin of the lateral tibial condyle. The first two were probably lateral capsular avulsions, which usually involves proximal fibular avulsion. The latter was present in Greenwich 3177, but not in Greenwich 3143. In the latter, extensive granular bony deposits covered the femoral joint surfaces, and followed the line of the menisci of the tibial plateau (possibly calcium pyrophosphate dehydrate crystal deposition (CPPD) or haemarthrosis) (Fig. 6.80). Bilateral indentations in the anterior aspect of the femoral metaphyses of the same skeleton may indicate bilateral bursitis or capsular ligament damage, but this is very uncertain.



Figure 6.80 *Avulsion of the posterior joint margin of the lateral condyle of Greenwich 3143 (arrow). Note the granular bony deposition on the joint surface following the line of the meniscus.*



Figure 6.81 *Compression fracture of the posterior joint surface and margin of the medial condyle of the right tibial plateau of Greenwich 3168 (arrow).*

The lesion on the right medial condyle of Greenwich 3168 is a rim compression fracture (Fig. 6.81)- usually secondary to rupture of the lateral collateral ligament (Galloway 1999). A possible ilio-tibial band avulsion was noted on the right anterio-medial rim of Greenwich 6053.

Patellar ligament avulsion of the right tibial tuberosity in adolescent Haslar 323 (Fig. 6.82) is typical of healed Osgood-Schlatter's disease. This ligament damage may occur spontaneously (an osteochondrites) or during sudden patellar ligament contraction, and is commonly a jumping injury in childhood (Galloway 1999).



Figure 6.82 *Healed Osgood- Schlatter's lesion of the right tibial tuberosity of Haslar 323 (arrow).*

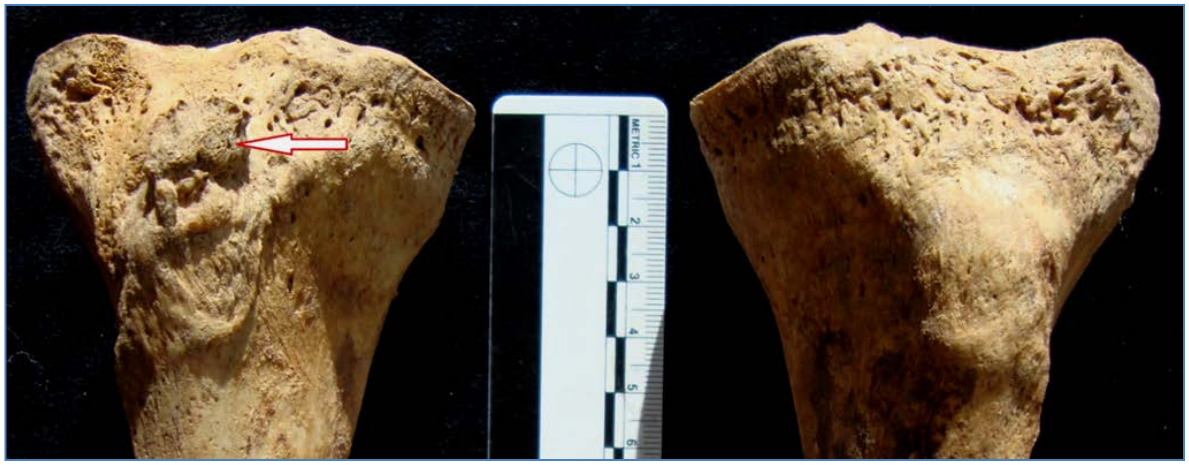


Figure 6.83 *Left and right proximal tibiae of Greenwich 3143 showing the large bony outgrowth, possibly a partial patellar ligament avulsion fracture to the right tibial tuberosity (arrow). The left tibia is normal.*

In Greenwich 3143, patellar ligament damage manifested as a large rugose bony outgrowth or spur on the superior margin of the right tibial tuberosity, which extended 10mm superiorly

(Fig. 6.83). It was either a partial avulsion of the tubercle, or an extensive syndesmosis or re-attachment of the ruptured patellar ligament.

(xi) Leg fractures

'Leg' fractures in the hospital musters referred to fractures of the distal segment of the lower limb or lower leg, distinguishing them from thigh, knee and ankle fractures. The 31 leg fractures of the combined skeletal assemblage comprised ten tibial shaft fractures (TPR left 2.54%, right 1.28%), five proximal fibular fractures (TPR left 0.97%, right 3.85%) and 16 fibular shaft fractures (TPR left 3.65%, right 3.65%) (Table 6.16). Side dominance was not signifcant (15 left; 16 right) (chi-squared= 0.03, critical value 6.64, p= 0.01).

Table 6.16. *Leg fractures in the skeletal assemblages, L= left, R= right, TPR is given in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
L tibia shaft	1/ 42 (2.38%)	3/ 101 (2.97%)	2/ 93 (2.15%)	6/ 236 (2.54%)
R tibia shaft	0/ 43 (0%)	1/ 100 (1%)	3/ 91 (2.2%)	4/ 234 (1.28%)
L fibula proximal	0/ 16 (0%)	0/ 39 (0%)	1/ 48 (2.08%)	1/ 103 (0.97%)
L fibula shaft	0/ 41 (0%)	1/ 94 (1.06%)	7/ 84 (9.52%)	8/ 219 (3.65%)
R fibula proximal	0/ 14 (0%)	0/ 41 (0%)	4/ 49 (8.16%)	4/ 104 (3.85%)
R fibula shaft	0/ 41 (0%)	1/ 94 (1.06%)	7/ 84 (4.76%)	8/ 219 (2.28%)
Total	**1/ 167 (0.60%)**	**6/ 389 (1.54%)**	**24/ 352 (6.82%)**	**31/ 908 (3.19%)**

Tibial shaft fractures were located on the mid- to distal shaft, and in five cases were associated with a fibular shaft fracture. Two tibial fractures were recognised by abnormal unilateral curvature of the shaft (Haslar 007 and Plymouth 991). No fracture lines could still be discerned, and these were probably greenstick fractures of childhood.

Direct blunt force trauma was probably responsible for the transverse fractures of the left tibial and fibular shafts of Greenwich 6003 (Fig. 6.82). There was marked overlap of the fractured parts, the left tibia being 38mm shorter than the right. Overlap and associated mal-alignment occurred principally in the sagittal plane. Fractures were well-healed and there was no indication of secondary infection in either element.



Figure 6.84 *Well-healed, united, but malaligned transverse fractures of the left distal tibial and fibular shafts of Greenwich 6003, with element shortening. The right tibia and fibula are normal.*

The left fibula was fractured at the same level, indicating that the same blow fractured both elements. The fracture type was difficult to identify due to advanced remodelling, but appeared to be transverse or slightly oblique. Overlap of the broken fibular parts was also present, but there was greater lateral angulation of the distal part (*c*. 30°) in the sagittal plane than was present in the tibia. These injuries suggest a direct lateral blow to the leg.

Blunt force trauma to the remaining distal shafts were oblique or spiral fractures- most commonly twisting injuries to the lower leg, which frequently included both tibia and fibula. There were well-healed oblique fractures of the right distal tibial and fibular shafts of Greenwich 3051 (Fig. 6.85), with 16mm overlap of the tibial parts, and medial angulation of the distal part by 10-20° in the sagittal plane. The distal fibular fragment was also displaced medially and overlap of the fractured parts had caused 9mm shortening of the element.

More proximally located, but not a dissimilar well-healed oblique tibial and fibular shaft fractures, were present in Greenwich 3164 (Fig. 6.86). Shortening of the elements due to overlap of the fractured parts was present, the tibia being shortened by 22mm. The distal part was displaced anteriorly and laterally relative to the proximal part, with slight anterior and medial angulation

(*c.* 10° and 5° respectively). There was only slight well-healed periostitis associated with these injuries. The different levels of the two fractures are consistent with a twisting injury.



Figure 6.85 *Well-healed but malaligned oblique fractures of the right distal tibial and fibular shafts of Greenwich 3051.*



Figure 6.86 *Well-healed oblique fractures of the left tibial and fibular shafts (arrows) of Greenwich 3164 (arrows).*

Greenwich 3148 displayed a well-healed united spiral fracture of the distal right tibia and a comminuted but united fracture of the distal fibular shaft. A twisting injury of the right lower limb of Greenwich 3177 was more extensive, involving a spiral fracture of the distal tibial shaft and proximal fibula, and a posterior avulsion fractures of the lateral tibial condyle. Overlap of fractured ends had shortened the tibia by 18mm.

Extensive periostitis was not associated with tibial fractures, suggesting that compound fractures were rare, or that such damaged limbs had been amputated and discarded. Eight amputated limbs were discovered in the backfill of graves in the Haslar and Plymouth Hospital burial grounds

(presumably discarded medical waste), but none showed profuse infection secondary to fracture. Two lower limbs amputated below the knee did display necrosis secondary to trauma, however (Plymouth assemblage 662 and 914). The anterior aspect of the right tibia and fibula of Plymouth 662 showed butterfly fractures just distal to the midshaft (Fig. 6.87). The fibular fracture was complete, but the tibial injury involved the loss of a broadly wedge-shaped section of bone from the anterior shaft, leaving the posterior aspect intact. Fracture analysis was complicated by extensive bony necrosis of the tibial lesion, particularly of the proximal wound edge, which had destroyed all but a short, straight edge of the wound. The distal fractured portion was less necrotic, and some evidence of new bone deposition was present on the shaft surface. One enigmatic feature was the near-perpendicular straight edge of the anterior fractured edge. This is suggestive of sharp force trauma (either a sword cut or aggressive debridement). There were no saw striations, and it would appear this edge was produced by a heavy blade. There was a short, flat edge on the proximal fragment also.

The corresponding fibular fracture did not display such straight edges, and was more clearly an unmodified butterfly fracture. Although the fractured edges were still sharp, slight smoothing was present on close inspection, reinforcing the probability that both fractures occurred simultaneously. Butterfly fractures indicate the application of considerable force, with modern butterfly fractures most commonly caused by projectile trauma. Musket-ball or grapeshot may well be the cause here, but the sections of straight edges on the tibial wound suggest sharp force trauma with a heavy blade. Failure to heal and necrosis were the probable reason that this limb was amputated.

This was probably also the second below-knee amputation of Plymouth 914. In this skeleton, there was an area of missing bone (30 x 17mm) on the anterior aspect of the left tibial midshaft (Fig. 6.88). Necrosis was evident on the distal margins of the lesion, giving the wound edge a ragged, moth-eaten appearance. Bone surface destruction extended several centimetres from the lesion. The



Figure 6.87 *Top: Amputated right lower limb of Plymouth 662 with butterfly fractures of the tibia and fibula. Middle left: Proximal edge of the tibial fracture showing considerable necrosis. Middle right: Distal edge of the tibial fracture showing some necrosis and healing. The straight near-perpendicular edge may be medical debridement or a sword wound. Lower: Butterfly fracture of the fibula.*

lesion edges were much whiter than the surrounding bone surfaces, indicating post-depositional damage (possibly during excavation or skeleton processing). Nevertheless, the necrosis was genuine. The sharp, flat proximal wound edge appeared to be obliquely angled sharp force trauma caused by a heavy blade (e.g. a cutlass or surgical knife). Necrosis of this surface was also present.

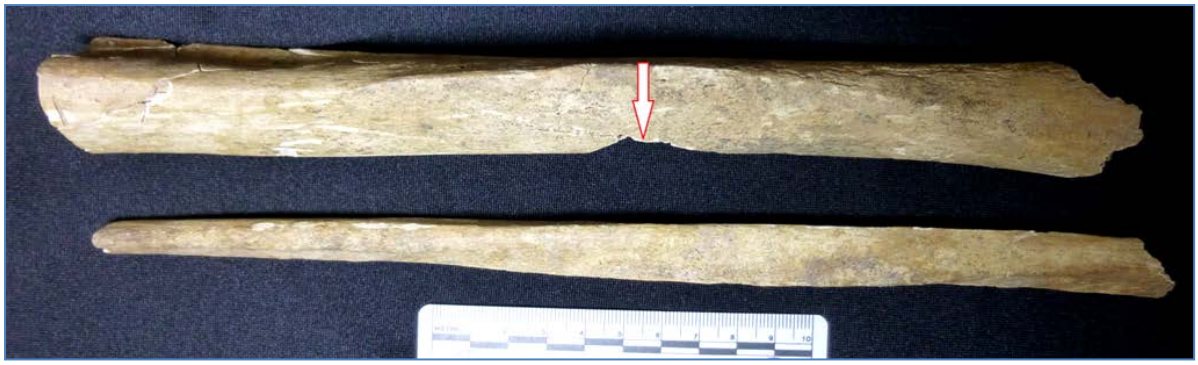




Figure 6.88 *Above: Amputated left tibia and fibula of Plymouth 914 showing necrotic injury of the anterior tibial midshaft (arrow). Left: Close-up of the injury showing bony necrosis and the flat angled proximal surface of possible sharp force trauma. Post-depositional damage to the wound edges is apparent in the white colour.*

No fractures or necrosis were apparent on the adjacent fibula, but active periostitis was present on the midshaft, adjacent to the tibial lesion. There was no periostitis on the tibial shaft. In cross-section, the cortical thickness of both elements at the amputated surface, appeared reduced (arguing for chronic disuse or non-weight-bearing). Unfortunately, being a discarded amputated limb, there was no right tibia with which to compare.

Perimortem sharp force trauma was present on the anterior left tibial shaft and distal MC1 shaft of the very incomplete, disturbed skeleton Plymouth 564. These cutmarks took the form of transverse single or grouped incisions on the tibial tuberosity, the antero-medial aspect of the mid-shaft and distal shaft (Fig. 6.89). The cutmarks were only 1-2mm wide, indicating incision with a fine blade, but were deeper (2-4mm) and more substantial than scalpel blade marks seen on several other skeletons of this assemblage. The cutmarks had a V-shaped profile, the distal edge being more oblique than the proximal, and the latter edges being raised above the level of the bone, having been lifted on withdrawal of the blade (a typical feature of sharp force trauma to 'green' bone). This angulation indicates that the incisions were made by an upwardly obliquely angled blow or incision.

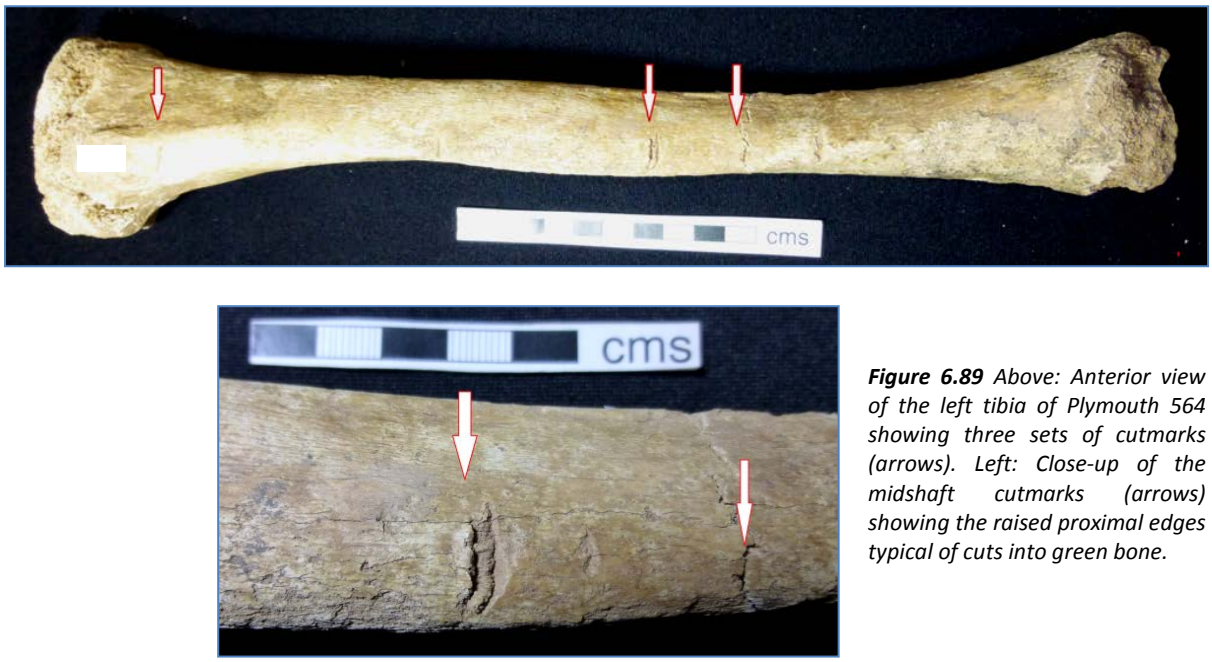


Figure 6.89 *Above: Anterior view of the left tibia of Plymouth 564 showing three sets of cutmarks (arrows). Left: Close-up of the midshaft cutmarks (arrows) showing the raised proximal edges typical of cuts into green bone.*

Seven fibular shaft fractures were transverse, one was a butterfly fracture, one was comminuted and the remainder were spiral or oblique fractures. The most common aetiology of the first three is direct trauma to the element (such as a lateral blow to the leg), whilst spiral and oblique fractures are generally twisting fractures sustained by on landing from a jump or fall, or when one's balance is lost from a standing position.

(xii) Ankle fractures

Ankle fractures in the combined skeletal assemblage comprised 17 distal tibial joint surface and medial malleolar fractures, seven joint surface and metaphyseal fibular fractures (lateral maleolar fractures) and 10 talar dome fractures (Table 6.17). Thirteen ankle bone fractures were located on the left and 21 on the right, suggesting right-sided dominance, but this was not statistically significant (chi-squared 1.44, critical value 6.64, p= 0.01). There were no ankle fractures in the Haslar assemblage, and no fibular fractures in the Plymouth assemblage. All but six right-sided fractures were found in the Greenwich assemblage.

Table 6.17 *Ankle fractures in the combined skeletal assemblage. L= left, R= right, TPR is given in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
L tibia distal	0/ 30 (0%)	0/ 87 (0%)	7/ 93 (7.52%)	7/ 210 (0.33%)
R tibia distal	0/ 26 (0%)	4/ 85 (4.71%)	6/ 91 (6.59%)	10/ 202 (4.95%)
L fibula distal	0/ 27 (0%)	0/ 79 (0%)	3/ 48 (6.25%)	3/ 154 (1.95%)
R fibula distal	0/ 28 (0%)	0/ 72 (0%)	4/ 84 (4.76%)	4/ 184 (2.17%)
L talar dome	0/ 35 (0%)	0/ 86 (0%)	3/ 49 (6.12%)	3/ 170 (1.77%)
R talar dome	0/ 36 (0%)	2/ 81 (2.47%)	5/ 84 (5.95%)	7/ 201 (3.48%)
Total	0/ 182 (0%)	6/ 339 (1.77%)	28/ 352 (7.96%)	34/ 873 (3.9%)

Crushing or impaction of the distal tibial joint surface was present in four individuals, suggesting falls onto the foot (Figs 6.90-6.92). Three vertical and one transverse medial malleolar fracture in three other skeletons (all Greenwich pensioners) suggest that the twisting injuries of the foot were due to landing badly from a jump or fall, or overbalancing from a standing position. The probable mechanism of injury was deduced from fracture patterning in paired distal tibial and fibular fractures, and is summarised in Table 6.18. There was a supination-external rotation injury in Greenwich 6073, supine-adduction injury in Greenwich 3019 and Greenwich 6082, and pronation-external rotation and vertical crushing in Greenwich 3208 (Trafton et al. 1992). The other entries are slightly more speculative.

Table 6.18 *Summary of the seven paired distal tibial and fibular fractures in the Greenwich assemblage.*

Fractures	Medial malleolus	Distal tibial joint surface	Lateral malleolus	Distal fibular shaft	Tibial shaft	Possible ankle injuries
3019	vertical	-	-	-	-	supination-adduction
3148	-	posterior & lateral fracture lines	-	comminuted fracture proximal to plafond	spiral distal shaft	Pronation- abduction injury
3208	vertical	impaction of most of joint surface	oblique proximal to plafond		-	pronation-external rotation with vertical iimpaction
6017	-	posterior metaphysis and joint surface	oblique at plafond	-	-	supination- external rotation injury
6053	-	postero-medial # line	oblique at plafond	-	-	supination- external rotation injury
6073	transverse	-	oblique at or distal to plafond	-	-	supination- external rotation injury
6082	vertical	-	transverse	-	-	supination-adduction



Figure 6.90 *Transverse fracture of the posterior aspect of the distal joint surface of the left tibia of Greenwich 3148 (arrow).*



Figure 6.91 *Multiple fracture lines on the left distal tibial joint surface of Plymouth 671.*

An extreme ankle injury was seen in the left ankle bones of Greenwich 3208 (Plate 6.92), involving extensive impaction of the distal tibial joint surface and a vertical medial malleolar fracture, an oblique lateral malleolar fracture, and impaction of the talar dome. Bony outgrowths at the point of articulation between the distal tibia and fibula suggest lateral collateral ligament rupture. This is a typical pronation-external rotation injury, but given the extent of tibial joint surface crushing, probably followed a fall from a height. In this skeleton, a right distal fibular shaft fracture, which had ankylosed to the tibia (possible interosseous membrane tearing), a left Colles'



Figure 6.92 *Severe left ankle injury in Greenwich 3208. Left: Extensive crushing of the left distal tibial joint surface and fracture of the medial malleolus (arrow); Middle: Crush fracture of the left talar dome with eburnation (horizontal arrow) and an incomplete Shepherd's fracture (vertical arrow). Marked marginal osteophytosis is present; Right: Transverse to oblique lateral malleolar fracture of the left fibula (arrow) with extensive remodelling.*

fracture and a burst fracture of the body of L1 are all consistent with a high impact landing, probably from a fall. All lateral malleolar fractures were found in the Greenwich assemblage: one transverse and four oblique fractures. The former is consistent with a supination-adduction injury, whilst the latter suggests external-rotation injuries. All were well-healed, and only the left fibula of Greenwich 3208 showed marked entheseal damage and extensive periostitis.

Axial impaction and sheer forces may fracture the talar dome. Ten talar dome fractures were present, with three of the left and seven of the right-side. The left talar dome of Greenwich 3208 showed the most marked injury with crushing, secondary eburnation and marginal osteophytosis (Fig. 6.90). This fracture was associated with supination-adduction injuries in other ankle bones. The right talar dome of Greenwich 3139 displayed a characteristic high impact sheer injury: a round depressed lesion characteristic of *osteochondritis dissecans*, but also showed fine fracture lines radiating from the lesion (Fig. 6.93).



Figure 6.93 Posterior view of dome of the right talus of Greenwich 3139 showing the round sheer fracture consistent with osteochondritis dissecans (arrow) with fine radiating fractures.

(xiii) Foot trauma

There are 130 foot bone fractures in the combined assemblage (TPR 2.19%), comprising 70 tarsal, 29 metatarsal, 29 foot phalangeal and two sesamoid bone fractures (Table 6.19). Sixty-nine fractures

were left and 61 right-sided. Side dominance was not statistically significant (chi-squared= 0.38, critical value 6.64, p= 0.01).

Table 6.19 *Foot bone fractures in the skeletal assemblages. L= left, R= right. TPR is given in brackets.*

Elements	Haslar	Plymouth	Greenwich	Combined
L tarsals	1/ 199 (0.5%)	15/ 434 (3.46%)	20/ 504 (3.97%)	36/ 1137 (3.17%)
R tarsals	2/ 183 (1.09%)	14/ 429 (3.26%)	18/ 527 (3.42%)	34/ 1139 (2.99%)
L metatarsals	0/ 158 (0%)	4/ 359 (1.11%)	16/ 408(3.92%)	20/925 (2.16%)
R metatarsals	0/ 168 (0%)	2/ 356 (0.56%)	7/ 404 (1.73%)	9/ 928 (0.18%)
L foot phalanges	0/ 156 (0%)	5/ 327 (1.53%)	7/ 350 (2%)	12/ 833 (1.44%)
R foot phalanges	0/ 118 (0%)	6/ 326 (1.84%)	11/ 383 (2.87%)	17/ 827(2.06%)
L sesamoid	0/ 2 (0%)	1/ 9 (11.11%)	0/ 25 (0%)	1/ 36 (2.78%)
R sesamoid	0/ 4 (0%)	1/ 8 (12.5%)	0/ 22 (0%)	1/ 34 (2.94%)
Total	**3/ 968 (0.3%)**	**48/ 2248 (2.13%)**	**79/ 2724 (2.9%)**	130/ 5940 (2.19%)

Tarsal fractures were dominated by 49 fractures of the lateral process of the posterior tubercle of the talus (Shepherd's fracture). In accordance with modern medical diagnosis (Judd and Kim 2002), only those lesions that showed an irregular fracture surface were included in this study, in order to discriminate fractures from the smooth, rounded margin of *os trigonum*.



Figure 6.94 *Upper left: Bilateral Shepherd's fractures of the tali of Plymouth 845 (arrows); Upper right: Close-up of the healing fracture surface of the left talus of Plymouth 845 (arrow); Lower left: Incomplete Shepherd's fracture of Greenwich 3194 (arrow); Lower right: Complete Shepherd's fracture of Greenwich 3101 (arrow).*



Figure 6.95 *Upper left: Complete fracture of the left navicular bone of Greenwich 3139 (arrow). Upper right: Vertical impaction fracture of the left calcaneus of Greenwich 3255 (arrow). Lower left: Crush fracture of the subtalar joint (vertical arrow), and complete fracture of the posterior process of the medial tubercle of the right talus of Greenwich 3191 (horizontal arrow). Lower right: Fractured head of the left talus of Plymouth 3191(arrow).*

Thirty-eight were complete and 11 incomplete (the process still remaining attached but a clear fracture line crossing the joint surface) (Fig. 6.94)- that is 20.7% of all tali present. Sided dominance was not strongly marked, with 21 being left and 28 being right-sided (TPR left 16.9%; right 24.4%). Bilaterality was present in eight Greenwich and three Plymouth skeletons (involving 61.54% and 27.27% of the Shepherd's fractures, respectively). The markedly higher bilaterality in the older Greenwich assemblage suggests at least some incremental fracturing over time, rather than a single incident in which both processes were simultaneously fractured. Such fractures occur in hyperplantar flexion or forced inversion of the foot (Judd and Kim 2002).

The remaining 20 tarsal fractures involved eight naviculae, five calcanei, four tali (two heads and two sub-talar joints) and two medial cuneiforms. Sub-talar joint fractures of the calcanei and tali are consistent with axial loading, such as landing onto the heel from a fall (Galloway 1999) (Fig. 6.95). Navicular, talar head and cuboid joint surface fractures suggest more anterior impact or torsion injuries of the mid-foot and forefoot, although one complete navicular body fracture (Plate 6.90)

may be due to axial loading. There were no vertical crush injuries consistent with dropping a heavy object onto the foot.

There were 29 metatarsal fractures in the combined assemblage, of which 20 were on the left and nine on the right- side (Table 6.20, Fig. 6.96). Most commonly affected were first and fifth metatarsal fractures (MT1 and MT5), of which there were ten of each. The MT1 fractures included shaft and head fractures, the latter also involving the proximal joint surface of the first proximal phalanx, and in two cases, the sesamoid bones. MT5 fractures were either avulsion of the tubercle or spiral or transverse fractures of the proximal shaft.

Table 6.20 *Metatarsal fractures in the skeletal assemblages (n= 29), MT= metatarsal.*

	Haslar		**Plymouth**		**Greenwich**		**Combined**	
Element	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
MT1	0	0	1	1	7	1	8	2
MT2	0	0	0	0	3	1	3	1
MT3	0	0	1	0	1	1	2	1
MT4	0	0	0	0	2	0	2	0
MT5	0	0	2	1	3	4	5	5
Total	**0**	**0**	**4**	**1**	**16**	**7**	**20**	**9**

There were 29 foot phalangeal fractures: crush injuries to the shafts and joint surfaces (some with ankylosis), and two traumatic amputations of the distal first phalanx (Fig. 6.96).

No ankle or foot dislocations were observed osteologically. Abnormal articulation of the calcanei, tali and/or naviculae indicative of flat feet or *pes planus* (as described by Darton 2007) were noted in eight skeletons. This high prevalence suggests an occupational aetiology. Balancing barefoot on ropes may have stretched the ligamentous structures that maintain the arches of the foot. Alternatively, or additionally, aberrant collagen synthesis in scurvy may have led to increased laxity of the ligaments, producing fallen arches.



Figure 6.96 *Upper left: Proximal joint surfaces of the left metarsals of Greenwich 3143, showing fractures of MT1, 2 and 5. The shafts of MT3 and 4 were also fractured. Upper right: Impacted left MT1 head with remodelling. Lower left: Healed transverse avulsion of the tubercle of the right MT5 of Greenwich 3143, showing gross malalignment; Lower right: Amputated distal phalanx of the right hallux of Plymouth 844.*

6.2.3. Fracture prevalence and age structure

There were more than five times the number of fractures per person in the Greenwich than in the Haslar and Plymouth assemblages (Table 6.21). Fractures accumulate over a lifetime (Glencross and Sawchuk 2003; Jurmain 1999; Jurmain et al. 2009), and hence it is important to explore the extent to which this considerable difference is due to the greater mean age-at-death of the Greenwich assemblage. Correcting for age distributions of the three assemblages facilitates more meaningful comparison of fracture prevalence between the three assemblages.

The mean number of fractures in each age category showed a strong positive association between fracture frequency and increasing age (Figure 6.97; Table 6.21**).** There were no fractures in the single child skeleton (Plymouth 624), but in the combined assemblage, there was a mean fracture rate of 0.43 *per capita* in adolescents, 0.87 in young adults, increasing to 5.51 in prime adults. Crude prevalence dipped in the mature adults (3.64 fractures per skeleton), but then increased markedly in older adult categories (6.31 fractures per person). When the three

Figure 6.97 *The number of fractures per skeleton in each age category in the skeletal assemblages (N= 300 skeletons; n = 926 fractures).*

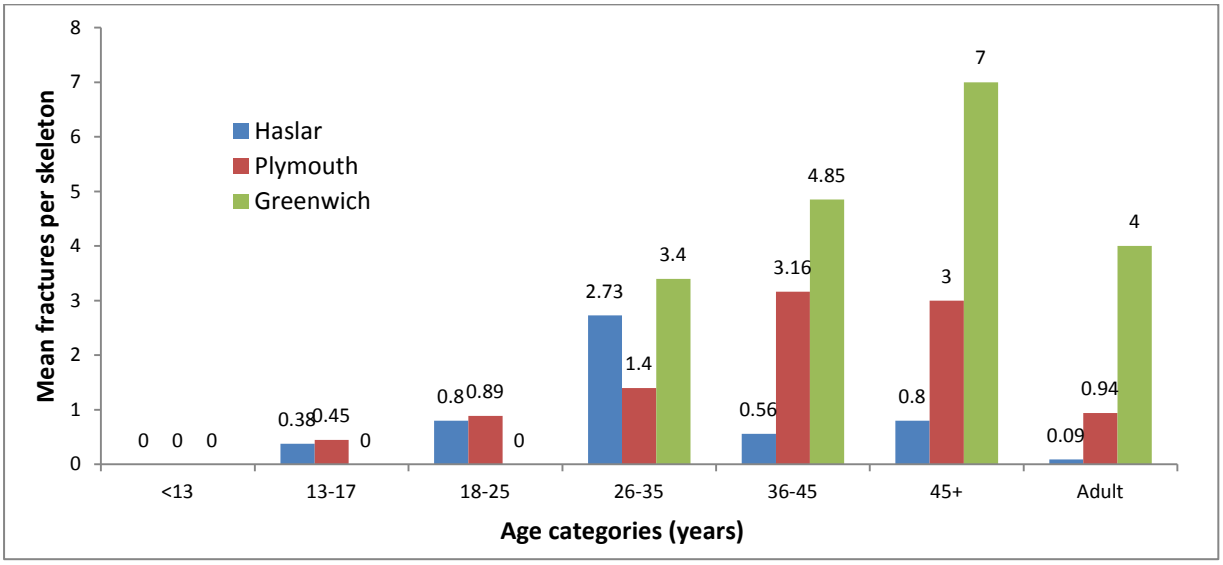


Table 6.21 *Fracture numbers in each age category in the three skeletal assemblages, and in the combined assemblage; N = number of skeletons; n = number of fractures; n/N= fractures per individual.*

	Haslar			Plymouth			Greenwich			Combined		
Age category	**N**	**n**	**n/N**	**N**	**n**	**n/N**	**N**	**n**	**n/N**	**N**	**n**	**n/N**
<13	0	0	0	1	0	0	0	0	0	1	0	0
13-17	8	3	0.38	20	9	0.45	0	0	0	28	12	0.43
18-25	10	8	0.8	28	25	0.89	0	0	0	38	33	0.87
26-35	11	30	2.73	43	60	1.40	5	17	3.4	59	107	5.51
36-45	5	9	0.56	31	98	3.16	20	97	4.85	56	204	3.64
45+	4	5	0.8	9	27	3	73	511	7	86	543	6.31
Adult	11	1	0.09	19	18	0.94	2	8	4	32	27	0.84
Total	**49**	**56**	**1.14**	**151**	**237**	**1.57**	**100**	**633**	**6.33**	**300**	**926**	**3.09**

assemblages were considered separately, the relationship of fracture increase with age is very clear in the Greenwich assemblage, but in the Plymouth assemblage crude prevalence rates did not increase much beyond 26-35 years. In the Haslar group, there is slight fluctuation but overall this relationship was not apparent.

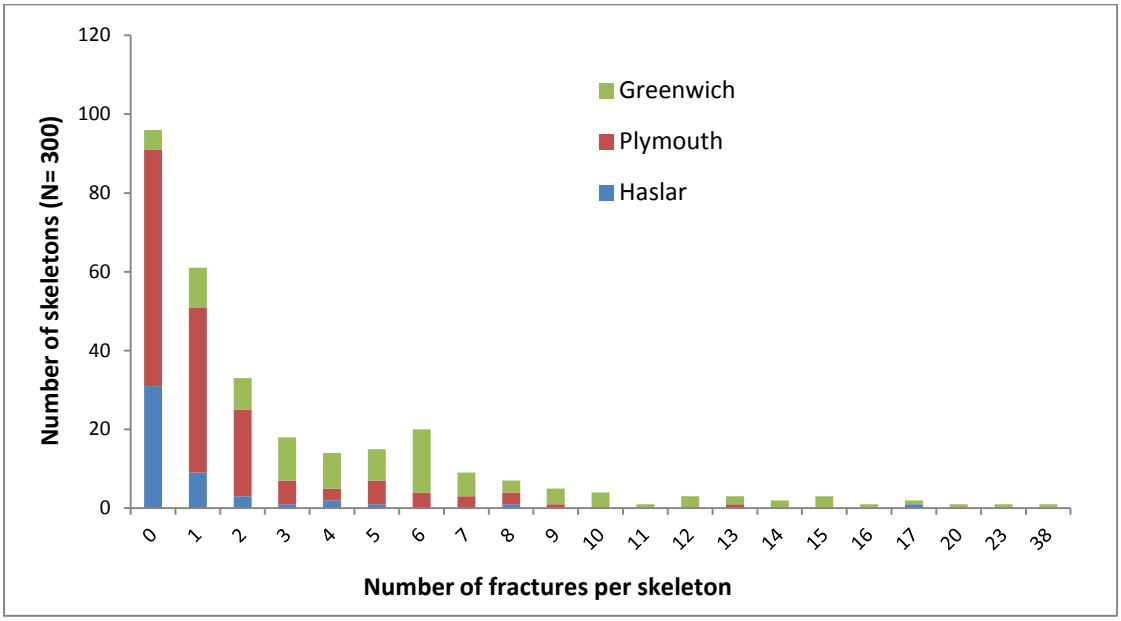
The mean number of fractures *per capita* was markedly greater in the Greenwich assemblage than in the Haslar and Plymouth assemblages in all adult age categories, suggesting that selection of in-pensioners was a significant factor in fracture rates. Correction for differing age structures of the

three assemblages was undertaken using Glencross and Sawchuk's (2003) person-years construct, by dividing the number of fractures in the assemblage by person-years (calculated by multiplying the number of individuals in each age category with the mid-point of each age range and adding these together). Due to the very wide age range possible within the 45+ year bracket, the historically known mean age of the Greenwich pensioners (70 years) was used as the mid-point of this group. There were 0.03 fractures per person year in Haslar, 0.04 in Plymouth and 0.10 in Greenwich. Thus, even after correcting for age, the Greenwich assemblage had more than three times the number of fractures of the Haslar assemblage, and 2½ times more than the Plymouth assemblage. Thus, it is clear that the Greenwich fracture rate was not representative of seamen and marines on active service, but represents the extremes of injury in that force. Plymouth's fracture numbers per person years is greater than in Haslar, but this difference is less marked.

6.2.4. Multiple fractures in individual skeletons

The number of fractures per skeleton in the combined osteological assemblage ranged from nil to 38. No fractures were noted in 96 skeletons (32%). Sixty-one individuals had suffered one fracture (20.33%), 33 had suffered two (11%), 18 had suffered three (6%), 14 had suffered four (4.67%), 15 five (5%), and 20, six (6.67%), nine suffered seven (3%), seven eight (2.67%), five nine (1.67%), and four ten fractures per skeleton (1.33%) (Fig. 6.98). Thirteen individuals displayed between 11 and 15 fractures per person (4.33%), four between 16 and 20 fractures (1.33%), a single skeleton displayed 23, and another, 38 fractures. With the exception of Plymouth 674 with 13 fractures, and Haslar 214 with 17 fractures, all individuals with ten or more fractures were Greenwich pensioners. The skeletal catalogue in Appendices 13-15 summarises the distribution of fractures in each individual. Association between fractures, and their probable aetiology in a naval context is discussed in Section 7.4. The question of injury recidivism is discussed in Section 7.3.3.

Figure 6.98 *The number of fractures per skeleton in the three R.N. osteological assemblages (n= 926 fractures; N= 300 skeletons).*



6.3. Historical evidence for trauma

6.3.1. Introduction

Historical evidence of trauma patterning in this section is based on a sample of eight years of the Haslar and Plymouth musters: 1792-1796, 1800 and 1810-1811 (Haslar Hospital Musters 1792-1824; Plymouth Hospital Musters 1792-1824). Evidence from Greenwich Hospital is largely based on Hospital Entry Books records compiled from Wilcox's (2011) database, selecting those entries in which the individual died after 1749, when the Goddard's Ground cemetery was open.

6.3.2. Trauma over time

Despite the manifold hazards of life at sea, trauma (including soft tissue and bony injury) affected only a very small proportion of admissions to Haslar and Plymouth Hospitals in the eight years studied (Table 6.22). Trauma rates (a percentage of total admissions) fluctuated between 2.83% and 8.52% of Haslar admissions, and 5.17% and 12.57% of Plymouth ones. The rates in Haslar were highest in the peacetime of 1792 (8.52%) and then fluctuated between 4.2% and 6.73% in the 1790s in the French Revolutionary Wars, and gradually dwindled to 2.83% by 1811 during the Napoleonic Wars. Trauma rates in the Plymouth musters were also highest in 1792 (12.57%), and fluctuated

between 5.46% and 8.08% in the years that followed, but did not display the downward trend seen in the Haslar musters of 1810 and 1811.

Being the larger hospital, the absolute number of admissions for trauma to Haslar was greater than those admitted to Plymouth Hospital (Table 6.22). The mean proportion of trauma cases was consistently higher in the Plymouth assemblage, in all years, bar 1793 (Haslar 5.77%, Plymouth 5.46%), however (Fig. 6.99). This difference may reflect a subtly different composition of the two populations, possibly due to the difference in theatre of operations from which the two populations were drawn. Analysis of those sea surgeon's logs that recorded transferring patients to Haslar and Plymouth Hospitals between 1790s and 1815, revealed subtly different 'catchment areas', with Haslar patients serving predominantly in the Channel and Mediterranean, whilst more Plymouth seamen served in the West Indies and Americas (Roberts et al. 2012). Mortality rates in Plymouth Hospital were consistently lower than in Haslar in each sample year, bar 1811. This may reflect intrinsic differences between the two patient groups, or, indeed, better care in Plymouth Hospital over this period.

Table 6.22 *Mortality rates and the number and proportion of traumatic admissions in the Haslar and Plymouth Hospital musters of 1792-96; 1800 and 1810-1811.*

Haslar						**Plymouth**				
Year	**Number of deaths**	**Hospital admissions**	**Mortality rate**	**Trauma cases (n)**	**Trauma admissions (%)**	**Number of deaths**	**Hospital admissions**	**Mortality rates**	**Trauma cases (n)**	**Trauma admissions (%)**
#1792	45	1327	3.39	113	8.52	21	859	2.44	108	12.57
1793	330	5654	5.84	326	5.77	122	6188	1.97	338	5.46
1794	496	8949	5.54	591	6.60	164	4237	3.82	407	9.61
1795	473	8087	5.85	340	4.20	165	3569	4.63	259	7.26
1796	459	6474	7.09	436	6.73	219	2859	4.69	231	8.08
1800	312	4755	6.56	199	4.19	281	6358	4.42	329	5.17
1810	324	3675	8.82	147	4.00	229	3289	6.96	259	7.87
1811	328	6534	5.00	185	2.83	193	2889	6.69	182	6.30
Total	**2767**	**45455**	**6.09**	**2337**	**5.14**	**1394**	**30248**	**4.61**	**2113**	**6.99**

Trauma admissions to both hospitals were predominantly due to soft tissue injuries (commonly wounds and contusions). Of the above-mentioned trauma cases, 478 fractures were recorded in the

Haslar and 373 in the Plymouth musters- comprising 20.45% and 17.7% of trauma admissions, respectively (Table 6.23). This proportion varied over time. When combined, fracture rates as a percentage of trauma admissions were constant from 1792-1794 at 14.8-14.9%, but escalated in the French Republican Wars in 1795 (19.7%), dropped slightly in 1796 and 1800 (16.9% in both years), but then almost doubled to 32% in the 1810s. The last rapid rise may be explained by a change in battle tactics in the latter years of the Napoleonic Wars, such as increased amphibious attacks, which involved more close-quarters fighting than in most sea battles.

Figure 6.99 *Trauma rates recorded in the Haslar and Plymouth Hospital musters of 1792-96; 1800 and 1810-11; N = 45,455 Haslar admissions and 30,248 Plymouth admissions.*

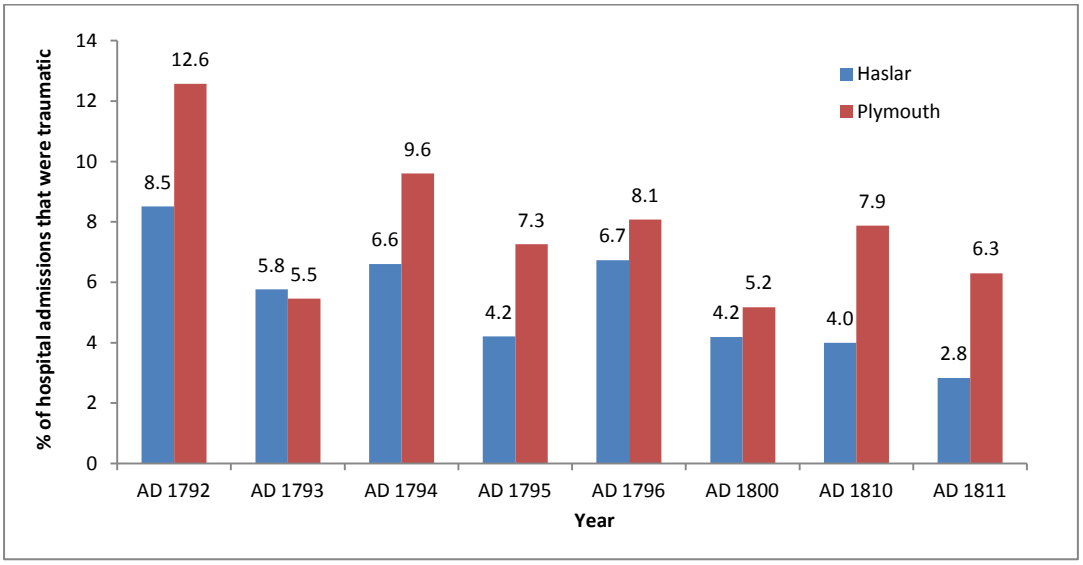


Table 6.23 *Percentage of fractures to trauma cases in the combined Haslar and Plymouth Hospital musters (N= 4,450 trauma cases).*

Years	1792	1793	1794	1795	1796	1800	1810	1811
Fractures	33	98	148	51	113	89	130	108
Trauma cases	221	664	998	259	667	528	406	367
Percentage	14.9	14.8	14.8	19.7	16.9	16.9	32.0	29.4

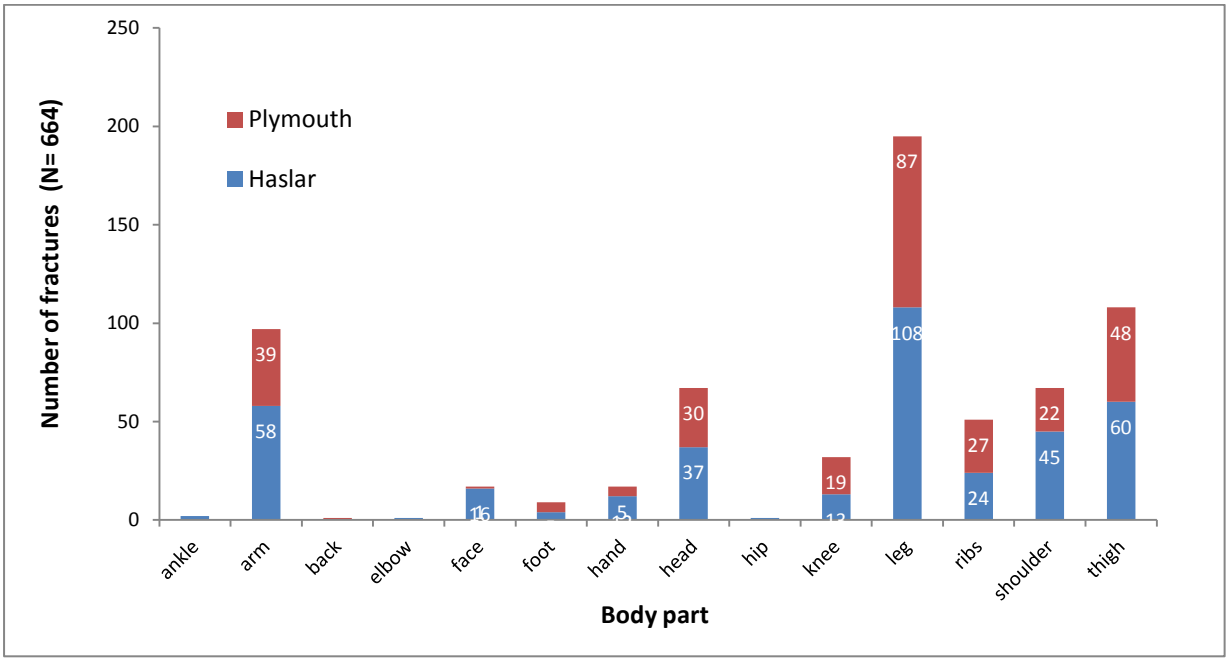
6.3.3. Fracture distribution

A total of 851 fractures were recorded in the combined hospital musters, and their location by body part was detailed in 664 cases (Table 6.24). Unfortunately, the side affected was only recorded in a minority of cases, and hence side dominance of injuries could not be explored.

Table 6.24 *Number of fractures by body part in Haslar and Plymouth musters (N = 851).*

Years	1792	1793	1794	1795	1796	1800	1810	1811	Total number	% of all fractures	% fractures of known location
ankle				1				1	**2**	**0.2**	**0.3**
arm	3	10	26	13	17	7	12	10	**97**	**11.4**	**14.6**
back					1				**1**	**0.1**	**0.2**
chest		7	6	17	8	4	2	7	**51**	**6.0**	**7.7**
elbow					1				**1**	**0.1**	**0.0**
face	2	3	4	2		2	3		**16**	**1.9**	**2.4**
foot	1	1		3	3	1			**9**	**1.1**	**1.4**
hand	4	3	2	2	1	2		3	**17**	**2.0**	**2.6**
head	3	7	11	12	8	10	5	11	**67**	**7.9**	**10.1**
hip			1						**1**	**0.1**	**0.2**
knee	1	4	4	10	1	4	5	3	**32**	**3.8**	**4.8**
leg	9	30	32	23	25	16	31	29	**195**	**22.9**	**29.4**
shoulder	4	9	9	11	14	9	7	4	**67**	**7.9**	**10.1**
thigh	2	8	23	18	17	12	12	16	**108**	**12.7**	**16.3**
Not specified	4	16	30	20	18	22	53	24	**187**	**22.0**	
Total	**33**	**98**	**148**	**132**	**113**	**89**	**130**	**108**	**851**	**99.8**	**100.0**
% of total fractures	**3.9**	**11.5**	**17.4**	**15.5**	**13.3**	**10.5**	**15.3**	**12.7**		**100**	

Figure 6.100 *The number of fractures of known location in each body part compiled from the Haslar and Plymouth musters (1792- 1811), N= 664.*



Long bone fractures constituted 60.5% of all hospital admissions for fracture: leg (29.4%), then thigh (16.3%) and arm (14.6%). Head (excluding the face) and shoulder both comprised 10.1%, and the chest (7.7%) (Table 6.24; Fig. 6.100). Facial injuries only comprised 2.4%. The shoulder was most

frequently fractured joint (29.4%), followed by the knee (4.8%), whilst only one case of elbow, hip and back fractures and two of ankle fractures were recorded. Fracture patterning appeared very similar in both hospitals (Fig. 6.100).

Eighty-one dislocations were listed in the hospital muster sample (Table 6.25). These are generally described by joint, but the patella and clavicle are two elements frequently specified. The clavicle suffered most frequent dislocation (25%), followed by the shoulder (23.6%) and the arm (15.3%). The last was probably dislocated at the shoulder joint, but this was not specified. If so, shoulder dislocations accounted for 63.9% of all dislocations. This was followed by ankle (13.9%), 4.9% hand (including one thumb dislocation) and patellar dislocations (4.2%). There was a single recorded dislocation of the hip, and one of the thigh (joint unknown), foot, knee and elbow.

Table 6.25 *Hospital admissions for joint dislocation recorded in the Haslar and Plymouth Hospital musters (n= 81).*

Element	Haslar	Plymouth	Total dislocations	% of dislocation of known location
jaw	2		2	2.8
ribs			0	0
clavicle	13	5	18	25
shoulder	6	11	17	23.6
arm	10	1	11	15.3
elbow		1	1	1.4
hand	2	1	3	4.2
thumb	1		1	1.4
finger			0	0
hip	1		1	1.4
thigh	1		1	1.4
knee	1		1	1.4
patella	2	1	3	4.2
leg	2		2	2.8
ankle	4	6	10	13.9
foot		1	1	1.4
Not specified	5	4	9	
Total	**50**	**31**	**81**	**100**

The majority of patients with trauma admitted to Haslar and Plymouth Hospitals had soft tissue injuries, most commonly wounds (20.99% of trauma admissions), contusion (37.03%) and loss of

voluntary motor control of a body part (including hemiplegia, palsy and '*lameness*') (5.80%). Detailed bodily distribution in each of these categories is presented in Appendix 6. In brief, the head was the common location of wounds, followed by the leg and then the arm. Contusions showed a very different distribution, with the loins being most affected, followed by the back and the head, then the side and breast. '*Lameness*' most commonly affected the arm, and then the hand, followed by the leg, foot and ankle. There were 173 individuals admitted with amputated limbs, of which the ankle was the most common site, followed by the arm, elbow and finger. Two individuals had amputations at the hip- an ambitious but not unknown operation at that time (Crumplin 2007). One knee and one leg amputation were listed, but there were no thigh amputations.

Of the 899 trauma cases described in the Greenwich Hospital in-pensioner entries listed in Wilcox's (2011) database, only 19 fractures are listed (Table 6.26). Fourteen were major limb bones (arm 11%, leg 26% and thigh 26%). Rib (26%) and shoulder fractures (11%) comprised the remainder. One pensioner was described as having a '*weakened and distorted ankle*' (presumably chronic dislocation and/or fracture) and four were listed as '*lame through old wounds'*. Several others were described comprehensively as '*broken*'. It must be stressed that only the most debilitating and visually arresting injuries were recorded, and this list does not reflect the true fracture numbers in this group.

The vast majority of the Greenwich trauma cases were described as '*wounded*', most commonly in the leg (n= 153), followed by the eye (n= 141), the arm and hand (n= 91) and the thigh (n= 41). It is unclear if these were soft tissue injuries or also included fracture. There were also 86 amputations, of which the leg was most common (n= 37), followed by the arm (n= 26), hand (n= 22) and ankle (n= 1). No thigh amputations were listed, although three of the seven amputations in the Greenwich skeletal assemblage were femoral (possibly post-dating this historical sample).

Comparison of major long bone fractures recorded in the combined Haslar and Plymouth musters (Fig. 6.101) and the Greenwich Entry Books (Fig. 6.102) revealed that the proportion of arm fractures

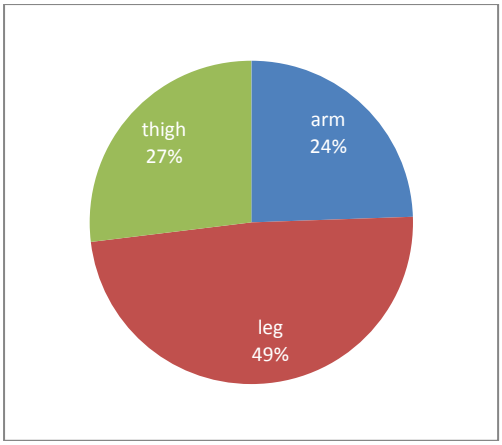


Figure 6.101 *Pie chart showing the proportion of major long bone fractures recorded in the combined Haslar and Plymouth musters (n= 401).*

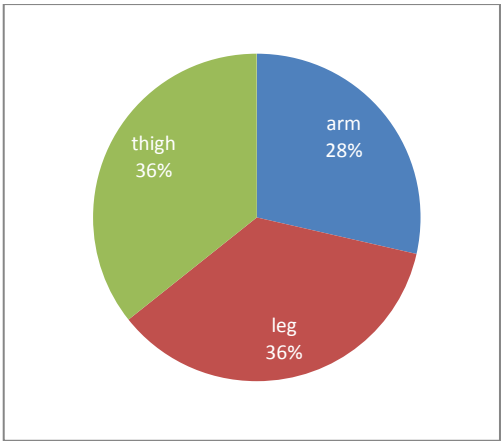


Figure 6.102 *Pie chart showing the proportions of major long bone fractures recorded in the Greenwich Entry Books (n= 14).*

Table 6.26 *Trauma listed in the Greenwich Entry Books from 1749 (N= 889).*

Element	Fracture	Dislocation	Amputation	Wound	Lameness	Total
head				47		**47**
eye				141		**141**
face				6		**6**
jaw				1		**1**
neck				6		**6**
back				24		**24**
breast				14		**14**
ribs	5			17		**22**
side	2			52		**54**
abdomen				6		**6**
loins				11		**11**
hip				3		**3**
shoulder	2			22		**24**
arm	2		26	91	1	**120**
elbow						**0**
hand			22	91		**113**
thumb					3	**3**
thigh	5		0	41		**46**
knee				27		**27**
leg	5		37	153		**195**
ankle			1	5	1	**7**
foot				18		**18**
Not specified				1		**1**
Total	**21**		**86**	**777**	**5**	**889**

was broadly similar (24% and 28%, respectively), but that femoral/ thigh fractures were more prevalent in the Greenwich assemblage and leg fractures in the combined Haslar and Plymouth assemblage. This presumably indicates greater disability associated with femoral fractures, which encouraged greater selection for in-pensioner status than did below the knee fractures. Caution with interpretation is necessary, however, given the small sample size of the Greenwich fractures.

7. Discussion

7.1. Introduction

The principal aim of this study is to compare the osteological evidence for trauma in the late 18th- early 19th century R.N. with documentary evidence, taking into account the strengths and limitations of each approach. Through the examination of both bodies of evidence, it is apparent that there was considerable trauma experienced by seamen and marines in the R.N., with fractures numbering more than 900- that is more than three per individual. Fracture types and locations were very diverse suggesting a range of aetiologies.

In order to compare the datasets critically and to explore what the fracture patterning reveals about life in the late 18th- to early 19th century R.N., it is seminal to explore (1) the strengths and limitations of these datasets, (2) if the skeletal assemblages of this study are representative of the '*lowerdeck*' of R.N. of this period and, similarly, for the muster data on which the historical perspective is chiefly based (3) if the fracture patterning seen in the combined R.N. skeletal assemblage really is different from 18th century civilian assemblages, and (4) what insights into life in the R.N. may be gleaned from fracture type and distribution, using both the historical and osteological sources.

7.2. The strengths and limitations of the datasets

7.2.1. The skeletal assemblages

The combined skeletal assemblage of Haslar, Plymouth and Greenwich Hospitals is a rare and osteologically valuable representation of a specialist group in which the effects of a very specific lifestyle on the skeleton may be explored. Together, the skeletons constitute a fairly large contemporary assemblage of late adolescent and adult males, who lived a rigidly regulated lifestyle, undertook repetitive, dangerous and physically strenuous tasks, consumed a tightly prescribed diet, and spent a significant proportion of their lives in relative isolation of their civilian contemporaries. The assemblages are broadly contemporaneous, and, by archaeological standards, date to a narrow time period, during which the lifestyle of the 'lowerdeck' did not fundamentally change.

The assemblages date to a historic period in which Britain was almost constantly at war, and relied extensively on her Navy to protect her national interests. These conflicts were truly global in their dispersal. As a result, seamen and marines were at sea for long periods, either in local waters (such as the long-running blockade of Brest, or patrolling the Channel and North Sea), or further afield, particularly in the Mediterranean, Atlantic and Caribbean. Multiple small-scale enemy engagements as well as large battles, including Cartagena (1758), Quiberon Bay (1759), the Glorious First of June (1794), the Battle of Cape St Vincent (1797), Camperdown (1797), the Nile (1798), Copenhagen (1801) and Trafalgar (1805) and all fall within this period. Thus, it is highly probable that a significant proportion of the individuals whose remains were analysed in this study did indeed see action, and spent much of their working lives at sea, frequently on long cruises. In this way, they may be seen to differ from earlier and later seamen, who spent more time in port or undertook shorter sea voyages often in home waters (such as the *Mary Rose* seamen) (Stirland 2005a).

Another major difference between the 18th century R.N. crews and other maritime assemblages excavated from shipwrecks (reviewed in Appendix 2) is that the former did not normally include terrestrial soldiery. Marines (becoming the Royal Marines in 1802) differed from land-based soldiers, in being specifically trained to operate at sea from a young age, and spent a significant proportion of their working lives afloat (Donald and Ladd 1982). Thus, although they probably did not incur the injuries of sailors associated with working aloft, they would have been equally susceptible to injuries sustained on and between decks, and in combat. There was no archaeological or historical means of distinguishing between seamen and marine burials in the three burial grounds, and osteological attempts to distinguish between their skeletons were highly speculative, and were abandoned early in the analysis. In this analysis, it is assumed that they constituted a similar small proportion of the skeletal assemblage as those aboard ship (at most 15-18% of the assemblages (Lewis 1960b)).

A seminal issue surrounding all osteological attempts to interpret aspects of past lives from skeletons is the question of representation. Do the dead really reflect the demographical

composition, health and activity patterns of the living population from which they were drawn, or do they represent an uncharacteristic 'biologically weak' sub-group within that society- the issue coined the Osteological Paradox (Wood et al. 1992)?. In the R.N. assemblages, this question may be explored on several levels. Firstly, the Haslar and Plymouth assemblages were drawn directly from seamen and marines serving aboard ship, and as such may well directly represent them, but afterall, they are hospital populations. Such hospital populations may well be considered unrepresentative of serving men, as they may be seen as comprising the physically weaker members of the group, who were vulnerable to contracting and subsequently dying of diseases. However, unlike patients with disease, one might argue that individuals suffering trauma are not necessarily 'weaklings', but just unfortunate- that their injury was due to chance alone. In the R.N., some of the strongest, fittest men (the topmen) had the most dangerous jobs, and were most expose to serious accident, but, when injured, cannot be regarded as atypical 'weaklings' of the group. A wide range of other organisation factors may also influence risk of trauma in seamen and marines. For example, in a sea battle, where a seaman or marine was positioned in the ship had considerable bearing on his risk of death or serious injury, with those on the upper deck being most exposed to enemy fire (Crumplin 2007; Fremont-Barnes 2008). This location had little or nothing to do with an individual's personal attributes. Everyday injuries on deck would have affected most of the crew alike, although those less adept at keeping balance of a moving deck, those more reckless, or those with a penchant for heavy drinking (see below) may well have been more vulnerable to falling or brawling injuries. Such individuals might be termed 'injury recidivists' (Judd 2002; Poole et al. 1993; Poole et al. 1997) (see Section 7.3.3).

Hospital musters indicate that the majority of trauma cases in the hospitals survived, and were either 'discharged unserviceable' or discharged to their ships (Haslar Hospital Musters 1792-1824; Plymouth Hospital Musters 1792-1824). Differences in individual physiology and pervading health status influence those who survived and who did not, and were interred in the burial ground. Trauma patients, admitted several days or weeks after injury to Haslar and Plymouth Hospitals, had

survived the most immediate life-threatening effects of trauma (such as fat embolism and haemorrhage), but were still vulnerable to the risks of secondary infection, the hazards of prolonged bedrest and immobility (such as hospital-acquired pneumonia, deep vein thrombosis and pressure sores) and surgical procedures. Osteological analysis revealed that many individuals with trauma suffered active co-morbidies, such as scurvy, chronic respiratory disease (active rib periostitis being present in 25.35% of skeletons) and non-specific infections (summarised in Appendices 13-15), which may have influenced healing and, ultimately, recovery. That said, the overwhelming majority of fractures and dislocations in the osteological assemblages were well-healed, incurred long before death, and probably had no bearing on the cause of an individual's demise. Thus, the question of how representative overall trauma patterning in the skeletal assemblages is of trauma patterning in the living 'lowerdeck' of the R.N., is a complex one, but may not be as unrepresentative as it initially appears.

Greenwich Hospital, in essence, was a retirement home housing long-serving and severely disabled naval veterans, who principally comprised elderly, retired seamen in the last few years of life (Boston et al. 2008). Both the selection for age and disability have considerable bearing on how representative was the trauma patterning in this group of serving seamen and marines of the day. One of the most obvious inter-group differences was age structure, with Haslar and Plymouth muster and skeletal assemblages being much younger than the Greenwich pensioners (using both historical and osteological datasets). These differences have a direct bearing on fracture prevalence, patterning and the question of representation.

Hospital musters record only seamen and marines from ships treated in Haslar and Plymouth Hospitals- that is men on active service. Historical analysis by Rodger (1986) and Slope (2006) indicate a young age distribution aboard ship peaking in the young adult category. The Haslar and Plymouth skeletal assemblages were slightly older, peaking in prime adulthood, but both groups were nevertheless young assemblages. The subtle age differences between the historic 'living

population' and the dead (skeletons) suggest a slight age differential in survivorship, in which more prime adults were admitted to the hospital and/or died there- an example of the osteological paradox (Wood et al. 1992).

One might argue that whilst the dead of Haslar and Plymouth Hospitals constitute the 'biological failures' of the R.N., the elderly Greenwich pensioners represent survivors *par excellence*. But are these battered, old survivors any more representative of the lowerdeck than the dead of Haslar and Plymouth Hospitals? Fractures accrue incrementally over a lifetime, and hence, there is an expected correlation between increased longevity and fracture count (Lovejoy and Heiple 1981). Thus, the predominantly elderly Greenwich pensioners would be expected to display a higher fracture count than younger men on active service. Osteological analysis revealed that the Greenwich fracture rates outstripped younger Haslar and Plymouth skeletal assemblages three- to four-fold (TPR 4.6%, 1.0% and 1.6%, respectively).

Whilst fracture numbers accrue with age, the location and type of fractures are frequently linked to the age of the sufferer at the time of fracture (Van Staa et al. 2001). The mechanical properties of bone change over a lifetime, being much more pliant in childhood and becoming stronger but less flexible in adulthood, until osteopaenia in older age renders bone brittle and liable to fracture (Galloway 1999; Hipp et al. 1992; Roberts and Manchester 2005; Stuart-Macadam et al. 1998). Incomplete greenstick and bowing injuries are common in the first two decades of life when bone is more pliant (Resnick and Niwayama 1995), and several examples were present in the skeletal assemblages. Heavy loading of immature bone, before it has attained full structural strength, however, may result in failure more readily than adult bone (e.g. spondylolysis, Schmorl's nodes and *osteochondritis dissecans*) (Mays 2006; Mays 2007). High prevalences of *osteochondritis dissecans* in the distal humerus and *os acromiale* suggest strenuous use of the shoulder and upper limb from a young age, and is consistent with seamen joining the navy as children and adolescents,.

Overall fracture rates peak at two periods in the lifecycle: in adolescents and young adulthood (due to risk-taking behaviour), and in older age, secondary to osteoporosis (Lovejoy and Heiple 1981), although specific fractures show more individual patterning (Buhr and Cooke 1959; Court-Brown and Caesar 2006). In modern populations, young males are 2.9 times more likely to suffer fractures than females, but, in older adulthood, post-menopausal female osteoporotic fractures dominate (2.3 times the male rate) (Buhr and Cooke 1959; Court-Brown and Caesar 2006; Singer *et al.* 1998; Van Staa *et al*. 2001).

Although older males do not suffer the oestrogen level drop and associated osteoporosis of post-menopausal females, greater vulnerability to fracture in older males may be associated with poorer vision and balance, coupled with marked reduction in muscle strength and disuse atrophy of the skeleton (Buhr and Cooke 1959). These fractures tend to occur much later than in females (over 70 years for wrist and hip fractures; over 75 years for femoral and tibial diaphyseal fractures; and over 80 years in vertebral fractures (Singer et al. 1998)). The historical mean age-at-death of Greenwich pensioners was 70 years, with many amongst them being octo- and nanogenerians. Thus, some such fractures in the Greenwich pensioners may have been age-related. The very advanced state of healing in an overwhelming majority of fractures, however, suggests they occurred many years, even decades before death.

The propensity to fall and fracture a bone is probably heightened in elderly men in which gait is adversely affected by fracture complications. A prime example is Greenwich 3229 where an ununited floating rib and sacral neural arch fractures were still healing at the time of death. This individual showed well-healed bilateral femoral fractures with unequal shortening of the lower limbs and rotation of the distal parts (Plate 6.69). He also suffered from tertiary syphilis. Thus, a backward fall from standing height as a consequence of unsteady gait induced by advanced age, femoral fracture malunion and/or *tabes dorsalis* of neurosyphilis was probable. Like seamen of all ages, the Greenwich pensioners were notorious for drunkenness (Newell 1984), and this may well have

contributed to fractures later in life. Healing sharp force trauma to the maxilla of Greenwich 3272 (Plate 6.18) indicates that there was no upper age limit to interpersonal violence either.

As a converse to the advancing-age-equals-more-fractures equation, is the consideration that some incomplete or very well-aligned fractures may completely remodel with time (e.g. greenstick fractures of childhood), so that they are no longer macroscopically nor radiologically visible (Mays 2008). In effect, they disappear from the osteological record. This effect is obviously greater the longer the individual survives the insult, and is particularly pertinent to the elderly Greenwich pensioners, who may have lived many decades after incurring an injury.

Whilst modern medical research undeniably offers invaluable insights into fracture epidemiology, there are extraneous factors complicating direct comparison with past populations. As modern Western populations age, so the proportion of fractures associated with osteoporosis in the elderly rises. Serial epidemiological studies in Britain in the 1950s (Buhr and Cooke 1959), 1980s and 1990s (Singer *et al.* 1998; Van Staa *et al.* 2001) and 2000s (Court-Brown and Caesar 2006) demonstrate this temporal trend. In addition, the incidence of high energy trauma (e.g. motor vehicle accidents and occupational hazards) in the younger age categories has fallen due to tighter traffic and health and safety regulations in recent decades. Today, fractures traditionally associated with high energy trauma are more common in elderly osteoporotic females (e.g. femoral shaft fractures) (Court-Brown and Caesar 2006). Thus, modern Western fracture epidemiology is increasingly diverging from probable patterning in past populations, and generally becoming much less relevant as a comparative population to osteoarchaeologists.

The effect of age structure on inter-populational comparisons may be profound, and correction for different age structures of the three R.N. skeletal assemblages was undertaken using the person-years construct (Glencross and Sawchuk 2003; Lovejoy and Heiple 1981). Even after correction for age, the Greenwich assemblage still showed three times the Haslar and 2.5 times the Plymouth fracture rate.

The relationship between longevity and fracture rates is not necessarily a linear one, however, as certain episodes in an individual's life may carry more physical risk than others. Thus, length of sea service may have had considerable influence on fracture rates in the R.N. assemblages, as well as age-at-death. Mean years of sea service in the *Bellerophon* crew (Rotheram 1799- 1815) was markedly lower than that of Trafalgar veterans who became Greenwich in-pensioners (Boston *et al.* 2008) (10.6 years and 15.7 years respectively). Thus, long service was probably a key factor in such marked inter-populational fracture rate differences. Specific selection criteria for disability for admission to Greenwich Hospital probably accounts for the rest. Thus the Greenwich pensioners represent the extremities of trauma in the R.N. of this period.

Fracture patterning in naval and civilian archaeological populations

In order to be able to assert that fracture rates in the R.N. skeletal assemblage were particularly high, it was necessary to compare them with contemporaneous civilian rates. Due to the low fracture prevalence in most skeletal assemblages, many TPRs were based on the presence of a single fracture per element, making meaningful comparison difficult. The problems associated with low fracture prevalence in most archaeological assemblages are discussed in other fracture studies (e.g. Glencross and Sawchuk 2003; Jurmain 1999). Indeed, some oft-quoted studies comprise very small fracture numbers. For example, a study of fractures in medieval skeletons from St Helen-on-the-Walls, York, was based on only 41 fractures (Grauer and Roberts 1996), whilst another contrasting the rural assemblage of Raunds Furnells, Northamptonshire, with contemporary urban medieval assemblages was based on only 39 fractures (Judd and Roberts 1999).

Another critique of inter-populational comparison is that in spite of the tremendous influence of sex on fracture prevalence and type (Jurmain 1999; Singer et al. 1998; Van Staa et al. 2001; Waldron 2009), many osteological reports fail to display fracture rates according to sex. This greatly impeded meaningful comparison with the all-male naval assemblages. Given that males generally experience

higher fracture rates than females, the TPR differences between the all-male R.N. rate and that of civilian assemblages were probably narrower.

Comparisons between R.N. and civilian fracture patterns were limited by the dearth of osteological studies in which TPRs are presented. Five comparative osteological studies were collated (Table 7.1): a compilation of eight post-medieval sites (sites not specified) in Roberts and Cox (2003, Table 6.4, p. 302), St Benet's Church Sherehog, London (Miles et al. 2008b), the Baptist Chapel, Butt Road, Poole (McKinley 2008), St George's Church, Bloomsbury, London (Boston *et al*. 2009) and St Martin's Church, Birmingham (Brickley *et al*. 2006). Data was incomplete in all the studies. Most authors reported only on elements that were fractured, and thus an overall TPR of all skeletal elements was not available for comparison. In addition, low fracture rates in individual elements of the civilian assemblages rendered the value of some comparisons doubtful. The most useful fracture TPR study of civilians were pooled data of 172 fractures from up to eight assemblages (Roberts and Cox 2003) and, to a lesser extent the 64 fractures (largely long bones) of St Martin's Church, Birmingham (Brickley *et al*. 2006).

Bearing the above caveats in mind, it is immediately apparent is that, in general, fracture rates in the combined R.N. skeletal assemblage were considerably higher than in contemporary civilian assemblages. The former displayed almost three times the overall TPR of selected fractures of the Roberts and Cox study (3.01% and 1.1%, respectively), and considerably more in the other

Table 7.1 *TPR of fractures by element in the combined R.N. skeletal assemblage and post-medieval skeletal civilian assemblages; n= number of fractures present, N= number of elements.*

	Combined R.N. assemblage			Roberts and Cox (2003)[1]			St Benet, Sherehog, London[2]			Baptists' Chapel, Poole[3]			St George's, Bloomsbury[4]			St Martin's, Birmingham[5]		
	n	**N**	**TPR (%)**	**n**	**N**	**TPR (%)**	**n**	**N**	**TPR (%)**	**n**	**N**	**TPR (%)**	**n**	**N**	**TPR (%)**	**n**	**N**	**TPR (%)**
Skull	220	1299	16.94	5	1291	0.39							4	62	6.45	10	1483	0.67
Ribs	200	2108	9.49	88	2081	4.23				7	946	0.7	88	2081	0.75			
Sternum	3	149	2.01													2	241	0.83
Vertebrae	49	5149	0.95	4	1202	0.33							3	678	0.43			
Sacrum	1	805	0.33	1	160	0.63							1	62	1.16	1	293	
Pelvis	73	1186	6.2	2	968	0.21												
Clavicle	14	448	3.13	10	1305	0.77	1	41	2.4	1	74	1.3				9	788	
Humerus	21	491	4.28	1	92	1.09	1	71	1.4							1	862	0.12
Radius	14	467	3.00	8	1249	0.64	1	70	1.4	1	108	0.9	1	123	0.81	27	776	1.14
Ulna	14	478	2.92	9	1400	0.64	1	70	1.4							5	831	
Hand	79	6702	1.18	2	308	0.65												
Femur	13	486	2.67	23	1838	1.25										2	887	0.23
Tibia	35	470	7.45	8	1157	0.69				3	107	2.8				7	805	0.87
Fibula	29	438	6.62	12	1582	0.76				2	48	1.2	3	107	2.8			
Tarsals	70	2276	3.08							2	759	0.3						
Foot bones	130	5940	2.19										1	983	0.1			
Total	**895**	**28892**	**3.10**	**172**	**14633**	**1.10**	**4**	**252**	**1.59**	**16**	**2042**	**0.78**	**101**	**4096**	**2.47**	**64**	**6966**	**0.92**

[1] Roberts and Cox (2003), [2](Miles et al. 2008b), [3](McKinley 2008), [4.] (Boston et al. 2009),[5.] (Brickley et al. 2006)

assemblages. Ribs showed the least difference between the R.N. and the Roberts and Cox sample (9.5% and 4.2%, respectively), but the latter's rib fracture rate was considerably higher than those of St George's, Bloomsbury (0.75%) and the Baptist Chapel, Poole (0.7%) assemblages, and may represent a specific class or sub-section of post-medieval society.

Major long bone TPRs were most consistently recorded across the five assemblages. The tibia was the most commonly fractured long bone in the R.N. assemblage, displaying a TPR 2.6 times that of the Poole assemblage, more than 8.5 times that of the St Martin's assemblage, and more than 10 times the TPR of the Roberts and Cox's study. Femoral fractures were more than double the Roberts and Cox's study (2.67% and 1.25%, respectively), and more than ten times the St Martin's rate (0.23%). Least difference was seen in radial fracture TPR, where St Martin's TPR (3.48%) actually exceeded the R.N. rate of 3%- largely due to high osteoporotic fractures of the distal radius in the Birmingham group.

The skull fracture rate was up to 43 times higher in the R.N. assemblage than civilian groups- largely due to the very high nasal fracture rates of the Greenwich assemblage. Thus, it is indisputable that the R.N. skeletal assemblages of this study show extraordinarily high fracture rates compared to their civilian contemporaries.

Table 7.2 ranks fracture frequency across the skeleton from most to least common in the R.N., archaeological (largely early medieval) and modern British datasets, the last two being compiled by Waldron (2009, Table 8.5, p. 149). Direct comparison is complicated by slightly different fracture groupings, but it is clear that skull fractures are very much more prevalent in 18th century seamen than in the other two groups. High rib fracture numbers were common to both the R.N. assemblage and the archaeological group, but less frequent in the modern group. The last was dominated by osteoporotic fractures of the wrist, hand and distal forearm but, interestingly, osteoporotic spinal fractures were much less frequent (being ranked tenth). In the R.N. assemblage, hand and foot fractures were more common than major long bone fractures, as were pelvic and spinal fractures.

Foot fractures were the third most commonly fractured body part in the R.N. assemblage, and fourth in the modern group, but were not even listed in Waldron's archaeological group. Hand fractures were relatively common in all three groups. Pelvic fractures were proportionally more common in the R.N. assemblage than in the modern group, and were not ranked in Waldron's archaeological group. Spinal fractures in this group shared the same ranking as the clavicle, humerus, skull and femur. This was very different in the R.N. assemblage, where there were less than a third of humeral and femoral fractures compared to spinal fractures.

Table 7.2 *Rank order of fractures in the R.N. skeletal assemblage and in archaeological and modern assemblages (data for last two taken from Waldron (2009).*

R.N. seamen and marines			**Archaeological**		**Modern**	
Body part/ element	**Fracture numbers**	**Rank**	**Body part/ element**	**Rank**	**Body part/ element**	**Rank**
Skull	220	1	Rib	1	Wrist/ hand	1
Ribs	200	2	Radius	2	Tibia/ fibula/ ankle	2
Foot	131	3	Ulna	3	Radius/ulna	3
Hand	79	4	Hand	3	Foot	4
Pelvis	68	5	Fibula	3	Skull	5
Spine	52	6	Tibia	6	Rib	5
Tibia	37	7	Skull	7	Humerus	7
Fibula	26	8	Clavicle	7	Femur	7
Shoulder	24	9	Humerus	7	Clavicle	9
Ulna	17	10	Spine	7	Spine	10
Humerus	15	11	Femur	7	Patella	11
Radius	13	12			Pelvis	12
Femur	13	12			Scapula	12

Thus, fracture prevalence in the combined R.N. skeletal assemblage was considerably greater than in selected post-medieval civilian assemblages, supporting historical accounts that life aboard a fighting ship was one of considerable hardship and danger. Differing rank orders of fractures indicate that fracture patterning across the skeleton was also very different.

7.2.2. The documentary record

The survival of a large corpus of documentary evidence of the 18th century R.N. in the Admiralty Papers in the National Archives allows for considerable qualitative and quantitative historical analysis. In recent years, there has been a growing interest in the social history of the R.N. and in the

history of medicine. Despite this, trauma has been a neglected subject, and there is minimal qualitative, and no quantitative analysis, on which to draw.

Unfortunately, no hospital musters of the first three decades of Haslar and Plymouth Hospitals were available. Thus, there is no way of ascertaining temporal changes in trauma patterning in the years 1752-1791. In the sample years between 1792 and 1811, there were temporal fluctuations in trauma prevalence, with an overall downward trend in the proportion of trauma cases over time (Haslar 8.5% to 2.8%, and Plymouth 12.6% to 6.3% in those years). Factors underlying this temporal trend are not well understood, but may be due to changes in the provision of medical care in the R.N. over time. Certainly, fluctuations did not occur in concert with years of conflict, peace or reduced hostilities. In fact, trauma rates were highest in 1792, a year of peace. Most of the remaining years until 1816 were characterised by near-continuous and often intensive naval conflict.

Figures on the diseases treated at Haslar Hospital between 1758-1760 and 1780 collated by Lind and Blane (cited in Lloyd and Coulter 1963), and earlier musters of both hospitals reveal that the vast majority of hospital admissions were for fevers, scurvy and the bloody flux (dysentery). These disorders had reduced considerably in numbers by the 1800s (Haslar Hospital Musters 1792-1824; Plymouth Hospital Musters 1792-1824). A small sample of 45 Trafalgar veterans, who were treated and died in Plymouth Hospital in the years following the battle (1805), showed this changing disease profile. There were much higher respiratory disease rates (38%) than previously, whilst fever accounted for 13.3% (as opposed to 39-57% of admissions in the earlier years cited above). Interestingly, the high respiratory disease rate above is supported by considerable osteological evidence, in the form of active periostitis on the visceral surfaces of the ribs (CPR 14.3% in Haslar, 25.2% in Plymouth, and 31% in Greenwich Hospitals, overall CPR 25.3%). Only one scorbutic and five dysentery admissions (11.1%) were historically recorded in the Trafalgar veterans above (compiled from Ayshford and Ayshford 2004).

In the light of this changing profile, a proportion higher trauma admission rates might be expected, but musters indicate that this was not so. It may well be that many more injuries were treated in the large and more numerous R.N. hospitals abroad as the centuries progressed, and/or that, latterly, sea surgeons treated fractures aboard more competently, and hence, did not require hospitalisation. Indeed, sea surgeons' journals (Appendix 9) cite many cases where fractures were treated at sea, and that the patient returned to work after approximately 1-2 months' respite without hospital admission. Cruises away from home waters would also have prevented off-loading the sick and hurt to Haslar and Plymouth Hospitals.

Lacunae in the documentary record are a major issue in reconstructing the past. So too is projection of modern perceptions onto the past, and in a history of medicine context, the misunderstanding of medical terms and past perceptions of disease (Mitchell 2011). Eighteenth century medical treatment was governed by the pervading medical paradigm of humoral theory, but this slowly was giving way to, or uneasily co-existing with, more empirical notions, the growing awareness of diseases as mass entities, and a deeper understanding of human anatomy and the effect of disease processes on human tissue. Happily for this study, fractures and dislocations are probably the least enigmatic in terms of interpreting past diagnoses. Indeed, modern medical definition of a fracture of Roberts (1988) is interchangeable with that cited in Northcote (1770), as are basic fracture classifications. Although diagnostic and operating techniques have advanced immeasurably since the 18th century, and the 18th century antiphlogosal regime of bleeding and purging has long since been abandoned the fundamental surgical principles of reduction, immobilisation and rest in treating fractures remain the same.

Comparisons of fracture rates between 18th century R.N. assemblages, hospital musters and modern epidemiological studies are complicated by another important consideration. The last two are based on independent fracture cases treated in medical establishments, where previous fracture histories are not reported. By contrast, traumatic lesions observed in archaeological assemblages represent a

cumulative record of injuries over each individual's lifetime (Lovejoy and Heiple 1981). In this study, it is hoped that, on a population level, the serially accumulated fractures identified in the skeletons of individual seamen and marines, were comparable to a compilation of isolated fractures suffered at a particular point in the life of each seaman or marine admitted to the hospitals. This may indeed not be the case. Some seamen and marines only went to sea in adulthood, and fractures incurred in their early lives would have reflected their previous terrestrial occupation and lifestyle. Similarly, in the Greenwich assemblage, many years or even decades had elapsed between leaving the navy and death. Trauma incurred in these intervening years would have reflected their lives on land, which for many veterans was one of hardship and rough living.

7.3. Trauma prevalence in the osteological and historical datasets

The above sections have considered the overall fracture prevalence in the hospital muster sample and the R.N. skeletal assemblages, and compared the latter with other post-medieval skeletal assemblages and modern epidemiological studies. Methodological and material differences between these datasets have been explored, and their effects on results discussed. This section will contrast fracture distribution across the skeleton in the osteological assemblage with that of the hospital musters, and will then explore the probable aetiology of these injuries using historical and modern medical and forensic sources. The fractures mentioned below are described in Chapter 6.

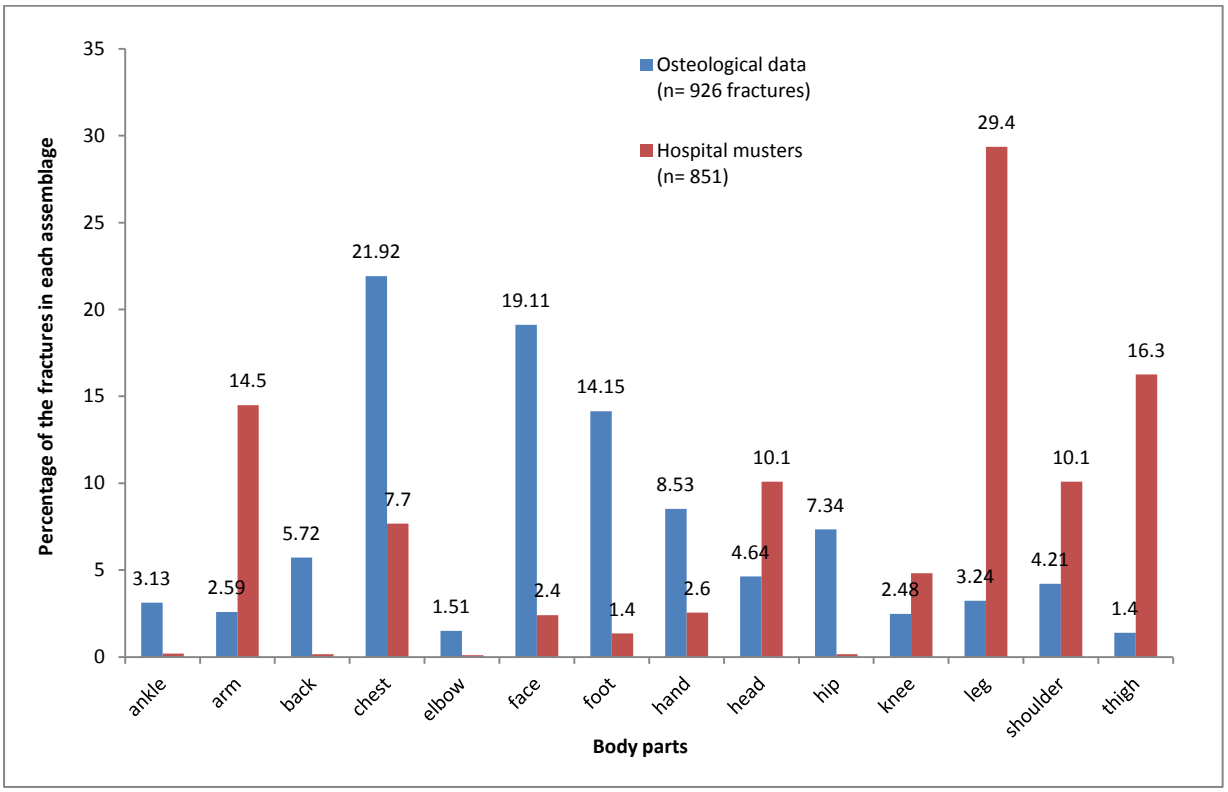
7.3.1. Fracture distribution

To explore fracture distribution across the skeleton, the percentage of the total sum of fractures was calculated for each body part. The same method was used to explore dislocations and soft tissue trauma (although the last cannot be discussed fully here). Fig. 7.1 displays fracture distributions in the combined osteological assemblage and the muster data.

The preponderance of fractures of the major long bones (60.5% of all fractures) is most striking in the muster records. This distribution is dominated by the leg (29.4%), then the thigh (16.3%) and then the arm (14.5%). In contrast, in the osteological assemblage the major long bones comprised

only 8.2% of all fractures (4.21%, 1.4% and 2.59%, respectively). Limb fracture counts in the osteological assemblage may have been slightly lowered by subsequent amputation of a fractured limb after admission to the respective hospital. There were 24 amputations in the skeletal assemblage, of which 16 were femoral, and four were below-knee amputations. Only three were humeral and one a possible hand amputation. With the exception of one Plymouth amputation (Plymouth 547) and all four Greenwich stumps, all were either unhealed or healing, indicating that the operation had been performed soon before death- either aboard ship or in the hospital. If the latter, the muster diagnosis would reflect the medical condition on admission (e.g. fracture) rather than amputation. Eight amputated skeletal elements distal to the amputation (probable medical waste) had been deposited in Haslar and Plymouth Hospital graves. Two of these were fractured (Plymouth 662 and 914). Four distal elements were disarticulated isolated bones, however, so trauma to more distal parts (such as the forearm or lower leg) could not be explored.

Figure 7.1 *Fractures by body part in the Haslar and Plymouth Hospital muster and osteological datasets, by percentage of each assemblage.*



The difference in major long bone fracture prevalence between the osteological and historical datasets may be largely one of survivorship: that most long bone fracture sufferers did not die, but recovered and left the hospital, either discharged to their ship or discharged unserviceable. Given that femoral shaft fractures are associated with high mortality rates through haemorrhage and fat embolism, it is surprising that more were not observed in the skeletal assemblages, but it is possible that many died before reaching the hospital. The probability that most seamen and marines admitted to Haslar and Plymouth Hospitals survived their injuries is supported by the long bone shaft fracture distribution between the three skeletal assemblages. The overwhelming majority of shaft fractures were found in the Greenwich pensioners (the 'super-survivors') rather than in the other two hospital assemblages (the 'biological failures'). Polytrauma sufferer Haslar 214 was a notable exception (see below).

The above long bone fracture rates do not include the joints of the appendicular skeleton, which were categorised separately. Interestingly, the osteological fracture rates of these major joint fractures were higher than the historical rates for the elbow (1.51% and 0.1%), hip (7.34% and 0.2%), knee (4.8% and 2.48%) and ankle (3.13% and 0.2%), but shoulder fractures were higher in the historic assemblage (4.21% and 10.1%). Either some were listed in the musters under the major long bone involved, or were not recognised by the sea surgeon in attendance. The latter is highly probable in incomplete joint fractures, such as crush fractures of the distal tibial joint surface and impaction fractures of the acetabular surface, which may have been ascribed to sprains or contusions. When 'contusion' distributions are considered (including sprains), however (Appendix 17), the knee accounts for only 4.67%, the ankle for 2.78%, the shoulder 2%, the elbow 0.44% and the hip 0.33%. Instead, contusions are dominated by the loins, back and head.

Skull fractures were categorised as head/cranial vault and face (including the mandible). Osteological facial fractures comprise 19.11% of all fractures, but only 2.4% of the muster dataset. This considerable difference is largely due to the very high nasal fracture rate in the Greenwich

assemblage. In his surgical manual, Northcote (1770) advocated treatment for nasal fractures by manual manipulation, plaster board splints and the insertion of small lead or silver tubes into the nostrils to keep them open during healing. In reality, very few muster or sea surgeons' journal entries record nasal fractures, indicating that they were rarely treated. This may account for the mal-alignment seen in so many nasal bridges of the R.N. skeletons of this study. Nasal fractures are most commonly due to interpersonal violence or falls (see below). Fighting with another member of the R.N. was a punishable offense, which could escalate to court-martial (Article 23 of the Articles of War 1747 cited in Eder 2004). This also applied on shore (Article 35) (*Ibid.*). Thus, it is probable that many men with noses fractured in a fight did not present to the sick bay for treatment for fear of punishment. Alternatively, sea surgeons may not have recorded treatment in their journals in a bid to protect such patients from official punishment. Another reason is that nasal fracture treatment may have been regarded as an aesthetic concern, and nasal fractures would not have greatly impeded the seaman's ability to perform his duty, and therefore, were not medically treated.

In the skeletal assemblages, cranial vault fractures account for 4.64% of all fractures (generally minor depressed fractures), whilst a much higher proportion (10.1%) are recorded in the musters. The most severe cranial trauma in the skeletal assemblages involved a penetrating injury of the occipital bone (Haslar 002) and a perimortem probable pistol-shot to the occipital bone of Plymouth 651. In the hospital musters, the head was the most common site of wounds, and 'head contusions' and 'concussions' were the third most frequently recorded of all contusions. Physician Thomas Trotter wrote that '*seamen are so exposed to blows and wounds to their head, from the nature of their duty*' (Trotter 1804a p. 127), and noted that this damage made them more susceptible to intoxication with alcohol, and liable to epilepsy (two seamen that he knew drowned having a seizure). It is probable that many brain injuries did not include cranial vault fracture. Endocranial new bone may hint at more chronic traumatic brain injury (intracranial haemorrhage or infection). New bone was present on 27.6% of observable endocrania (N= 156). Ascribing such lesions to traumatic complications is very uncertain, however, as in this context they may have resulted from intracranial bleeding in

scurvy (see Appendix 7), chronic infection (e.g. chronic meningitis, tuberculosis or cerebral malaria) (Lewis 2004) and, in Haslar 106, was associated with scaphocephaly.

Fracture prevalence in the chest region was markedly higher in the osteological assemblages than in the muster data (21.92% and 7.7%, respectively). In both datasets, these principally comprised rib fractures. One reason for this difference is that the number of fractured ribs is rarely given in the muster entries. Thus, only two were counted for each entry of 'fractured ribs', when in reality the number may have been higher. Contusion of the back, breast and side account for 27.78% of contusion cases, and some of these probably included unrecognised rib fractures.

Back fractures were much more common in the osteological than muster dataset (5.72% and 0.2%, respectively). These included spinous process fractures, which, with the possible exception of clay shoveller's fractures, suggest direct posterior impact (such as a backwards fall), although in modern population such injuries are relatively uncommon (Zmurko et al. 2003). Most vertebral fractures involved the body, either manifesting as crush, wedge fractures or burst fractures. The first may be caused by age-related osteoporotic collapse, but like burst fractures, may be due to indirect trauma from the impact of a fall onto the feet or buttocks (Galloway 1999). The 1796 Plymouth Hospital muster recorded one admission for '*a broken back*', but, generally, back fractures were rarely recorded. The back was a common site of contusion (15.89%), and may have included unrecognised vertebral fractures, particularly of the spinous processes. '*Sprained back*' was a not uncommon admission diagnosis, as was lumbago, although lower back pain from intervertebral disc prolapse and spinal nerve impingement is more probable than lumbar vertebral fracture.

High osteological rates of *os acromiale*, shoulder dislocation and rotator cuff enthesopathies suggest strenuous, repeated use and trauma to the shoulder and upper limb in the R.N. assemblages. Fractures to bones of the shoulder joint comprised 4.21% of all osteological fractures and 10.1% of historic ones. In the latter, 95% of these were clavicular. Shoulder fractures in the osteological assemblages were more evenly distributed between the component elements. The dearth of

scapular and proximal humeral fractures in the muster entries suggests that these fractures went unrecognised. Hill-Sach's and Bankhart's fractures associated with shoulder subluxation are also unlikely to have been diagnosed.

There was only one muster entry of a fractured '*os cubit'*, and no other entry for elbow fractures. These comprised 1.51% of fractures in the skeletal assemblage.

The percentage of hand fractures was much higher in the osteological dataset than in the musters (8.53% and 2.6%, respectively). This was despite under-representation of hand phalanges through poor taphonomic survival and/or archaeological retrieval. In this assemblage, hand bone fractures were dominated by metacarpal fractures (75%), particularly Bennett's fractures and MC3 styloid process avulsions, whilst thumb and finger fractures and traumatic finger amputations are the most commonly described hand injuries in the musters. As with nasal fractures, Bennett's fractures are associated with interpersonal violence (Brickley and Smith 2006), and injured seamen guilty of brawling may not have presented for medical treatment, or were not recorded by sea surgeons (see above). Working with a fractured hand was probably more difficult than with a broken nose, but the dearth of sea surgeons' and muster entries does indicate that many hand fractures were either not recorded or not treated.

There was only one muster entry of a fractured hip (0.2%), but these injuries accounted for 7.35% of fractures in the osteological assemblage. The latter was dominated by acetabular impaction fractures (possibly also involving labral tears), which the modern clinical literature associates with joint pain (Crawford et al. 2007). Given that the hip joint retained its normal range of movement and stability, and medical treatment was limited, it is probable that many injured seamen continued to work untreated. A more debilitating hip injury is described in a 1797 sea surgeon's journal: '*James Grafton, aged 20,... fell on the .... major [? greater trochanter] of the left thigh, excruciating pain in the joint and incapable of moving it in any direction'* (ADM101/98/3A/1/Folio 7). Northcote (1770) describes similar symptoms in a patient with a fractured neck of femur, but writes that reduction to

correct limb shortening and abnormal distal rotation was virtually impossible without the use of traction, due to strong thigh muscle contractions. However, given the extent of overlap in several lower limb shaft fractures in the skeletal assemblage, it seems doubtful that traction was widely used. Indeed, aboard ship, swinging of the traction weights with the ship's movements would have made this treatment largely impracticable.

Knee fracture rates were higher in the muster dataset than in the osteological assemblage (4.8% and 2.48%, respectively). The patella (usually given its correct anatomical name, but sometimes referred to as the '*kneecap*' or '*kneepan*') constituted the bulk of knee fractures. In addition, '*swelling of the knee*' was a fairly common diagnosis. Although many cases were probably traumatic, knee swelling was not included in contusion counts (4.67%) as several other disorders, namely arthropathies (such as gout), tuberculosis ('*white swelling of the knee'*) and Charcot's joint of syphilis, may also be the cause. Gross lysis of the femoral and tibial joint surfaces, and abscess formation in the right knee joint of Plymouth 976 is an example of such joint tuberculosis.

Only one ankle fracture is recorded in the muster sample (0.2%), but ankle fractures comprised 3.13% of osteologically recorded fractures. The latter largely involved impaction fractures of the distal tibial joint surface, and malleolar fractures from twisting injuries. Ssome of the many hospital admissions for '*ankle dislocations'* in the hospital musters probably also included fractures.

There was a markedly higher proportion of foot fractures in the osteological assemblage than in the muster data (14.15% and 1.4%, respectively). Foot fractures in the former were dominated by Shepherd's fractures, although several vertical impaction fractures of the tarsals and phalanges were also present. In modern clinical practice, Shepherd's fractures are often misdiagnosed as ankle sprains (Judd and Kim 2002), and were probably also not recognized by 18th century naval surgeons. Although prolonged ankle pain associated with this condition may have impaired a seaman's ability to function aloft, this would not have precluded him from duty.

7.3.2. Luxations and subluxations

Dislocation was a commonly recorded injury in the hospital musters. In his medical manual, Turnbull (1800, 75) urged *'The reduction of a simple luxation has every advantage at sea, from the number of assistants at hand, and the degree of force which can readily be applied to effect it'.* In view of this, many hospital admissions were probably the more complicated or serial subluxations or luxations that the sea surgeon was unable to reduce or stabilise onboard. Some dislocations undoubtedly involved fracture (as in Greenwich 3159 and Plymouth 661), in which circumstance Northcote (1770) and Turnbull (1800) recommended that the dislocation should not be reduced until the fractures had united. By this time, a bony response to the luxation was probably advanced.

Dislocation distribution in the musters was dominated by the shoulder joint (63.9%), followed by the ankle (13.9%) and knee (5.6%). A quarter of all dislocations, and 45% of shoulder dislocations involved the clavicle. Sea surgeons, hospital musters and surgeon's manuals (e.g. Northcote (1770) and Turnbull (1800)) fail to describe whether these involved the sternoclavicular or acromioclavicular joints, but modern epidemiology indicates that the former is rare (Court-Brown et al. 2006), whilst the latter is relatively common, accounting for 9% of all shoulder injuries in one study (Chillemi *et al.* 2013). Acromioclavicular dislocations result either directly from a vertically orientated superior impact on the lateral part of the shoulder, forcing the joint inferiorly (tearing supporting ligaments and tendons), or indirectly by falling onto an outstretched abducted arm, causing the humeral head to be driven superiorly into the acromioclavicular joint, and dislocating it (Chillemi *et al.* 2013).

With the possible exception of the left clavicle of Greenwich 6103, there was no osteological evidence for clavicular subluxation. Traumatic *os acromiale* is probable in Greenwich 3159, and such lesions may well have been interpreted as acromioclavicular dislocation. Many older skeletons displayed florid osteophytosis and eburnation of the joint, which was interpreted as degenerative changes and osteoarthritis associated with wear and tear over a lifetime, but may well have been exacerbated by joint trauma. However, there is no clear evidence of mal-alignment. Sternoclavicular

disarticulation may have been interpreted in the cases of costoclavicular ligament damage, although this ligament is not directly involved in the joint. Syndesmoses of this ligament were extremely common in the R.N. skeletal assemblage from a young age (from 14-15 years).

In the osteological assemblage, shoulder luxation, subluxation and humeral impingement were the only clear dislocations, with the possible exception of the right knee of Greenwich 3151. Although Hill-Sach's and Bankart's fractures occur in acute subluxation, bony changes of chronic dislocation were present in all but two cases. Marked rotator cuff muscle enthesopathies of the humeral tubercles were present in all these cases, and would have contributed to joint instability (Norris 1992; Roberts et al. 2007).

The right knee of Greenwich 3151 was the only other joint to show chronic subluxation. Chronic lateral displacement of the right patella was indicated by eburnation of the antero-lateral femoral and corresponding patellar joint surfaces. The patella and medial femoral condyle showed well-healed fractures. Three cases of dislocated patella are recorded in the muster sample.

Three posterior tibial plateau avulsions and several marked syndesmoses of the anterior cruciate ligament were not associated with chronic subluxation, although both injuries are clinically known to cause joint destabilisation and dislocation (Galloway 1999). It is assumed that in these individuals, the damaged joints were reduced and stabilised before secondary bony changes developed.

There are no records of hip dislocation in the muster sample, although these injuries occasionally did occur in the R.N. Northcote (1770, 252) comments that '*luxation of the thigh bone happens but seldom for the round head of this bone is so strongly articulated into the deep acetabulum*', and goes on to comment that for every hip luxation there were 19 neck of femur fractures, and that the latter was often mistaken for the former. That said, he does assert that the femur may be dislocated more readily in weak, cachectic or scorbutic individuals [Seamen are elsewhere described as cachectic (emaciated) following bouts of malaria]. One sea surgeon's journal entry does describe femoral

luxation from a blow by the anchor (ADM101/125/3/12/Folio 40), but with the exception of the above cases, there is little mention of hip pain or disability.

Despite fairly high historic rates of ankle dislocation (13.9%), no clear osteological evidence was present. This would suggest successful reduction of acute injuries or the misdiagnosis of sprains and/or ankle fractures as dislocations. Flat-footedness or *pes planus* was the only abnormality of articulation seen in the foot bones of the osteological assemblage (as described by Darton 2007), and may have been occupational or scorbutic in origin.

7.3.3. Recidivism

Multiple fractures in individual skeletons may occur as the result of a single event (such as a fall, battle or brawl), or may be incremental, accumulating over that person's lifestyle. Some modern clinical research suggests that repeated trauma in one individual is not entirely a matter of chance, but that some individuals have a greater tendency to injury than the norm- so-called 'injury recidivists'. Factors predisposing such individuals to repeated trauma are innate clumsiness, occupational risk, or a penchant for assault (either as victim or assailant) (Judd 2002; Poole et al. 1993). Modern injury recidivists are typically young males, and in the case of intentional trauma, are generally of lower socio-economic status, lower intelligence, may suffer depression or have anti-social personalities (Poole et al. 1997).

Identifying recidivists in archaeological skeletons with high trauma rates is complicated by the difficulty in distinguishing between multiple trauma from a single event, and attritional trauma (which typifies a recidivist), once the injuries are healed. Forensic and modern medical research does give valuable insights into the more common sequence of injuries that occur in a single event, such as falling from a height (see Section 7.4.1), and associating multiple fractures with a single event, and may be helpful in unpicking occasional versus attritional trauma. One might argue that seamen, by virtue of their very hazardous profession, were all recidivists, and that the prevalence of trauma in each individual was more reflective of length of naval service and increasing age (see below) than

any individual tendency to recklessness, aggression or other predisposing social or personality traits. In reality, age, personality, life experience and occupational risk are inextricably linked. For example, topmen working high in the yards aloft, were picked for their seamenship and agility, but also for their courage and recklessness. The physicality of a topman's job ensured that it was a position held overwhelmingly by young men in the prime of life.

The culture of the 18th century R.N. also encouraged headlessness of danger, which probably lead to greater risk of trauma. Masculinity was celebrated, and courage was instilled as defining virtue (Pietsch 2010). Physician Thomas Trotter wrote as:

> *'The courage that distinguishes our seamen, though it is in some degree inherent in their natural constitutions, yet is increased by their habit of life, and by associating with men who are familiarised to danger, and who, from natural prowess, consider themselves at sea as rulers by birth-rite..... The mind, by custom and example, is thus trained to brave the fury of the elements in their different forms, with a degree of contempt for danger and death, that is to met with nowhere else, and which has become proverbial.'* (cited in Turnbull 1800, 6).

There are so many skeletons with multiple fractures in the three R.N. assemblages, that identifying individuals as being particularly prone to trauma is highly problematic. Other factors, such as age, complicate the interpretation. For example, individuals with the top ten highest healed fracture numbers were generally older: five aged 45+ years, four aged 35-45 years and only one (Plymouth 633), aged 25-35 years. Plymouth 633 is probably the best candidate for a recidivist, in that his nine injuries showed different stages of healing and different probable aetiologies, demonstrating incremental trauma. He had sustained a spiral or greenstick fracture to his right humeral shaft- most commonly an injury incurred in childhood (Galloway 1999; Glencross and Stuart-Macadam 1998; Ward et al. 1992). He also had well-healed bilateral acetabular impaction fractures and a right third metacarpal avulsion fracture, both of which may be associated with seafaring, and hence were acquired during his maritime career (see below), and a small well-healed depressed cranial fracture of the left posterior parietal (cause and timing unclear). At the time of death, however, the right mandibular ramus was fractured and showed florid, active osteomyelitis (probably of several weeks'

or months' standing). There was also a probable projectile injury in the right ilium showing very early stages of healing. If the associated peritonitis did not caused his demise, surgical amputation of the right femur may well have done so. This midshaft amputation showed no macroscopic signs of healing, and it is highly probably that, in his already weakened state, this radical surgery sealed his fate.

7.4. The aetiology of fractures and dislocations in the R.N.

Even by the standards of the day, the life of an 18th century seaman was acknowledged to be particularly arduous and dangerous. Naval physician Thomas Trotter argued that a seaman's diseases '*spring from causes peculiar to sea life: laborious duty, change of climate, and inclement seasons.... bring on premature age, and few of them live to be very old*' (cited in Turnbull 1800, 6). This makes the advanced age of the Greenwich pensioners all the more remarkable.

By far the greatest perils at sea came not from engaging the enemy but from everyday dangers inherent in facing the elements and sailing a ship. Unlike merchant seamen, R.N. seamen could be ordered to journey to any part of the globe and at any time of year, rather than keeping to established trade routes in favourable seasons, and they often encountered more severe weather than did merchant shipping (Adkins and Adkins 2008). A less frequently encountered, but often devastating source of trauma was combat, in which the number and severity of casualties could be extreme.

Sea surgeons' journals give a good indicator of the most common causes of trauma in the R.N.: falls from a height or standing height, crush injuries, accidents and inter-personal violence. Repetitive strain injury from sailing a ship is another less well recognised category. These are discussed below.

7.4.1. Falls from a height

Ordinary and able seamen were required to be aloft at any time of night or day in all weathers, often performing feats that could only be expected of an acrobat or steeplejack (Figs 7.2. and 7.3). Falling from up to 100 feet (30m) onto the crowded decks below, or into the sea and drowning, was an

ever-present danger, particularly in rough weather. In his memoirs, seaman Samuel Leech also describes the dangers of the long night watches in the tops where, overcome by fatigue and lack of sleep, he repeatedly dozed off and almost fell to the deck below. '*Being compelled to stand at these crazy elevations when half-dead with seasickness'* was another hazard (Leech 1857, 53). Indeed, he commented that *'it has often been a subject of surprise to my mind that men so seldom fall from the tops'* (*Ibid.*, 53). That said, of the 29 fractures recorded in a sample of sea surgeon's journals (Appendix 9), 14 were falls from a height. In addition, 49 contusion injuries involved falls, and may well have included unrecognised fractures.

Not all falls were from the rigging, however. There were numerous falls down hatchways, into the hold from a deck above, and from the gangway into the waist. One seaman Michael Burns ignominiously fractured his patella on falling out of his hammock (*c.* 1.5m), and was admitted to Plymouth Hospital two weeks later (ADM101/98/3A/2/Folio 5).

Drunkenness was a perennial problem in the R.N. Despite it being a punishable offence, many seamen went to extraordinary lengths to secrete liquor stores onboard for future consumption. Leech (1857, 22) wrote that

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

In 1812, Admiral Lord Keith lamented that

> *'Almost every crime except theft originates in drunkenness, and 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)

Although probably overdrawn, Admiral Keith's account is certainly correct in identifying drunkenness as a key factor in many accidents. Ships' surgeons' journal entries and captain's notes pinned to the hospital musters, frequently mention that the patient was inebriated on falling. Falls down



Figure 7.2 *The precarious nature of lookout duty high in the maintop. Note how this young midshipman has secured his leg to the lookout with his handkerchief. Image courtesy of the National Maritime Museum, Greenwich.*



Figure 7.3 *Seaman reefing a sail at the yard arm. In a storm, seamen did lash themselves to parts of the ship to avoid falling or being swept overboard, but such safety measures greatly restricted movement, and were generally an emergency measure. Image courtesy of the National Maritime Museum, Greenwich.*

hatchways or from the gangway into the waist were particularly common in this state, whilst intoxicated seamen also fell overboard and drowned.

Falls from a standing position are discussed below. This section considers specific injury patterning in falls from different heights described in modern medical and forensic literature, and applies these insights to fracture patterning in the R.N. assemblages. Falls may cause direct and indirect blunt force trauma in multiple elements. The body part that first hits the ground experiences the greatest injury, but the severity and type of fractures from falls are dependent on a range of factors, such as the vertical distance, the area over which the impact is distributed (Tomczak and Buikstra 1999), body orientation and position, the material properties of the striking surface, and the mechanical properties of the bone under stress (*Ibid.*).

Vertical acceleration in a falling body is most dependent on the distance that the object falls, and not on its mass. However, air drag of clothing, humidity and a horizontal body position may all reduce

the final velocity (Tomczak and Buikstra 1999). A horizontal body position will dissipate the force on impact over a wider area than in a vertical landing (Christensen 2004). Mitigating against this benefit of horizontal landing is the role played by flexed joints in dissipating impact, reducing it by as much as 36 times (*Ibid.*). This protects the vital organs (especially the brain) from the full force of a fall, and may underlie the apparently dysfunctional instinctive response of a sentient faller to align their body towards the vertical whilst falling, so as to land on the feet (Christensen 2004). Longer falls in which this vertical alignment is achieved generally result in feet-first impacts. In contrast, an unconscious, intoxicated or already dead body falling the same distance tends to remain in the horizontal plane, incurring a very different suite of injuries (*Ibid.*).

Because planes of body orientation are directly related to the vertical distance of the fall, distinctive suites of lesions are characteristic of falls from different heights. In modern falls from stepladders, bracing injuries to the forearms and wrists (e.g. Colles' fractures and ulnar styloid fractures), and twisting injuries to the ankles (e.g. malleolar and oblique or spiral fractures of the tibial and fibular shafts) are very common, as is soft tissue spinal involvement (Muir and Kanwar 1993). In slightly higher falls where the body does not have sufficient time to vertically re-orientate, the most common fractures are to the skull (falling on the head), cervical vertebra (indirect head-first impact injuries) and forearms (bracing injuries) (Lowestein *et al.* 1989; Teh *et al*. 2003; Tomczak and Buikstra 1999; Turk and Tsokos 2004). The prominence of arm fractures (particularly of the distal forearm) was also noted in rural Melanesian tree-climbing accidents (Barss et al. 1984), in which the vertical distance ranged from 6m-25m. More serious injuries also seen in this group (presumably from higher falls) were major lower limb bone fractures (some compound), spinal and head injuries, although the last were few in number (*Ibid.*).

In modern American studies of falls greater than 12m (four storeys), fewer head injuries were present than at lower levels, but there were more lower limb, pelvic and abdominal injuries, and a high rate of fractures to the thoracolumbar spine (T11-L2), particularly burst fractures (Scalea *et al.*

1986; Tomczak and Buikstra 1999). Severe head injuries (including multiple skull fracture, severe intracranial haemorrhage and ruptured brain structures) have been noted in 84% of fatal falls below 10m, and in 90% of falls above 25m, but in falls between 10-25 m, were present in only 28% of cases (Turk and Tsokos 2004). This is due to more foot-first landings, where impact to the skull is much least direct. Hyoid bone fractures are strongly suggestive of strangulation (Ubelaker 1997), but have been also associated with neck muscle bleeds in high level falls, with 33% of hyoid bones being fractured in falls from more than 10m in one modern study (Turk and Tsokos 2004).

In a study of 161 modern falls, Scalea *et al* (1986) found that 79% of 12m (four storeys) falls resulted in a major long bone fracture, and almost always multiple fractures. Radial and ulnar fractures were greatest in falls from 9m (32.3% of forearm fractures), but were less prevalent in higher falls. Femoral fractures were greatest in falls of 12m (33.3% of all femoral fractures). Pelvic fractures were present in 10% of falls from 3m (one storey), but gradually increased with increasing height of fall to 35% at 12m, and to 65% at 18m (six storeys). Retroperitoneal haemorrhage was a major, often fatal complication associated with pelvic fracture and abdominal injury. Major spinal trauma was present in 10% at one storey, 24% at four, and 50% at six. Neurological sequelae were common, including parasethesia ('pins-and-needles' sensation), paraplegia and spinal shock. Rib fractures were present in 75% of all fatal falls examined by Turk and Tsokos (2004), with multiple fractures increasing with increasing height of fall. Few individuals survive a fall of greater than 18m, and virtually none survived a fall greater than 20m (Scalea *et al.* 1986).

High fracture rates in the Greenwich skeletons, and the advanced fracture healing in the three assemblages makes it extremely problematic to determine if multiple fractures in an individual skeleton were incurred during a single traumatic event, or whether the fractures were attritional. Greenwich 3241 showed an exceptionally high count of 43 well-healed fractures, predominantly of the right side. He had suffered fracturing of the right talar dome and distal tibial joint surface, and right proximal femoral neck impaction. Five vertebral bodies showed burst fractures, collapse and

marked kyphosis. Both distal radii and ulnae were fractured, as well as several hand bones: the left first and second metacarpals, the right pisiform and triquetral. There was fracturing of the anatomical neck and tubercles of the right humerus, and marked rotator cuff muscle enthesopathy, as well as a right clavicular fracture.

These injuries are consistent with landing heavily on the right foot, the force of the impact travelling up the limb and back. It would seem that he overbalanced on landing, breaking his fall with outstretched upper limbs. The impact transferred from the hand, up the arm to the shoulder. Depressed cranial fractures of the right sphenoid and parietal bone suggest that he may also have hit his head on landing, but these injuries do not appear to be severe. However, the extent of brain injury does not necessarily correlate with the severity of cranial fracture (Goggio 1941; Gurdjian et al. 1950; Knight 1996). It is unclear if other fractures, such as 17 rib fractures and nasal fractures, relate to this traumatic event. All the fractures were well-healed, with no sign of secondary infection. Despite his injuries, this man survived well into old age.

Although it is impossible to be certain, the exceptionally high fracture rate does suggest that at least some were incurred in a single traumatic event. Patterning is consistent with vertical feet-first landing. Unless he commenced his fall in an upright position (quite possible if he was balancing on rope stirrups beneath the yard), his injuries are consistent with modern impact injuries from falls of approximately 9-12m- a height well below the maximum vertical height of the masts of a man-of-war of this period (30m).

A second skeleton displaying multiple fractures consistent with falling from a height was prime adult Haslar 214. His fractures were ununited, but in an advanced state of healing, comprising complete fractures of the mental eminence, both mandibular condyles, the midline of the maxilla, the left and right lateral maxillae, and the right malar. The left glenoid fossa of the temporal bone and left hyoid horn were also fractured. The left radial shaft displayed non-union of a comminuted fracture with shards of bone held within the callus. There were also non-union of the head and shaft of the right

radius and of the right olecranon, and non-union and marked pseudoarthrosis of a comminuted fracture of the right humeral shaft, a necrotic un-united right scaphoid fracture, and a fractured joint surface of the right first distal hand phalanx. The humeral shaft fracture showed gross malalignment and pseudoarthrosis formation. The lower limbs were also damaged, with a severe ununited comminuted or butterfly fracture of the right femoral midshaft, and crush fracturing of the left tibial plateau.

The injury pattern is consistent with falling from a great height and landing with his body in the horizontal or oblique plane. He had clearly extended his upper limbs to try to break his fall, causing bracing injuries to both hands and upper limbs, but appeared to have hit the deck, or similar, with his chin, the impact being transferred through his mandible to his upper face and hyoid bone. Fractures of his lower limbs may have resulted when they hit the deck shortly afterwards. Interestingly, no rib or cranial vault fractures were present. It is possible that the multiple facial fractures had dissipated the force of impact, thereby protecting the cranial vault and, possibly, the brain.

This individual had not achieved a vertical orientation during his fall, which suggests a fall below 12m, but the severity of his injuries indicates considerable force of impact. Of course, it is possible that the individual was inebriated when he fell, or that the body position and projection of his fall were altered by hitting the yards or shrouds on the way down. In his memoirs, Samuel Leech describes such an incident, where a seaman fell from the fore-top but, fortunately, struck the foot-rope of the fore-yard, which broke the force of his fall. He '*bouncing down on a tall, stout Irishman*' working on the deck beneath (Leech 1857, 53). Remarkably, neither man was severely hurt. Both resumed duties after two or three days' respite. Haslar 214 was not so fortunate.

Haslar 214's fractures showed advanced healing, indicating that he had survived for several months. This raises interesting insights into medical and nursing care, particularly as non-union of multiple facial fractures would have impeded normal mastication. Given the extent of his injuries, he would

have been limited to liquids and pureēd food, probably consumed via a rubber tube, straw, spout or spoon, depending on the extent of soft tissue damage and swelling of the mouth and pharynx. Nursing care in terms of maintaining hygiene and repositioning to prevent bedsores would have been highly problematic, and probably extremely painful for the patient.

In some fractures, such as those of the mandibular condyles and right zygoma, the bones had a smooth, well-healed appearance, while limb fracture edges had compact callus formation but also active bone, probably the poor immobilisation of the broken ends precipitating continued callus formation. Without modern fixation, comminuted fractures are notoriously difficult to unite, as are olecranon process fractures (Horne and Tanzer 1981). The lack of union of more simple fractures, such as of the left radius, is less easily explained. Eighteenth century surgeons did attempt reduction and splinting of fractures, but prior to the development of Plaster of Paris in the mid-19th century (Colton 1992), had to be content with positioning, firm binding with many tailed or roller bandages and, sometimes, splinting (Crumplin 2007; Crumplin 2009; Crumplin and Starling 2005). Sometimes the bandaged limb was encased in a wooden box or fracture apparatus for greater stability (Crumplin 2007), but given the extensive fracturing of multiple limbs, and probable soft tissue damage in this individual, it is improbable that such cumbersome apparatus was used. Firm bandaging, slings and careful positioning of fractured limbs on pillows to relax muscle spasm and facilitate bone knitting were the mainstays of treatment (*Ibid.*), but the difficulty in managing so many fractures would account for the lack of union seen here. Like Greenwich 3241, none of the fractures were associated with secondary infection. Immobilisation of multiple limbs over several months would have left this individual at high risk of developing complications of bed rest, such as bedsores, deep vein thrombosis and chest infection (Olson et al. 1990). It is not unlikely that it was one of these complications that hastened his end, rather than the injuries themselves.

Falls from a height were probably responsible for many other fractures seen in the R.N. skeletons, in particular high energy fractures, such as femoral and humeral shaft and impaction fractures of the

neck (Galloway 1999). One sea surgeon's entry records a femoral fracture from a fall from the gangway into the waist when the seaman was drunk (ADM101/86/3E/2/Folio 23-24). Another, records a seaman's fall from the foretop when assisting to reef the topsail, breaking his fall by some ropes before he hit the deck, which resulted in a fractured neck of femur, and a much bruised ankle, shoulder and arm on that side. This individual was subsequently invalided from the service (ADM101/86/3E/2/Folio 15-16).

Probably the most common osteological evidence of falls in this assemblage was indirect trauma: bracing injuries of the upper limb, where the individual tried to break his fall with an outstretched arm (more often the right, dominant one), and foot-first landings causing crush fractures to the ankle joint and indirect injuries to the lower limb, hip and lower back.

Indirect impaction injuries to the upper limb included three ununited and one necrotic scaphoid fracture, nine distal radial fractures (including five Colles' fractures) and six ulnar styloid fractures. In higher impact falls onto an outstretched arm, the force transfers to the upper arm and shoulder. With the exception of Haslar 214, humeral shaft fractures were typical incomplete fractures of immature bone. Such fractures are commonly the consequence of falls in childhood or adolescence. In young naval recruits, these injuries may well have occurred at sea. Proximal humeral fractures are often associated with shoulder fracture and dislocation, the most florid example in this assemblage being Greenwich 3159. Sea surgeons' journal entries record humeral and clavicular fractures from falls from a height, as well as shoulder dislocations. One humeral dislocation occurred from a fall from the main deck into the orlop (a lower deck below the waterline) (ADM101/93/2D/6/Folio 30), and a dislocated clavicle (presumably acromioclavicular) from a fall down the forehatchway (ADM101/93/2C/2/Folio 14).

Seldom does an individual land squarely on the heel from a fall, and consequently inversion/eversion, adduction/abduction and/or supination of the foot frequently occurs on landing, leading to oblique and spiral fracturing of the tibial and fibular shafts, and fracturing of the malleoli

(Galloway 1999; Lovell 1997). Patterning in ankle fractures of seven individuals with medial and lateral malleolar fractures showed a range of twisting injures, of which supination-external rotation was most common (Table 6.18). More proximally, oblique and spiral fractures to the tibial and fibular shafts are often the result of twisting injures. The oblique fractures of the right tibia and fibula of Greenwich 3051, and the left tibia and fibula of Greenwich 3164 are two examples.

Indirect force from a feet-first fall referred upwards to the hip is the probable cause of most acetabular rim fractures and some neck of femur fractures. Similarly, localised crushing of the joint surface was present on the supero-posterior aspect of 63 acetabula, and may indicate less extreme superior femoral displacement. The location on the articular surface suggests landing with the knees flexed. This interpretation is reinforced by the co-existence of lower limb impact trauma (particularly ankle injuries). Acetabular impaction lesions, acetabular flange lesions, rim fractures and supra-acetabular cysts may well have a linked aetiology, and were often found together in the same joint. Flange lesions may develop where a rim fracture results in the loss of marginal definition, but rim collapse may also be the result of coalescence of multiple supra-acetabular cysts (Mays 2005). Labral tearing and increased superior femoral displacement are probably mechanisms behind the development of such cysts (Mays 2005; Mintz et al. 2005), and these are often associated with impaction lesions. The role of flattened, wide acetabula in facilitating superior displacement is discussed below.

Given the high number of distal tibial crush fractures, there were surprisingly few direct vertical crush fractures of the calcaneus from landing on the heel (an exception being Greenwich 3255). Similarly, subtalar and talar dome fractures were rare. *Osteochrondritis dissecans* and the right talar dome fracture in Greenwich 3139 were associated with similar lesions on the corresponding distal tibial joint surface, and a complete vertical fracture of the left navicular (also associated with vertical impact), but no superior injuries were noted, suggesting a relatively low velocity impact. Greenwich 3208 showed more extensive bilateral foot-first injuries, involving severe crushing and twisting of

the left ankle, and a right distal fibular shaft fracture and ankylosis with the tibia. Extensive periostitis on the left tibia and fibula, and a large ossified haematoma on the right tibial midshaft indicate widespread soft tissue damage and secondary infection. This skeleton also displayed a left Colles' fracture and a burst fracture and wedging of the body of L1, but, interestingly, in this feet-first landing, no knee or hip joint involvement was noted. The co-occurrence of upper limb bracing and feet-first landing injuries were fairly common in the skeletal assemblage (Appendices 13-15).

Direct impact to long bones may result in fracture, classically transverse fractures. In the R.N., such injuries occurred in several scenarios. One sea surgeon's entry describes a tibial fracture following a fall onto a gun carriage. Another entry records that a 27 year old seaman, Timothy Buskley, suffered a transverse fracture of the tibia and fibula falling down a hatchway ladder. The bones had been fractured twice before in the same location. He remained on the sick list for over four months before returning to duty (ADM101/84/6A/Folio 19). Perhaps this time the bones were given sufficient time to heal fully. However, weakening of previous calluses may well be associated with scurvy. Recoiling gun carriages and gunshot have also been cited as causes of femoral and tibial fractures in the sea surgeons' journals.

Direct posterior blows from falls from a height, or from being thrown against a static object in a storm or battle, are suggested in the compression of the humeral head, scapular spine fracture and anterior luxation of the right shoulder of Plymouth 661. In other skeletons, direct posterior blows from falls backwards are the probable cause of fractures of some spinous process of the vertebrae, posterior rib fractures, two intertrochanteric crest fractures of the femur, and olecranon process fractures of the ulna.

7.4.2. Falls from a standing position

Losing one's balance on a heaving deck could also lead to similar ankle injuries discussed above. For example, one sea surgeon's journal of 1802 records:

'John Phillip Baptiste, aged 24, Seaman; fracture of the tibia and fibula of the right leg, with luxation of the foot outwardly, occasioned by a heavy lurch of the ship throwing him off his legs, the right leg getting jammed between the casks and on the ship's righting, one cask gave way and rolled over his leg. Taken ill, 3 November 1801, at sea. Discharged to duty, 2 January 1802'. (ADM101/115/3A/7/Folio 43).

A journal entry of 1796 describes another twisting injury to the ankle from a standing height:

'....*ankle much swelled, inflamed and painful, with a small contused wound by each malleolus, occasioned by slipping his foot in a small scuttle near the head and in which position he fell to the deck'* (ADM101/93/2D/Folio 3).

Six months later, the seaman was still on the sick list, and was discharged to Plymouth Hospital for further treatment. This suggests unstable malleolar fractures. Slipping on a wet and heaving deck also resulted in soft tissue and bony trauma.

7.4.3. Crush injuries

Crush injuries cited in sea surgeons' journals range from being struck by falling blocks and yards in a storm or battle, catching fingers and hands in blocks when adjusting tension on the ropes, or between a gunport sill and a gun during gunnery practice, a limb being crushed between the boat and the side of the ship when preparing to board. Crush injuries to the feet from recoiling gun carriages and dropped shot were not uncommon accidents related to firing the great guns. This sometimes resulted in traumatic amputation of a digit, hand or foot (ADM101/93/2C/4/Folio 30). The amputated leg of one Haslar patient who had suffered roundshot being dropped on his foot, crushing several tarsals and metatarsals, is curated in the Gordon Medical Museum of Guy's Hospital, London.

Osteologically, crush fractures of the hands and feet were not common in the skeletal assemblage, although admittedly many distal phalanges did not survive. Two traumatic amputations of the distal phalanx of the hallux were present. Sea surgeons record amputating damaged digits at sea, and in the hospital musters fingers were the most commonly amputated body part. Amputations at the joint may well not have left any cutmarks, however, and no finger amputations were osteologically identified.

7.4.4. Interpersonal violence

Interpersonal violence in the lowerdeck of the R.N. took several forms, including personal disputes between the men, brawling in foreign ports, recreational contests (such as boxing matches), officially sanctioned corporal punishment, and battle injuries.

(i) Boxing and brawling

Although fighting between the men was forbidden by the Articles of War (the official code of conduct in the R.N.), it seems inevitable that personal differences between individuals in a crew of upwards of 600 men crammed together within the isolated, contained world of a ship at sea would break out sporadically into physical violence. Indeed, in his memoirs seaman Samuel Leech (1857) reflects with glee on a seaman's defeat of a tyrannical marine in a fistfight kept secret from the officers. Drunken brawling in foreign ports is a commonly mentioned feature of naval life. Surgeons' logs describe knife and razor attacks (ADM101/93/2B/1/Folio 3) and beatings severe enough to hospitalize the men concerned (ADM101/98/3A/2/Folio 16).

Modern Western medical and forensic research exploring the most common fracture patterns associated with blunt force interpersonal violence, indicate that the head, particularly the face, are the most commonly targeted body part in violent assaults, accounting for 45-69% of violence-related injuries. This was followed by accidents (commonly road traffic accidents), falls and sporting injuries (Brickley and Smith 2006). Walker (1997) examined 205 cranial vault fractures for evidence of interpersonal violence, and found the frontal bone (62.1% of fractures) and parietal bones (35%) were most commonly fractured, followed by the occipital and zygomatic bones (2.9%). Sided dominance was apparent, with 63% of lesions located on the left. This suggests that a higher proportion of blows were delivered to the front and side of the head by a right-handed assailant facing the 'victim'. Such patterning was not so clear in the R.N. crania (see Fig. 6.3). Although there were slightly more anterior and lateral lesions, these were widely distributed and did not show distinct side dominance. Thus, whilst some may well have been due to interpersonal violence, other causes, such as falls and accidents, probably account for many lesions.

This fairly 'global' spread of cranial fractures did not apply to the facial region, where clear predilection for the nose and zygomas was evident. A cross-cultural study by Brickley and Smith (2006) reveals considerable differences in the proportions of facial injuries attributable to violence in different populations. This ranged from less than 10% to greater than 80%, but was generally higher in modern Western populations than non-Western ones. After road traffic accidents, falls were a leading cause of facial injuries in non-Western populations, supporting the interpretation of culturally specific targeting of the face in violent assaults in the West (Brickley and Smith 2006). This echoes Walker (1997)'s osteological study of modern and archaeological populations across the globe. He found that facial fractures, particularly nasal fractures, were much more common in several post-medieval and modern skeletal assemblages of European ancestry than in non-Western archaeological assemblages, including those displaying high cranial vault fracture rates.

Walker associated facial targeting with fighting behaviour copied from bare-knuckle boxing, a very popular spectator sport in all social classes from the Regency period onwards (Walker 1997). Boxing's predilection for the face, especially the nose and eyes, has continued to influence street fighting and wife battering ever since (*Ibid.*). There were 111 nasal fractures (12.2% of all fractures) in the R.N. skeletal assemblage. Contemporary illustrations such as *'A Milling Match'* (Fig. 7.4), show that like so many of their contemporaries, boxing was popular amongst R.N. seamen, possibly as a recreational sport or as a non-lethal way of settling disputes. Interestingly, the movement of both pugilists is constrained by a rope around the waist, suggesting that the principal aim of the fight was not to inflict major bodily harm. This moderation may also account for the surprisingly low number of parry fractures of the ulna (two possible examples) in the R.N. assemblage, given the high prevalence of nasal, Bennett's and anterior rib fractures.



Figure 7.4 *The lowerdeck in port showing seamen carousing with prostitutes on board. The free-for-all that prevails has extended to a boxing match between two seamen. Note the upright fists of bare-knuckle boxing of the period and the ropes around the waist of both pugilists. Image courtesy of the National Maritime Museum, Greenwich.*

Bennett's fracture of the MC1 is another fracture culturally associated with bare-knuckle boxing and emulative brawling in the post-medieval period (Brickley and Smith 2006; Walker 1997). In modern populations, they account for a third of all MC1 fractures, are ten times more common in males, and usually located on the dominant hand (Galloway 1999). Right-sided dominance was apparent in the R.N. skeletal assemblage, with 14 of the 20 Bennett's fractures being right-sided. Punching injuries in modern Western societies are more commonly associated with MC4 and MC5 (Leclerq 1999; Muller 2006), but are relatively rare in earlier populations. Their prevalence today is probably due to changes in modern fighting styles, which now emulate the sideswipe of modern gloved boxing, rather than the upright jabbing of earlier bare-knuckle styles (Brickley and Smith 2006). In modern

populations, Bennett's fractures may also result from falls (*Ibid.*)- another probable scenario in an 18th century R.N. context.

There were 200 rib fractures in the R.N. skeletal assemblage, of which half of known location was anteriorly or laterally located. Rib fractures in these locations result from an anterior blow to the chest, interpersonal violence and forward falls being the most common scenarios today (Brickley 2006). In a naval environment, being flung against the ship's sides or contents in a storm or battle, or being hit by flying objects during a broadside should also be considered. Nevertheless, interpersonal violence probably accounted for many cases. In sea surgeon's journals, the few recorded rib fracture were a consequence of falls, but like MC1 and nasal fractures, brawling injuries were probably not reported or treated.

(ii) Flogging

Corporal punishment was commonplace in the R.N., with many boatswain and mates using switches to *'start'* seamen who were slow to their posts. There are many reports of R.N. officers striking men as punishment or to enforce discipline, but striking a man's face was deemed completely unacceptable (Rodger 1986). Facial fractures in the seamen skeletons are therefore unlikely to be due to such corporal punishment. That said, Samuel Leech (1857) does describe a particularly brutal lieutenant punching seamen in the head.

Flogging with a cat-of-nine-tails was an officially sanctioned punishment in the R.N. (Fig. 7.5), and seamen's memoirs leave embittered accounts of excessive, frequent punishments meted out for a wide range of perceived misdemeanours (e.g. Leech 1857; Nicol 1822; Robinson 1836). After two dozen lashes, Leech (1857, 9) described that the '*the lacerated back looks inhuman; it resembles roasted meat burnt nearly black before a scorching fire*', whilst '*four dozen strokes have cut up his flesh and robbed him of all self-respect'* (*Ibid.*). Flogging through the fleet was the most extreme and



Figure 7.5 *'A Point of Honour' illustrates flogging in the R.N.. The man about to be flogged had been tied spread-eagled to the gratings in readiness for his punishment. Image courtesy of the National Maritime Museum.*

demeaning form of this punishment, which involved being rowed from ship to ship and being flogged in each. The total punishment varied between 100 and 300 lashes (Leech 1857).

Whilst soft tissue damage to the back was often extreme, it is unclear from contemporary accounts whether flogging injuries resulted in the fracture of underlying bones, such as the posterior aspect of the ribs or the scapulae. The only hospital muster entries suggestive of flogging injuries were '*excoriations*'. There were four crush fractures to the scapular body in the skeletal assemblages, which may have been due to severe flogging or beating (as seen in Blondiaux *et al.* 2012). Some posterior rib fractures may well be flogging injuries. With the arms at the sides, the posterior aspect of the upper thoracic ribs is usually protected by the overlying scapulae. In the R.N., flogging was a public punishment, in which the man to be punished was tied spread-eagled to a grating (Fig. 7.5). In this position, with the arms raised and abducted, the scapulae move laterally exposing the underlying ribs to possible injury. Direct posterior blows, such as falling or being thrown backwards

against a static object in a storm or explosion (e.g. from a grenade or bombardment) may equally have been the cause, however.

(iii) Battle injures

Naval engagements were another source of interpersonal violence, which was sporadic but devastating when they did occur. Large fleet actions largely involved bombardment by the great guns, and boarding an enemy vessel was relatively rare, the Battle of Trafalgar being an exception. Boarding was more common in encounters between smaller vessels, such as frigates, and here hand-to-hand fighting and small-arms fire played a greater role (Fremont-Barnes 2005). Amphibious attacks on shore defences, or cutting out operations, also involved more close conflict (*Ibid.*).

A range of blunt force, sharp force and projectile injuries were sustained during sea battles (as described in Chapter 2). Distinguishing between everyday trauma aboard ship and blunt force battle trauma is problematic, as many crush injuries and falls may have occurred in either scenario. Sharp force and projectile trauma are more likely to have been battle injuries, though some such injuries were due to accidents and suicides. For example, one sea surgeon's entry records a marine, John Hamlet, who put his gun down when answering the call of nature, but it slipped and went off as he tried to catch it, blowing off the middle finger (ADM101/115/3A/4/Folio 33). A captain's account of a suicide aboard a ship moored in Hamoaze attached to the 1812 Plymouth muster records that the gunner's mate was found dead in the gunner's storeroom '*in a welter of blood*' holding a pistol after shooting himself in the head (ADM102/623). He was buried in Plymouth Hospital's burial ground.



Figure 7.6 *A naval engagement involving bombardment and hand-to-hand fighting. Note the range of weapons, including pikes, cutlasses, muskets, pistols, tomahawks and roundshot. Image courtesy of the National Maritime Museum, Greenwich.*

The R.N. skeletal assemblage was remarkable for the low prevalence of 'battle trauma'. This may reflect the infrequency of naval engagements in the life of any one seaman or marine. Bodily protection, such as armour or specialised clothing, was not used in 18th century naval warfare (Fig. 7.6), and hence, would not have influenced the patterning in battle injuries. In addition, during a battle, corpses were commonly thrown overboard to keep the decks clear for fighting, and those that died soon afterwards were often buried at sea (Adkins and Adkins 2008; Lavery 2004; Lewis 1960b). Thus, the majority of battle fatalities would not have been interred in the burial grounds of Haslar and Plymouth Hospitals. Seamen had a superstitious dread of burial at sea, however, and preferred a land burial whenever possible (Stewart 2005). Thus, conveying the dead to land for burial sometimes did occur when the time lapse between death and landing was short.

Sharp force trauma

There were ten cases of sharp force trauma in the skeletal assemblage, of which only two were perimortem. The maxillary puncture wound of Greenwich 3272 was inflicted shortly before death. Location of the injuries ranged from the face, cranium, sternum, humerus and tibia. These cases did not include surgical operations, autopsies or dissections (see Appendix 19), which lay beyond the scope of this study.

Only one skeleton displayed sharp force trauma to the cranial vault: a long narrow superficial incision into the outer table of the posterior parietal and left temporal bones of Greenwich 3269. The narrowness of the lesion indicates a fairly fine blade, such as a knife or bayonet or the tip of a cutlass, which had slashed across the back of the skull. Other cranial trauma on this skeleton included a right parietal bone fracture (possibly the result of a spall from a slicing blade injury), and a narrow, linear vertical fracture of the frontal bone and greater wing of the sphenoid, which itself could be another cutmark. The advanced state of healing of all of the above lesions complicated interpretation. Amongst other fractures, the nasal bones, sternum and four anterior ribs of this skeleton had also been broken, indicating anterior blunt force trauma (potentially but not necessarily due to interpersonal violence). Unfortunately, in this older pensioner it is impossible to associate these lesions.

There were two examples of sharp force trauma to the face (Greenwich 3032 and 3103). Greenwich 3032 suffered vertical sharp force trauma down the left cheek, severing his zygoma and bisecting his left mandibular ramus (presumably a sword or cutlass injury). The morphology of the left condyle was greatly altered and atrophied, probably due to nerve damage. The distortion of the normal morphology of the injured ramus and condyle suggests gross facial disfigurement and functional impairment of mastication and, probably, of speech.

In addition, he probably was 'lame' in the left leg. Although no cranial fracture was present, the above facial injuries may well have been accompanied by right-sided blunt force cranial trauma, causing cerebral damage in that region, as extreme atrophy and osteopaenia were present in contra-lateral femur and pelvis. More distal elements of the limb had not survived. Somatic nerve damage (e.g. spinal nerves) may of course account for this extreme limb wasting, but no vertebral lesions were present, bar osteoarthritis. Northcote (1770) describes marked lower limb atrophy in hip luxation, but again there was no skeletal evidence of such an injury. Despite these severe disabilities, Greenwich was 60+ years when he died.

Fig. 7.7 shows a pensioner with a 'lame' leg, ambulating by means of a sling and under-arm crutches. If mobile, it is probable that Greenwich 3032 used a similar contrivance. Lameness was a fairly common admission diagnosis in the Haslar and Plymouth Hospital musters (n= 258), of which the leg, hip and thigh accounted for 11.2% of cases. Lame upper limbs were more common. However, it is unclear from the musters if these afflictions were chronic.

The skeleton of Greenwich 3103 displayed 26 fractures, including blunt force trauma to the nose and maxillae resulting in a grossly malaligned nose, a right zygomatic fracture and probable sharp force trauma to the left maxilla, resulting in the separation of the infero-lateral orbital floor and zygomatic arch, and the probable loss of that eye. All fractures were well-healed, and it is problematic to associate different fractures with a single event.

Healed lesions to the sterna of Plymouth 757 and 909 indicate anterior sharp force trauma- a probable puncture to the former and a shallow slash across the anterior chest in the latter. Although the former showed multiple fractures and a shoulder subluxation, this was the only sharp force lesion. Plymouth 909 also did not show other evidence of trauma, but active periostitis on multiple elements indicative of scurvy and chronic respiratory disease was present.



Figure 7.7 *Greenwich pensioners. The pensioner in the left foreground is using underarm crutches and his lame right leg in a sling to ambulate. The pensioner in the right foreground displays a below-knee amputation. A femoral amputee is in the background. Image courtesy of the National Maritime Museum, Greenwich.*

The right humeral head of Haslar 009 showed an unhealed straight-sided wedge-shaped lesion, probably a sword or tomahawk wound to the shoulder. Like Haslar 009, this young male showed extensive active periostitis across the skeleton in a pattern highly suggestive of active scurvy, as well as active rib periostitis. It is quite probable that pulmonary disease, scurvy or other co-morbidities caused his demise and that of Haslar 009 rather than the trauma, although it is of course possible that both suffered soft tissue trauma not apparent on the skeletons.

There were cutmarks to the tibiae of Plymouth 564 and possibly 662 (see above) and 914. In the first, multiple incisions to the anterior shaft were inflicted by a narrow blade, such as a knife, angled upwards. Attack from a lower vantage point is not surprising given the vertical construction and multiple levels in a ship. A lack of healing indicated perimortem trauma, but it remains uncertain if these lesions occurred before or soon after death. They may well have been due to interpersonal

violence, such as via a knife or bayonet, but equally may have been incised by a surgical knife post-mortem (although they are unusually deep for 'filleting' cutmarks). The latter interpretation is strengthened by the regularity of the cuts, and the presence of transverse cutmarks on the dorsal surface of the left MT1 shaft. A craniotomised skull was also present in the backfill of the same grave (possibly even of the same individual).

In Plymouth 914, taphonomic processes have made the necrotic lesion on the left anterior tibia of Plymouth 914 difficult to interpret, but, if the oblique straight edge is real, this suggested a single downwardly angled cut with a heavy blade, such as a cutlass.

A disarticulated fragment of femoral shaft from the Plymouth burial ground showed similarly angled cutmarks indicating slicing blows from a heavy blade, the protagonist using a slice then flicking action to dislodge the blade (each time carrying with it a sliver of bone). This slice-flick action was repeated at least four times. In addition, isolated cutmarks to other aspects of the shaft indicated at least three more blows to the thigh, and that the victim was clearly changing his position-presumably to escape or ward off further blows. The number of cutmarks so closely spaced suggests a frenzied attack. The rounded curvature of the cuts indicated that they had been inflicted with a curved blade, the most probable weapon being a curved-bladed cutlass, widely used in the French Navy of this period (Fremont-Barnes 2008).

Projectile trauma

The greatest carnage in a sea battle was caused by flying splinters, but also anti-personnel ordinance, such as grapeshot and canister shot, and grenades often dropped down hatchways to the decks below (Fremont-Barnes 2008; Henry 2004). Direct hits by roundshot often caused instant death or immediate amputation of a limb. This may account for the lack of evidence in the hospital assemblages. Small-arms fire in sea battles was limited to very close engagements or by snipers hidden aloft. It played a greater role in amphibious attacks (Fremont-Barnes 2008). It is thus not

surprising that the number of projectile injuries seen by naval surgeons was very much lower than their army counterparts, where salvoes of musket-fire in set-piece battles caused considerable injuries (Crumplin 2007).

There were six possible projectile injuries in the R.N. skeletal assemblage: two to the cranium (Haslar 002 and Plymouth 651), one to the distal humerus (Greenwich 6019), one to the right ilium (Plymouth 633), to the right tibia and fibula (Plymouth 662), and two to the scapular body (Plymouth 906 and 910). Diagnosis was complicated by healing and necrosis, with the exception of Plymouth 651.

The neat round perimortem penetration of the occipital bone just above the *foramen magnum* of Plymouth 651 bears the characteristics of projectile trauma, the size and shape being consistent with a pistol-shot. Although fracture location might suggest judicial execution, this form of capital punishment was not the norm for the lowerdeck. Hanging from the yardarm was the standard punishment for capital crimes, such as murder, mutiny, sodomy, cowardice or striking an officer (Eder 2004).

The lack of healing of the 'pistol-shot' lesion at first seems surprising given the probable time lapse between injury, hospital admission and death. Its postero-inferior location makes it highly improbable that this was one of the gunshot suicides described in captain's notes pinned to the Plymouth Hospital musters, but was probably a fatality from combat, conveyed as '*a corpse*' from a ship moored at Hamoaze to the hospital for burial. Alternatively, the individual may have been admitted alive but died soon afterwards. However, probable damage to the cerebellum, and even the brain stem, makes it likely that death was instantaneous or followed very soon after injury.

Rapid conveyance of the injured to Plymouth Hospital did sometimes occur following an engagement. For example, Plymouth Hospital muster entries of the 11th September 1810 record the admission of 26 gunshot victims from the *Dreadnought* ['Gunshot' included roundshot as well as

small-arms fire (Guthrie 1833)]. Four days previously the *Dreadnought* had attempted a cutting-out operation of a Spanish brig, the *Maria-Antonia,* west of Ushant (James 1837). Although no head wounds were recorded in these muster entries, two fatalities dying a day and six days later in the hospital would also not have displayed macroscopic evidence of fracture healing.

The broadly triangular penetrating injury to the occipital bone of Haslar 002 bore several features of a keyhole fracture of a spent musket-ball, or similar, glancing off the back of the head, but equally may be severe blunt force trauma from a spiked tomahawk poll (see Chapter 6). The wound edges appear modified by surgical removal of sharp or loose bone splinters, in accordance with surgical practices of the day. Smoothing of the wound edges indicates survival for several weeks. Prolonged survival with penetrating cranial injuries is described in Charles Bell's case notes accompanying the paintings that he made of soldiers that he treated in the Napoleonic Wars (some of them at Haslar Hospital) (Fig. 7.8) (Crumplin and Starling 2005). This was despite brain herniation (*fungus cerebri*) from cerebral oedema, intracranial bleeding and secondary infection (*Ibid.*). It is quite possible that Haslar 002 was similarly affected, although no endocranial new bone was present to substantiate this.

The right iliac blade of Plymouth 633 showed a lobular, slightly smoothed, but otherwise unremodelled lesion in the anterior cortex. This lesion is highly suggestive of a deformed musket-ball injury, the ball flattening on firing or contact. Such deformation and subsequently irregular wound shape has been noted in experimental studies (e.g. Magee 1995; Schats et al. 2013) and historical anatomical collections (Kaufman 2003). The absence of the ball shows surgical removal.



Figure 7.8 *Fungus cerebri in a Napoleonic soldier treated by Charles Bell. Note the bone splinters that had been removed. Image courtesy of the Edinburgh University Anatomy Museum.*

Smoothing of the wound edge indicated that the individual survived the injury for weeks, but ultimately may have succumbed to peritonitis. However, the abdominal wound was not his only injury. He also suffered an ununited mandibular fracture with active osteomyelitis, and an unhealed right femoral amputation. A compromised dietary intake (from the mouth injury) and sepsis probably left this patient too debilitated to survive the highly dangerous secondary amputation of the femur. Clearly this individual's abdominal and pelvic regions were of interest to the hospital surgeons, as multiple fine blade marks (probably by a scalpel) were present on the left anterior iliac crest, suggesting autopsy.

A possible incomplete crush fracture from a musket-ball fragment or similar projectile was the most probable aetiology for a discrete, broadly circular, concave lesion on the anterior aspect of the right distal humerus of Greenwich 6019, which has since been partly in-filled with irregular bone. Similar lesions, known to be musket-ball injuries, are present in the Allcock-Balligall collections of the University of Edinburgh's Anatomy Museum (Kaufman 2003). Fig. 7.8 shows Charles Bell's oil painting of a Corunna veteran with a not dissimilar gunshot wound to his distal humerus, thought to have been painted at Haslar Hospital.



Figure 7.9 *Oil painting by Charles Bell depicting a musket-ball injury to the arm of a Corunna veteran. Inflammation of the wound margin is evident. This painting is thought to have been painted at Haslar Hospital and depicts the tented encampment immediately south-west of the Paddock. Image courtesy of the Edinburgh University Anatomy Museum.*

The amputated lower leg of Plymouth 662 also displayed somewhat enigmatic butterfly fractures of the tibia and fibula. These fractures are generally associated with high energy impacts, such as ballistics. No musket-ball remained in the wound, and necrosis had destroyed much of the wound edge, complicating interpretation. One straight-sided edge made by a heavy blade suggests a sword cut rather than a musket-ball, but equally may be aggressive surgical debridement of the necrotic lesion. No such straight edge was evident in the butterfly fracture of the fibula.

The last possible projectile injuries were penetrating lesions to the left scapular bodies of Plymouth 906 and 910. Advanced healing had obliterated much of the original appearance of the wound margins, leaving them oval and smooth, and making identification of the aetiology problematic. Both lesions were associated with slight crushing of the adjacent bone, but this was localised and the rest of the blade was intact. No posterior rib fractures were identified in either skeleton. This suggests

that the scapular lesions did not involve extreme force. Wooden splinters of the ship's sides during a bombardment may well account for these lesions, but may equally have been puncture wounds from the tip of a sword, bayonet or pike inflicted from behind.

7.4.5. Occupational injuries in sailing a ship

The very specific lifestyle and hazards of sailing and fighting in a R.N. ship have resulted in distinctive trauma patterning from falls, crush injuries and interpersonal violence. There are four unusual lesions that do not fit into these categories, however, yet occur with such frequency that they might be regarded as characteristic of mariners. These are Shepherd's fractures of the talus, acetabular joint surface impaction fractures and flange lesions, and avulsion fractures to the MC3. Other fractures and bony modifications that occur in lower frequencies but, nevertheless, are unusually common in the R.N. assemblages are patellar fractures and Eagle's syndrome.

One of the most prevalent and unusual fractures in the R.N. skeletal assemblage were Shepherd's fractures (Shepherd 1882), found in 21 left and 28 right tali. Shepherd's fractures, colloquially known as nutcracker fractures, occur when the lateral tubercle of the posterior process of the talus is crushed between the distal tibia and the calcaneus during hyperplantar flexion or forced inversion of the foot (Hillier et al. 2004; Judd and Kim 2002). Modern cases are found in specialist groups, such as professional ballet dancers, footballers and baseball players (*Ibid.*). Their high prevalence in the R.N. assemblage suggests also occupational patterning. Why these fractures should be so prevalent in the R.N. assemblage is unclear. One possible mechanism of injury is that during a swell, barefoot seamen precariously balancing on ropes slung beneath the yards (Fig. 7.10), forcefully pointed their toes in order to maintain their balance on the rope in choppy or heavy seas. This sudden plantar hyperflexion of the feet may have resulted in a Shepherd's fracture. Being flung forward against the yardarm in a swell may also account for the high prevalence of contused loins in the musters, although, admittedly, no such cases were recorded in sea surgeons' journal entries. Shepherd's fractures were not described in the skeletons of the *Mary Rose, Swan* or *Vasa* skeleton reports (Black 2002; During 1994; Stirland 2005a; Stirland 2005b), but it is possible that they were mistaken

for *os trigonum*. *Os trigonum* is a non-metric trait or developmental anomaly, found in 2.5-14% of normal modern feet, where the tubercle is separate from the rest of the element (a developmental anomaly caused by a separate ossification centre just posterior to the posterior talar process) (Wheeless 2014). It remains uncertain if Shepherd's fractures are more widely characteristic of maritime assemblages.

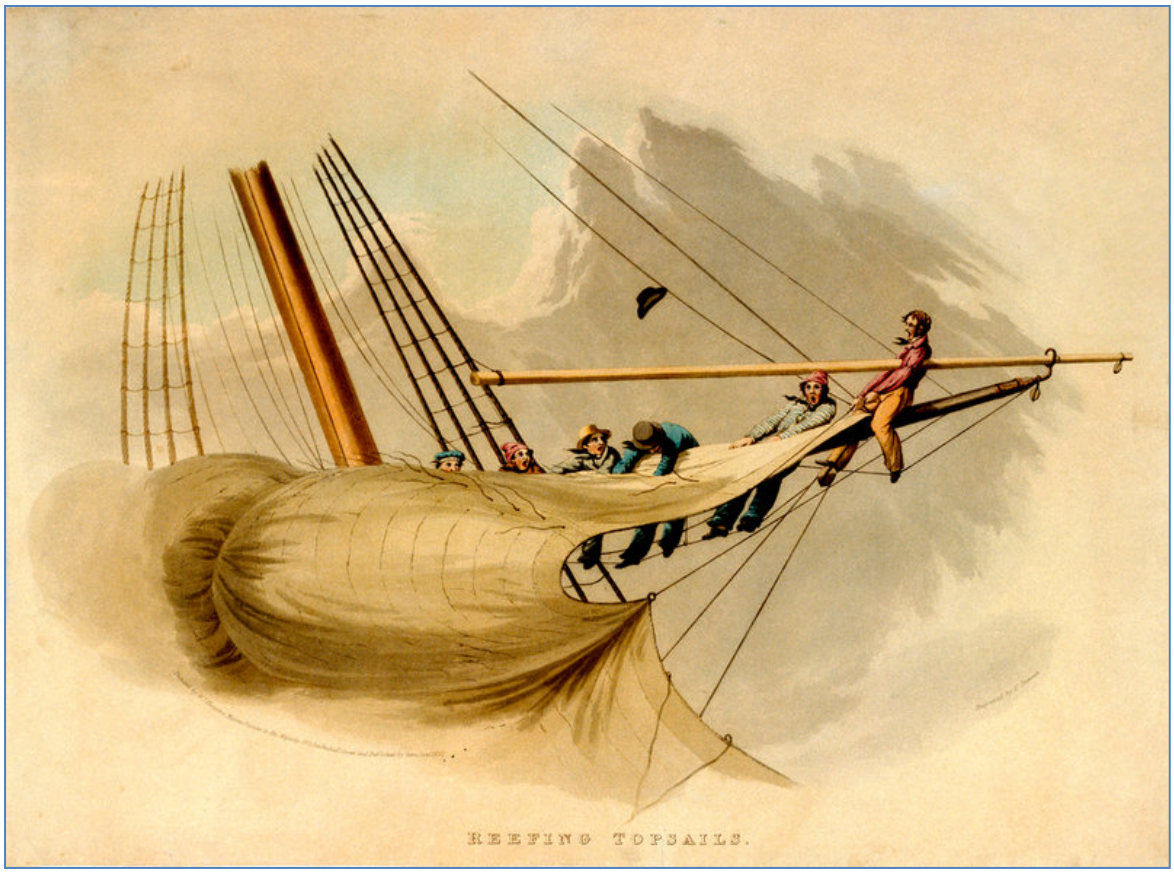


Figure 7.10 *Reefing topsails in a wind. Note the precarious balance of the sailors on rope stirrups ('the horse') slung beneath the yard. Image courtesy of the National Maritime Museum, Greenwich.*

Eighteen **acetabular flange lesions** were noted in the osteological assemblage, and 11 in the *Mary Rose* crewmen (Capasso et al. 1999; Stirland 2005a; Stirland 2005b). In the 17th century *Swan* skeleton from Mull, the dorsi-lateral rim of the right acetabulum is described as suffering '*cortical disturbance'* and the development of an *'impingement facet*' (Black 2002, 8), which suggests an acetabular flange lesion. In addition, '*irregularity on the articular surface*' may be an acetabular impaction lesion, which Black ascribes to the upward thrust of the femur. Similar impaction lesions

were recognised more recently in the *Mary Rose* skeletons (Drew 2013). Neither lesion was described in the *Vasa* publications (During 1994; During 1997a).

Acetabular flange lesions indicate slight superior subluxation of the hip joint onto the rim and juxta-articular surface of the ilium. The presence of these unusual lesions in three maritime assemblages suggests an occupational association with seafaring. A large proportion of 18th century R.N. skeletons showed distinctive widening and flattening of the acetabula. Although not mentioned in the *Mary Rose* or *Swa*n reports, it is possible that this morphological change developed as a consequence of seafaring, through a constant accommodating of stance to the ship's motion. It probably developed in childhood or adolescence before the tripartite elements of the acetabulum fuse and, hence, would have only affected those seamen who went to sea in the first two decades of life. Due to the limitations of this study, these morphological changes were not formally quantified.

The functional effect of a wide, flat acetabulum may well be reduced joint stability, with a much wider range of motion of the femoral head than is possible in a deeper, more restrictive socket, possibly predisposing the femur to slight subluxation. Sea surgeons' journals and muster entries do not describe such minor subluxations, but one contemporary captain's observations suggest that flexible, loose joints were a characteristic of seamen, particularly when contrasted with marines:

> *'A thorough-going, barrack-bred, regular-built marine, in a ship of which the sergeant-major truly loves his art, has without very exaggerated metaphor, been compared to a man who has swallowed a set of fire-irons.....While on the other hand, your sailor-man is to be likened to nothing except one of those delicious figures in the fantacoccini [puppet] show-boxes, where arms and legs are loosely flung about to the right and left, no one bone apparently having the slightest organic connection with another one....*' (Hall 1846, 152-3).

Such flexibility at the hip may well have been enhanced by shallow acetabula. Increased range of motion in the shoulder joint may in part be due to *os acromiale* (TPR 8.9%) and, possibly, muscle and ligament laxity from repetitive upper limb strain. Loaded, repetitive over-arm actions in seamen involved pulling on ropes, furling canvas, and moving aloft in the rigging. Such shoulder strain may account for the high dislocation rate in this occupation noted in both the osteological and historic

records, and for the robusticity and marked muscle insertions in the humerus of so many R.N. skeletons.

Another rare condition present in eight skulls of the R.N. assemblage was **Eagle's Syndrome** (15.5% of individuals with surviving styloid processes). Eagle Syndrome is an abnormal elongation of the styloid process of the temporal bone (Eagle 1948), beyond 30mm (Gokce et al. 2008; Raina et al. 2009). Ossification of the stylohyoid ligament is often implicated in its development, but factors predisposing the ligament to ossify are not well understood. Diverse factors, such as embryological development, chronic local irritants, mechanical stress and trauma during styloid process development, and elevated calcium and phosphate levels in chronic renal failure have all been implicated (Gokce et al. 2008). Why Eagle Syndrome was so prevalent in the R.N. assemblage is unclear, but may lie in localised mechanical stress induced by forceful, frequent use of the neck muscles as ancillary muscles during elevation and strenuous use of the upper limb. Although not quantified, a very high proportion of R.N. skulls did show well-developed nuchal lines, indicating pronounced posterior neck muscle development. Cervical osteoarthritis was also common, particularly in older individuals. Thus, the 'rare' condition of Eagle's syndrome either has been grossly unreported in the medical and osteological literature, or the R.N. assemblages show an extraordinary high prevalence, possibly linked to muscle development in response to their seafaring occupation.

The physicality of a life at sea is also demonstrated by the high number of avulsion fractures seen in the R.N. skeletal assemblage. In the lower limb, these involved the tubercle and shaft of MT5 (n= 10), two examples of patellar ligament avulsion, and two probable capsular ligament avulsion of the knee. There was only one case of Osgood-Schlatter's disease, compared with the 23 cases noted in the *Mary Rose* assemblage (Stirland 1991). The reason for this difference is unclear, but may relate to specific occupations of these *Mary Rose* skeletons, which Stirland suggests were specialist gunners, and that this injury was directly associated with gunnery (Stirland 2005a). In the 18th

century R.N., both seamen and marines fired the great guns, but this activity only a relatively small component of their everyday occupations (Adkins and Adkins 2008; Lavery 1989; Lewis 1960b), and hence, may not have resulted in as many patellar ligament injuries.

Overall, muscle insertions were much clearly defined in the upper than lower limb of 18th century seamen. Avulsion fractures of the hands included two chip fractures to the lunate and sixteen MC3 styloid process avulsions. The distribution of MC3 avulsions showed marked side dominance (five left, 11 right). Such injuries result from strain to the *Extensor carpi radialis brevis* tendon, which are involved in extension and abduction of the wrist, and generally acts as a wrist stabiliser. These avulsion fractures are extremely rare in the modern medical literature (Boles and Durbin 1999; Breeze et al. 2009; Rofman and Pruitt 1993; Tsiridis et al. 2001), due to the very specific mechanism of injury. Most authors report a flexion moment at the wrist, combined with a simultaneous contraction of the *M. extensor carpi radialis brevis,* with the elbow in full extension and the fist clenched (Tsiridis et al. 2001). Modern cases have involved falls onto an outstretched upper limb (Boles and Durbin 1999; Rofman and Pruitt 1993), striking the side of a vehicle with the hand whilst cycling (Tsiridis et al. 2001), and a badly placed punch by an amateur boxer (Breeze et al. 2009). In the R.N. assemblages, falls and brawls were a major source of other fractures, and probably account for many MC3 avulsion fractures in this assemblage. Like Bennett's fractures, MC3 styloid process avulsions were predominantly of the right side, supporting this possible aetiology of a punching injury. Mitigating against this interpretation is that they did not often occur in the same hand as Bennett's fractures, and were not noted in Brickley and Smith's (2006) study of fractures associated with bare-knuckle boxing.

Alternative occupationally-related activities that might involve the mechanism of injury described above may be grasping and pulling on ropes with an outstretched straight arm, reefing canvas aloft (Fig. 7.11), or heaving on the capstan to raise the anchor. The last was a laborious task involving a large team of men heaving on the spokes of the capstan in unison to make it revolve and wind up

the anchor rope. Fig. 7.11 shows this activity. Note the stance of the seaman in the foreground, with his elbows locked, his wrist in extension and the hand gripping the spoke. Sudden contraction on heaving on the spoke and flexion at the wrist may have caused an MC3 avulsion. Keeping time with the other seamen may have induced additional strain on the wrist joint, as each seaman was not at liberty to stop when tired. However, this proposed aetiology does not explain the sided dominance of the injury in the R.N. skeletons.

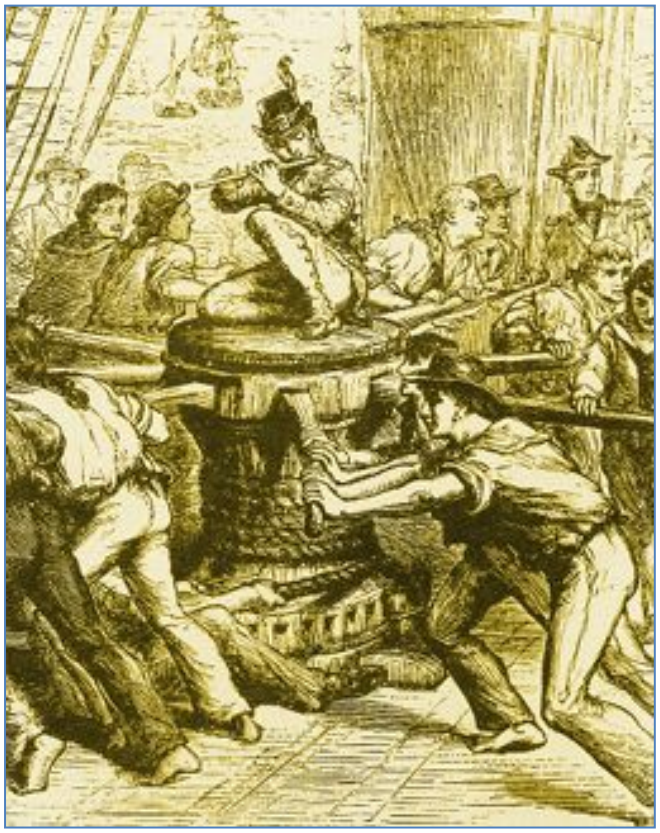


Figure 7.11 *Heaving on the capstan. In this image a marine boy helps the seamen keep time by piping. Several sea shanties are thought to have been composed for this purpose. Source unknown.*

8. Conclusion

8.1. Introduction

The aim of this thesis was to compare osteological evidence and historical data within an historic period. This was done through the prism of trauma patterning in the R.N., by conducting an empirical analysis of osteologically recognised fractures and joint trauma with the prolific primary documentary evidence in the Admiralty Papers, Kew. Through this process the strengths and limitations of each dataset has became apparent but, through critical analysis, fresh insights into the health and lifestyle of 18th to early 19th century R.N. seamen and marines have been made It is clear from this research that both disciplines can only provide a partial window into the past, and that, wherever possible, a combined approach will greatly enrich our knowledge of the past in a way that one discipline alone cannot.

8.2. The influence of theoretical frameworks and academic traditions

Osteology and history come from different academic traditions and consequently their approaches to the study of past peoples also differ. Osteology works very much within a quantitative, empirical tradition, whereas most historians, and certainly naval historians, adopt a more qualitative approach. The upshot of these differences to this study is that there was minimal empirical historical research with which to directly compare the osteological findings (with the exception of two studies of seamen's age distributions and two of stature). Historical analysis of naval trauma has been restricted to the exploration of the organisation of surgical care and surgical techniques (Crumplin 2007; Crumplin 2009; Crumplin and Starling 2005), but, to date, there has been no quantitative studies on fracture patterning in the 18th century R.N. or on the probable causes of such injuries. Indeed, over-generalisation across the time period, a heavy reliance on anecdotal accounts rather than empirical data and on secondary historical sources, has lead many naval historians to overlook some contradictory trends implicit in the data. One example identified in this study is the blithe acceptance that naval medical care improved over the late Georgian period. This study has

demonstrated that, in fact, mortality rates more than doubled in Haslar and Plymouth Hospitals from the 1760s to the end of the Napoleonic Wars. The multiple factors involved in this trend need to be carefully unpicked. Thus, one of the strengths of this study is the application of the more rigorous, quantitative approach of osteology to a historical dataset. Despite this critique of naval historical research, the existence of a rich qualitative background to the origins, onboard organisation, activities and lifestyle of the lowerdeck of the R.N. has greatly facilitated the osteological interpretation of the probable aetiology of many traumatic lesions in a way that is not possible in less well documented and well researched populations.

Although 18th century naval medicine was just emerging from the humoral Galenic tradition, naval surgeons of the late 18th and early 19th centuries were relying much more heavily than before on personal observations of effective treatments, and increasingly basing their surgical care on a sound knowledge of anatomy. This is particularly apparent in naval surgeons' manuals, when discussing fractures and subluxations. The interchangeable definitions of fractures and dislocations in 18th century surgical manuals and modern medical texts, and the similarity of fracture classifications over this period, enables a much more straight-forward comparison between osteological and historical evidence of trauma than would have been possible if other pathological processes had been explored. In addition, unlike most diseases, fractures by definition involve bone, and hence direct comparisons with historical prevalences may be made more readily than is possible in other conditions, where the extent of bony involvement is less predictable (e.g. in syphilis and tuberculosis).

8.3. Demographical composition and origins of the 'lowerdeck'

On a broad brush level, the general historic view that the life of the lowerdeck was arduous and short is largely borne out by the osteological evidence. The young age distributions of the Haslar and Plymouth skeletal assemblages support Trotter's claim that few seamen lived to be old. Indeed, few in the skeletal assemblages survived beyond 35 years. Broadly speaking, this reflected the young age distribution of seamen and marines on active service known from naval records, although the former

was slightly older than the latter- probably the result of a slight age differential in survivorship. The Greenwich pensioners were the exception, in that the majority survived into old age. Quantification of age-at-death of the Greenwich pensioners in both osteological and historical datasets concurred that the overwhelming majority were older adults, but the slightly lower proportion in the 45+ age category of the osteological assemblage probably reflects well-recognised methodological limitations of current osteological ageing techniques.

Historical evidence of the social composition of the lowerdeck of the R.N. indicates that most seamen and marines were working class in origins, that they were from eclectic geographic and national backgrounds, and that a very large proportion either joined the R.N. or merchant navy in childhood or adolescence. Commonly accepted osteological markers of childhood stress, and by proxy living conditions (such as *cribra orbitalia*, porotic hyperostosis and periostitis), were not very useful in this study, as many locations on the skeleton where they are situated were often obscured by bony deposition of subsequent scorbutic lesions or more recent periostitis. High rates of early onset activity-related stress lesions, such as *osteochondritis dissecans* and *os acromiale*, do support the notion that many seamen worked at a physically demanding job from a young age, and given the upper limb distribution, possibly as seamen. This concurs with the historical evidence that a high proportion of the lowerdeck went to sea in childhood or adolescence. It is probable that beginning a maritime career at an early age when the musculoskeletal system was still developing and malleable, lead to shallower, looser joints, which facilitated agility and mobility aloft, but may have predisposed the shoulders and acetabula to subluxation, labral tearing and other joint damage. A young age at going to sea may also account for some of the greenstick fractures and tubular bowing seen in the osteological assemblages.

Osteological analysis revealed that that the R.N. assemblage had the lowest mean male stature of 14 post-medieval skeletal assemblages with which it was compared, indicating that even by the standards of the day, the R.N. crewmen were particularly stunted. This stature broadly concurs with

historical analysis of the final stature attained by seamen and marines. Historical data distinguished between the mean stature of seamen and that of marines, as osteological analysis could not, and did reveal that the latter was greater than former. Given that marines and seamen consumed the same diet and were exposed to similar disease loads, tentatively suggests that it was the more strenuous workload of seamen in their growing years that impacted on final stature. However, this interpretation is complicated by possible differences in the social origins and occupations of the two groups before entering the R.N...

An historical insight that has considerable bearing on osteological age estimation in post-medieval studies is that both seamen and marines' final stature was only achieved in the 22nd or 23rd year (i.e. was delayed by three to four years compared with modern males). Similar historical work on Australian convicts also revealed continued longitudinal growth until this age (Nicholas and Steckel 2009). Together these studies suggest that delayed growth cessation was widespread amongst the working classes of 18th to early 19th century Britain. This finding has considerable implications for osteological age estimation of adolescents and young adults in this time period, which is largely based on the timing of epiphyseal fusion. Thus, in this instance, historical analysis has given additional insights that may inform osteologists working in this historical period.

8.4. Trauma patterning in the R.N.

In general, the very high osteological rate of fractures does concur with the historical view that life aboard a fighting ship was arduous and dangerous and, from the wide variation in fracture types and distribution, that there was a considerable range of probable aetiologies. However, the distribution of fractures and dislocations across the skeleton does show marked differences between the datasets. Long bone fractures were under-represented in the osteological data compared to the muster rates, strongly suggesting survival from these injuries was high. This is supported by the fact that the overwhelming number of long bone fractures in the skeletal assemblages was found in the Greenwich pensioner skeletons- the 'survivors'- and not in the other two younger assemblages- the 'biological failures'.

The type and skeletal distribution of many fractures in the osteological record suggests that a high proportion of fractures and shoulder dislocations were caused by falls from a height or a standing position. This finding concurs with sea surgeons' journal entries. In the skeletal assemblage, there were two major polytrauma cases that showed considerable osteological evidence of high energy impact injuries from falls. There were many less extreme cases that, nevertheless, involved impact or twisting injuries of the ankle joints consistent with falling and landing on the feet, and many cases of bracing injuries of the upper limb. In some cases, this indirect impact extended up the arm to the clavicle causing fracture and glenohumeral dislocation. Arm fractures and shoulder dislocations were also a common feature of the muster dataset. However, the high prevalence of clavicular dislocations in the musters was not reflected in the osteological record. Thus, trauma patterning in both datasets indicated that falls were responsible for a high proportion of seamen and marines' injuries, but the precise patterning of these injuries were slightly different.

Modern medical and osteological studies indicate that Bennett's fractures, anterior rib fractures, and facial fractures, particularly of the nose, are strongly, although not exclusively, associated with interpersonal violence of the street fighting/ brawling kind. Some MC3 styloid avulsions may also be punching injuries. These fractures were amongst the most common in the R.N. skeletal assemblage. Although the Articles of War forbade such fights between men, the very high rates of these injuries in the osteological assemblage strongly suggests that such fistfights were very common in the R.N.. Such fighting injuries were not well represented in the muster data, and are very infrequent in sea surgeons' journal entries. This dearth of recorded cases would indicate that those seamen and marines injured in this context did not report to the sea surgeon for treatment, probably for fear of punishment. Thus, in this example, osteological data gives important insights into the social organisation and private settlement of disputes between members of the lowerdeck, which could not be gained from official documents.

Hospital musters occasionally specify gunshot wounds, but otherwise do not indicate if injuries were incurred in battle. Battle trauma only featured in sea surgeons' journals on the rare occasion that the particular ship engaged the enemy. Naval historians have made general statements that battle injury comprised only a small component of trauma, but did not corroborate these statements with empirical evidence (e.g. Adkins and Adkins 2008; Lewis 1960b). There were 15 cases of sharp force and projectile trauma in the osteological assemblages, of which many were probably battle trauma- that is less than 2% of the total fractures present. Thus, both secondary historical sources and osteological data concur that battle injuries formed only a minority of trauma, but in the latter, this could be quantified.

Whilst the two datasets agree in many respects, there are large numbers of fractures that are greatly under-represented in the historical record, probable the consequence of under- or misdiagnosis. For example, many contusions of the back, side and chest probably included rib, sternal and vertebral fractures, whilst 'ankle dislocations' in the muster entries may in fact have involved fractures, possible even including the many Shepherd's fractures of the osteological record. The musters also included data with which to explore the prevalence and distribution of soft tissue trauma, as well as fractures, which skeletal studies are largely unable to do.

In conclusion, both datasets concurred on broad-brush level that the life of the lowerdeck in the R.N. was arduous, dangerous and often short, but, at a more detailed level, considerable differences in trauma patterning were present. These differences are probably due to unrecognised and unreported trauma by naval surgeons of the day, and differential survival from different injuries, such that the living patients of Haslar and Plymouth Hospitals differed considerably from the dead. The Greenwich pensioners represent the extremities of trauma in the R.N.- in the words of historian M. Lewis (1960, 330), they were '*the 'picked and brine-pickled survivors of a gruelling existence'*.

This study has demonstrated the complexities of comparing two very different datasets, and the inherent limitations of each. In undertaking this empirical approach, valuable but often alternative

insights have been gleaned about the physical effects of this gruelling existence within Britain's '*wooden walls*'. Although not always concurring, careful reading of the osteological and historical evidence has illuminated aspects of the past in a way that each on its own could not.

8.5. Trauma patterning and a seafaring occupation.

One striking contribution of this research has been the identification of several very unusual traumatic injuries and bony modifications, which may well prove to characteristic of 18th century seamen, and possibly, more generally of seafarers in the Age of Sail, as most appear to be sustained during everyday activities and conditions aboard a sailing ship, rather than battle injuries.

They include high rates of

- nasal and superior maxillary fractures
- Eagle's Syndrome
- shoulder trauma (*os acromiale*, dislocation, fracture and rotator cuff enthesopathies)
- Bennett's fractures of the MC1
- MC3 styloid avulsion fractures
- acetabular impaction fractures, supra-acetabular cysts, rim fractures and flange lesions
- wide, shallow acetabula
- patellar fractures
- impaction and twisting fractures of the ankle joint
- Shepherd's fractures of the talus

Although not formally part of this research project, other characteristics observed in this group were rugose muscle insertion and ligament sites in the clavicles and upper limb bones, but these were not marked in the lower limbs. There was considerable periostitis present on the skeletons, often on multiple elements, and often associated with evidence of ossified haematomas and ulcers. A suite of pathological lesions that were ascribed to scurvy (Appendix 7) were seen repeatedly in the R.N. skeletons, so as to appear characteristic of this profession.

Taken together, these lesions may be said to characterise the skeletons of seamen of this period, and may well prove to be markers of the profession when observed in more mixed assemblages in the future.

8.6. Recommendations for future research

The R.N. assemblages are a rare example of a specialist assemblage in which a specific lifestyle may be explored. Recommended areas for further research are listed below.

1. Soft tissue trauma was recorded, but analysis lay beyond the scope of this study. Entheseal changes showed a very definite patterning, being marked in the upper limb but not in the lower limb, and showed relatively little side dominance. Activity-related changes of the hand have already been explored in the Greenwich assemblage (Cashmore and Zakrzewski 2011), but other entheseal patterning should be explored further.
2. In-depth analysis of the geometry of bony elements in response to strenuous exercise may be explored using CT-scanning and macroscopic measurement (such as humeral head torsion and cross-sectional cortical thickening and morphology of long bone shafts). In the lower limb bones, particularly the tibial shafts, this may include marked bony buttressing.
3. Quantitative comparison of acetabular dimensions in R.N. skeletons with a terrestrial population will determine if flatter, wider acetabular joint surfaces are indeed a feature of naval populations. How this morphology relates to acetabular traumatic lesions could be explored further.
4. This study has revealed some distinctive and unusual fracture patterns in R.N. skeletons. It would be extremely interesting to expand this study to include other maritime assemblages (e.g. re-appraise the *Mary Rose*, *Vasa* and *Kronan* material, some of which have never been fully analysed, or were analysed several decades ago when palaeopathology was in its infancy, and to include more recently excavated material, such as 18th century skeletons from Antigua). This study has hypothesised that some rare lesions seen in the osteological

fractures are characteristic or very much more prevalent in mariners (e.g. Shepherd's fractures, MC3 styloid fractures and acetabular flange lesions). This needs to be verified by systematic research in other maritime assemblages.

5. Although recorded, analysis of medical interventions lay beyond the scope of this study. There are 23 amputations, eight craniotomies and four other individuals had cut- and saw-marks indicative of autopsy. Analysis of these findings in the light of the rich historical record may shed new light on 18th century naval surgery techniques and early investigations of pathology.

6. A particularly interesting avenue to explore is length of time of survival following injury or operation using macroscopic, microscopic and histological evidence on healing bone (as described by de Boer *et al.* 2012).

7. This study has concentrated exclusively on trauma, and a recently submitted Ph.D. thesis by Catherine Sinnott (Sinnott 2013) has explored osteological evidence for scurvy in these assemblages. In addition, these skeletons show high rates of bony infection and of degenerative joint disease (DJD), of which much concentrates in the cervical vertebrae and upper limbs. Exploring the association between DJD and osteoarthritis and activity may prove fruitful.

8. There is considerable historical and osteological evidence for the eclectic origins of seamen. A carbon and nitrogen stable isotope study of Haslar and Plymouth Hospital did identify several 'outliers' who probably consumed a mixed C3 and C4 diet (possibly Americans or Mediterraneans) (Roberts et al. 2012). The origins of seamen may be explored further through a systematic programme of strontium and oxygen stable isotope research, and possibly, DNA studies.

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