Urban–Rural Differences in Roman Dorset, England: A Bioarchaeological Perspective on Roman Settlements

Rebecca C. Redfern,[1]* Sharon N. DeWitte,[2] John Pearce,[3] Christine Hamlin,[4] and Kirsten Egging Dinwiddy[5]

[1]*Centre for Human Bioarchaeology, Museum of London, 150 London Wall, London, EC2Y 5HN, UK*
[2]*Department of Anthropology, University of South Carolina, Columbia, SC 29208*
[3]*Department of Classics, King's College London Strand, London, WC2R 2LS, UK*
[4]*Department of Anthropology, University of Wisconsin, Milwaukee, WI 53211*
[5]*Wessex Archaeology, Portway House, Old Sarum Park, Salisbury, SP4 6EB, UK*

KEY WORDS Roman Britain; rural; urban; mortality; health

ABSTRACT In the Roman period, urban and rural ways of living were differentiated philosophically and legally, and this is the first regional study of these contrasting life-ways. Focusing on frailty and mortality risk, we investigated how these differed by age, sex, and status, using coffin type as a proxy for social status. We employed skeletal data from 344 individuals: 150 rural and 194 urban (1st–5th centuries A.D.) from Dorset, England. Frailty and mortality risk were examined using indicators of stress (cribra orbitalia, porotic hyperostosis, nonspecific periostitis, and enamel hypoplastic defects), specific metabolic and infectious diseases (rickets, scurvy, and tuberculosis), and dental health (carious lesions and calculus). These variables were studied using Chi-square, Siler model of mortality, Kaplan–Meier analysis, and the Gompertz model of adult mortality. Our study found that overall, mortality risk and survivorship did not differ between cemetery types but when the data were examined by age, mortality risk was only significantly higher for urban subadults. Demographic differences were found, with urban cemeteries having more 0–10 and >35 year olds, and for health, urban cemeteries had significantly higher frequencies of enamel hypoplastic defects, carious lesions, and rickets. Interestingly, no significant difference in status was observed between rural and urban cemeteries. The most significant finding was the influence of the skeletal and funerary data from the Poundbury sites, which had different demographic profiles, significantly higher frequencies of the indicators of stress and dental health variables. In conclusion, there are significant health, demographic, and mortality differences between rural and urban populations in Roman Britain. Am J Phys Anthropol 000:000–000, 2015.

The Roman author Varro distinguished between urban and rural ways of living, with rustic life styles considered to be superior in morals and health prospects to those lived in cities (Varro, 1934; Goodman, 2006; De re Rustica 2.1–3). Textual and archaeological evidence shows that this was an ideal, limited to the free and wealthy, supported by a subordinate and sometimes enslaved population who were responsible for ensuring that rural areas were productive and lucrative for their owners (Joshel, 2013). This urban–rural division, complex and liable to subversion in its characterization by ancient authors, was a deeply embedded perception of the physical environment during this period, with civil law distinguishing between urban and rural locales, and other laws dictating a settlement's political status and what activities could take place within (e.g., trade) and without (e.g., burial) (Goodman, 2006; Laurence et al., 2011).

Our knowledge of how these urban settlements varied within the Roman Empire has long been a focus of research (Nevett and Perkins, 2000; Storey, 2006; Laurence et al., 2011; Taylor, 2013). In the Western provinces, a ranked system of urban communities developed, with the lowest being the *civitas* capital, an administrative and political center within a territory frequently of pre-Roman origin, whose inhabitants were of non-citizen status. These were beneath the *municipium* and *colonia* in status as distinguished by the legal and political privileges of their magistrates and citizens (Goodman, 2006). Regardless of status, these cities had a distinctive appearance in the landscape: they were bounded by walls, had orthogonal street plans, were surrounded by small-scale horticulture, and had suburban cemeteries lining the roads (Esmonde Cleary, 1987; Goodman, 2006; Laurence et al., 2011). In Britain, new urban settlements of all these types came into being during the 1st century AD, mostly as the centers of native communities (*civitas* capitals), with a small number of *coloniae* and a single *municipium*; these served as administrative, social, and economic hubs in their territories (Millett, 2001; Jones, 2004; Mattingly, 2006; Laurence et al., 2011). This process was referenced by the historian Tacitus in his account of the governorship of Britain by his father-in-law Agricola: "Agricola gave private encouragement and public aid to the building of temples, courts of justice, and dwelling-houses. . . ." (Tacitus, 1973, Agricola 21).

*Correspondence to: Rebecca C. Redfern, Centre for Human Bioarchaeology, Museum of London, 150 London Wall, London EC2Y 5HN, UK. E-mail: rredfern@museumoflondon.org.uk

Received 20 October 2014; revised 6 December 2014; accepted 16 December 2014

DOI: 10.1002/ajpa.22693
Published online 00 Month 2015 in Wiley Online Library (wileyonlinelibrary.com).

The rural environment of Britain also underwent significant changes post-Conquest, with some reorganization of the landscape through imperial appropriation and the creation of extensive estates, the introduction of new technologies and crops to improve productivity, expansion into environmentally marginal landscapes, and a likely increase in population size and density (Millett, 1997; Mattingly, 2006; van der Veen et al., 2008; McCarthy, 2012; Breeze, 2014). Although new Roman-style settlements were created, there is also evidence for widespread continuity in the use of Iron Age roundhouses (Hingley, 1989), and regional and other small-scale studies have documented considerable heterogeneity in rural housing (Mattingly, 2006; King, 2007; Taylor, 2001; Rogers, 2013).

Ancient writers were aware that diet and lifestyles, and therefore health, might differ between town and country, particularly because of the influence of Hippocratic medicine, which connected the wider environment to the behavior, appearance, and health of the people (Nevett and Perkins, 2000); writers were also sensitive to the diseases that could be caused by urban living (Soranus, 1991, Gynaecology). These differences, from living conditions to the impact of urbanism upon demography, have become a major focus of recent scholarship. In particular, the significance of the "urban graveyard effect," that is the higher urban mortality rate attributable to high human and animal population density, poor sanitation, and risk of exposure to disease through position on communication routes, is debated both for Rome and for the cities of the empire although often on the basis of comparative evidence from later European urban populations (Scobie, 1986; Scheidel, 1996, 2001, 2006, 2009, 2010; Jones, 2004; Morley, 2005; Paine and Storey, 2006; Shaw, 2006; Hin, 2008). Taking the example of Britain, environmental archaeology, material culture, and dietary stable isotope data suggest that not only were there differences in terms of living environment, social status and diet between rural and urban populations, but also that these varied across the province (Hurst, 1999; King, 1999, 2001; Cool, 2006; Locker, 2007; van der Veen et al., 2008; Müldner, 2013).

Human remains have also been used to explore the health of rural, suburban, and urban populations across the empire (Sperduti, 1997; Redfern and Roberts, 2005; Caldarini et al., 2006; Cucina et al., 2006; FitzGerald et al., 2006; Prowse et al., 2008; Peck, 2009; Minozzi et al., 2012; Bonsall, 2013; Jackson, 2013; Killgrove and Tykot, 2013; McIntyre, 2013). These studies give an indication that health patterns, particularly the presence of stress markers and infectious and metabolic diseases, varied between locales and higher frequencies of these conditions were often observed in urban cemeteries. One important caveat, which the example of Britain illustrates, is a sample bias toward urban populations in this period, produced by the dependence of the archaeological fieldwork on construction activity (Pearce, 2013a,b). Nevertheless, overall, these findings are in accordance with the historical and clinical data for urban dwellers of later periods, experiencing higher rates of disease, particularly infectious and metabolic conditions (Harrison and Gibson, 1978; Waldron, 1989; Wadsworth, 1997b; Roberts and Cox, 2003; Farmer, 2004).

The first British study specifically to focus on urban–rural inequalities was conducted by Pitts and Griffin (2012). Their study used eight health variables (including, dental diseases, nonspecific infection of the ribs, enamel hypoplastic defects, and cribra orbitalia), selecting data from 30 published site reports, which were categorized as rural, urban, or nucleated, based on their associated settlements. Their study found no significant differences in the age distributions between settlement types, but significant differences in health between urban and non-urban populations, with rural populations showing, somewhat surprisingly, higher frequencies of osteological markers of poor health than urban ones. Using artefact type and the average number of artefacts per grave, they discovered that urban burials contained more goods per grave with a more even distribution of furnishing across cemetery populations. Some correlations were noted between cemeteries with greater inequality in their distribution of furnishing, mainly rural examples, and higher frequencies of osteological indicators of poor health.

Our study seeks to further examine and elucidate their findings using a regional approach. As Pitts and Griffin (2012) acknowledge, the use of data from skeletal populations reported by many different workers over almost five decades introduces potential inconsistency into the observation and documentation of key traits and the extrapolation of key indicators such as age. Their study also includes several cemeteries acknowledged to contain burials of post-Roman date; on the basis of recent radiocarbon dating, a further key rural site in their sample, Bradley Hill in Somerset, is now considered to be a post-Roman cemetery (Gerrard, 2010). Additionally, their sample was drawn where data were allowed; urban and rural samples from the same region were not generally compared. We sought to investigate this theme at the regional level using rural and urban cemetery populations from Dorset, England, based on a sample of data osteologically documented to a common standard. This builds on earlier studies by two of the authors, which demonstrated that after the Conquest, mortality risk and the levels of infectious and metabolic diseases increased, with higher-status individuals having a lower mortality risk because of their social buffering (Redfern and DeWitte, 2011a,b). This sample also contains the urban site at Poundbury Camp, Dorset, one of the largest published cemetery samples from the Roman world and among the most frequently cited (Farwell and Molleson, 1993). Previous research by the authors (Hamlin, 2007; Redfern, 2007, 2008; Redfern et al., 2012) and the study by Pitts and Griffin (2012) found that the Poundbury Camp sample differed in terms of health and funerary practices from other cemeteries in Dorset and Britain.

This research seeks to apply a bioarchaeological approach, as defined by Buikstra (1977), as funerary, social, and skeletal data sets are used to investigate a series of context-driven hypotheses (Buikstra, 2006). It is the first regional study of rural–urban health differences in Roman Britain, and attempts to understand how health varied between the sexes and different age groups, but also how these related to social status, as evidenced by the funerary record, by investigating mortality risk and indicators of frailty: indicators of stress, metabolic and infectious diseases, and dental health. As summarized above, previous research has identified that Poundbury Camp is atypical for health and funerary practices within Dorset and Britain; therefore, we also investigated how the individuals from that cemetery and a later excavation at the site (Poundbury Pipeline) (hereafter grouped together as the Poundbury Sites) compared to other urban and rural cemeteries from the region.

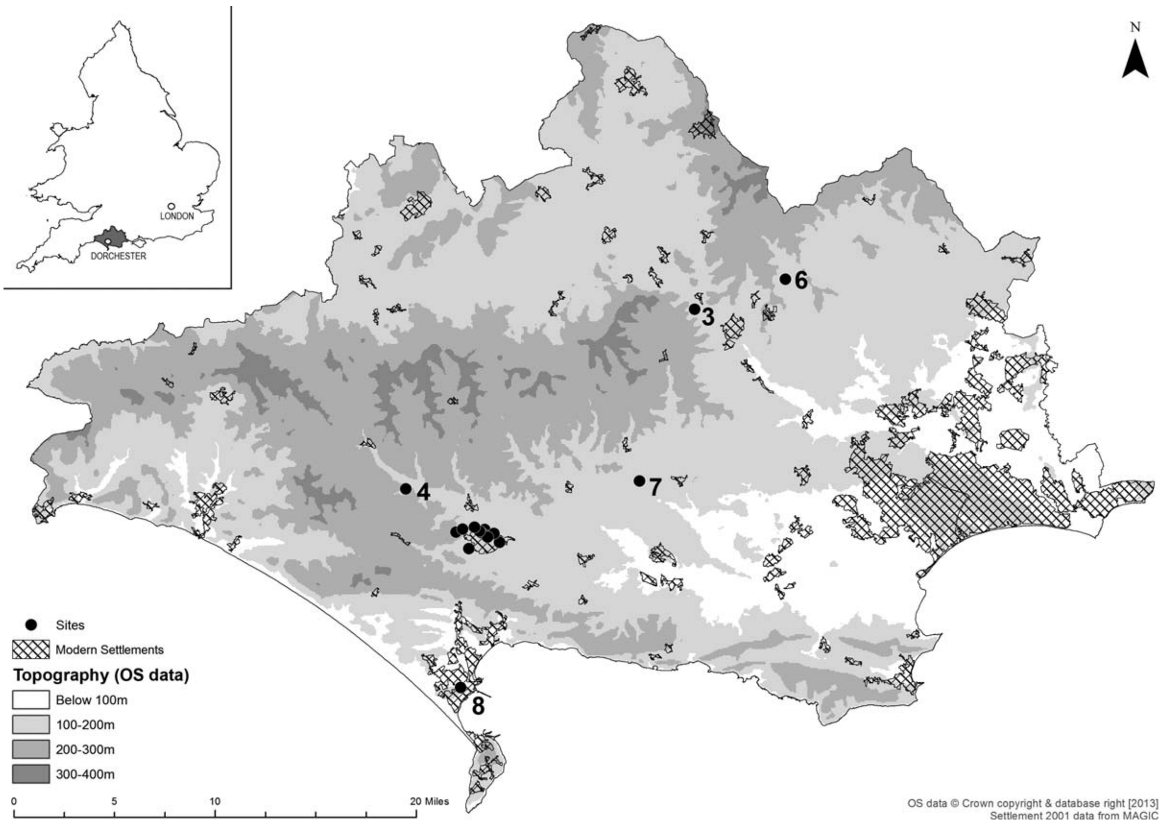

Fig. 1. Map showing the location of Dorset county and the rural cemetery sites outside of Dorchester. Numbers refer to sites listed in Table 1. © Katie Robbins.

ROMAN DORSET: URBAN AND RURAL SETTINGS

The study focuses on the burials excavated within the modern county of Dorset, associated with Dorchester itself, *Durnovaria*, the *civitas* capital of the Durotriges, and rural settlements in its environs (Figs. 1 and 2) (Table 1). These environs comprise a typical southern British rural landscape, dotted with a dense network of farmsteads, often originating in use from the Iron Age and taking various architectural forms, complemented by architecturally more complex and extensive structures in the late Roman period, to which the term villa is usually applied (Hingley, 1989; Whittaker and Garnsey, 1997; Putnam, 2007). These settlements, such as Alington Avenue and Poundbury Farm, maintained their rural aspects despite being quite close to the *civitas* capital's walls. The designators "rural" and "urban" reflect the immediately associated settlements, rather than strict geographic proximity to *Durnovaria*.

Of the rural sites four, Alington Avenue, Fordington Bottom, Maiden Castle Road, and Poundbury Farm (Table 1), are in Dorchester's immediate environs, between 1 and 2 km south of the town, whereas Littlewood Farm lies about 9 km northwest of Dorchester. The Tolpuddle Ball site lies about 10 km to the east, Wyke Regis is about 15 km to the south, and Hod Hill and Tarrant Hinton are about 35 and 36 km, respectively, to the northeast (Figs. 1 and 2). Where known, the associated settlements appear to be the modest farmsteads with little evidence of architectural pretension. On rural sites, in general, a distinction may sometimes be observed between the burial places of infants, closer to houses and those of older individuals, closer to settlement peripheries. This distinction is clearly visible, for example, at Alington Avenue. As it comprises mostly recent and sometimes very extensive excavation in advance of construction, we consider that there is no particular bias to the centers or peripheries of settlements which might significantly influence the age profile of the sample. The urban sites comprise intramural areas in which infant burials predominate, conforming to the Roman norm of an age-related distinction in burial space (County Hall, County Hospital, and Greyhound Yard) and samples from the extramural cemeteries (Albert Road, Crown Buildings, Fordington [Old Vicarage], Little Keep, Poundbury sites, and Southfield House). The analysis of infant burials has included only primary burials, not the scattered fragments of neonate skeletons which are often encountered when urban settlements are excavated (Pearce, 2001). Both the rural and the urban sites contain burials of predominantly 4th century AD date. The availability of recently documented skeletal data determines our focus on these burials which can, it is hoped, be amplified in future with new samples excavated from a wider hinterland and distributed over a longer period of time (see the discussion in Redfern and DeWitte, 2011a).

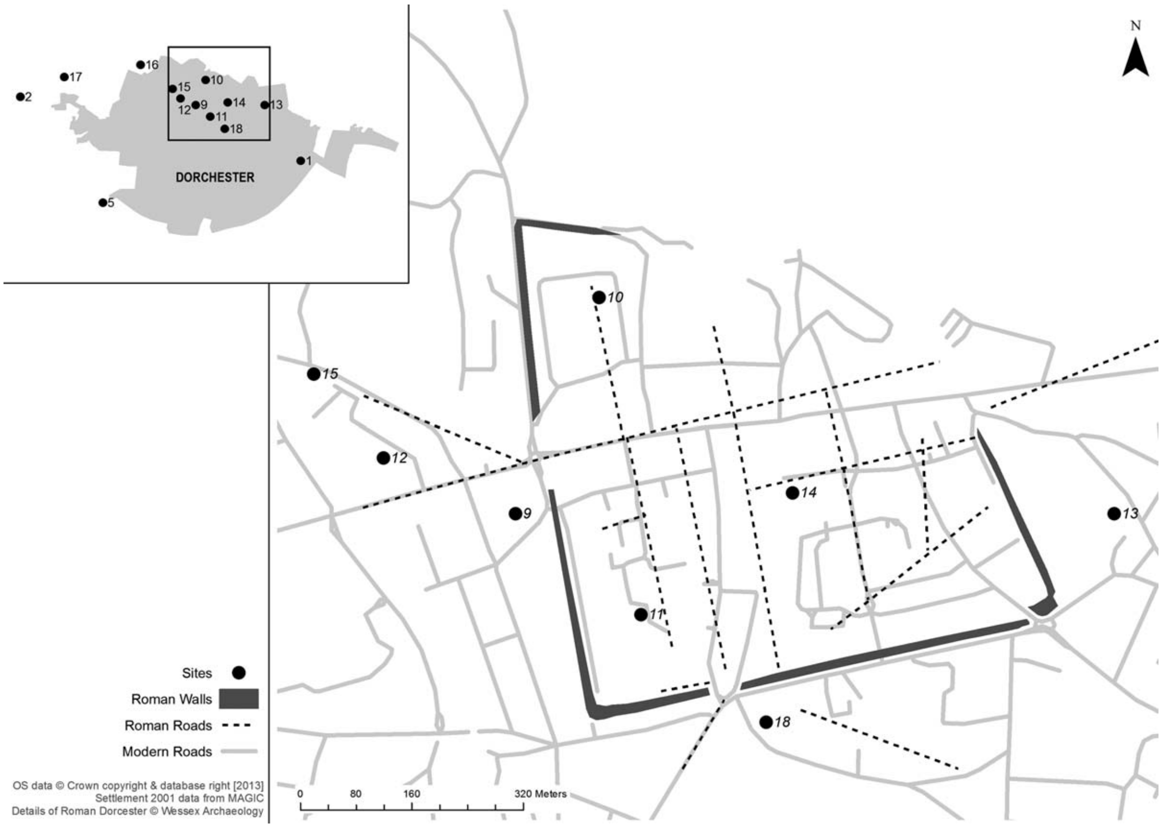

Fig. 2. Location of urban and rural cemeteries in the environs of Dorchester. Numbers refer to sites listed in Table 1.© Katie Robbins.

MATERIALS AND METHODS

Funerary data and attribution of status in Roman Dorset

The attribution of a socially or legally defined status to individual Romano-British burials is complex. There is a near total absence of *in situ* epigraphic evidence for the majority of burials. There is also significant diversity in burial tradition; many locales show continuity in the use of late Iron Age practices, whereas new practices were introduced to the province by migrants or by emulation of Roman burial practices, though mobility stable isotope studies have shown that grave-good types do not directly indicate a person's geographical origin (Philpott, 1991; Pearce, 2000, 2010; Pearce et al., 2000; Eckardt et al., 2014). Pearce's (2013b) review of the burial evidence concluded that it is difficult to make inter-regional comparisons of the expression of social status in death rituals because of the variations in local burial traditions (see also, Pitts and Griffin, 2012). Most importantly, perhaps, the burial process is determined by the participants at the funeral, using the resources available to them to represent the deceased in relation to the funerary conventions of the community. Although the form of display may have changed, the burial of the dead throughout the Roman period represents a competitive sphere where the differences of status or wealth, real or aspired to, were expressed by the mourners in the case study area and beyond (Hamlin, 2007; Pearce, 2013b).

In Roman Dorset, the majority rite was coffined interment in flat-grave cemeteries, with adults more likely than subadults to be buried in this manner (Hamlin, 2007). Therefore, as in our earlier study (Redfern and DeWitte, 2011b), we have selected coffin type as a proxy for status. The most frequently used coffin type was unlined wood, and there was no significant difference in the use of this type between subadult and adult burials, suggesting that age was not a factor in its use (Hamlin, 2007). In this study, we have used the absence or presence of a coffin (wood, stone, or lead) as a broad-brush measure of the status of the cemetery population in our samples as expressed by the actions of the mourners. This is a common characteristic of regional burial both of which requires a clear investment of the resources and labor and possesses archaeologically visible traces, in the form of soil stains, coffin nails and other fittings, though timber containers with no metallic elements may sometimes elude attention. In contrast, grave goods by the 4th century AD were infrequently deposited, less impressive in character and their presence depends very much on the traditions of the burying group. Small numbers of burials are distinguished by other characteristics, such as the size or material of the container; in our samples lead-lined wood and stone coffins were also documented. At Alington Avenue, Crown Buildings, and the Poundbury Sites, the preservation of elements of resin, hair, and cloth revealed elaborate preparation of the corpse for burial (Brettell et al., 2015). However, these properties of coffins or of funerary processes isolated too small a sample to be used as a subgroup within our study.

The burial ground represented by the Poundbury Camp and Poundbury Pipeline sites requires further

TABLE 1. Rural and urban cemetery sites in Roman Dorset: number of individuals included in the study

Location	Site name (and number)	Number of adult males	Number of adult females	Number of ambiguous sex (adult)	Number of undetermined sex (adult)	Number of subadults	Total (*N*)	Reference
Rural	1. Alington Avenue	24	15	5	–	13	58	Davies et al. (2008)
	2. Fordington Bottom	5	1	–	–	6	12	Smith et al. (1997)
	3. Hod Hill	1	–	–	–	–	1	Richmond (1968)
	4. Littlewood Farm	1	–	–	–	–	1	Putnam (Personal communication, unpublished)
	5. Maiden Castle Road (Dorchester Bypass)	11	9	1	–	14	35	Smith et al. (1997)
	17. Poundbury Farm	8	8	–	1	7	24	Egging Dinwiddy and Bradley (2011)
	6. Tarrant Hinton	–	–	–	–	8	8	Graham (2007)
	7. Tolpuddle Ball (Bypass)	2	3	–	–	2	7	Hearne and Birkbeck (1999)
	8. Wyke Regis	–	3	–	1	–	4	Leonard (2008)
Total rural		*52*	*39*	*6*	*2*	*50*	*150*	
Urban	9. Albert Road	8	2	–	1	10	21	Stacey (1987)
	10. County Hall	–	–	–	–	6	6	Smith (1993)
	11. County Hospital site	–	–	–	–	9	9	Trevarthen (2008)
	12. Crown Buildings	1	–	–	–	–	1	Sparey-Green (1981)
	13. Fordington (Old Vicarage)	5	1	–	–	–	6	Startin (1982)
	14. Greyhound Yard	–	–	–	–	8	8	Woodward et al. (1993)
	15. Little Keep	17	9	–	–	3	29	Egging Dinwiddy (2009); McKinley and Egging Dinwiddy (2009)
	16. Poundbury Camp	33	23	3	–	55	114	Farwell and Molleson (1993); Green (1987)
	16. Poundbury Pipeline	–	3	1	–	1	5	Davies and Grieve (1986)
	18. Southfield House	–	1	–	–	–	1	Davies and Thompson (1987)
Total urban		64	39	4	1	148	194	
Total sample		116	78	10	3	198	344	

comment. Hamlin (2007) found that mortuary patterning at the sites differed significantly from other cemeteries in Dorset and, in some cases, from patterns seen in cemeteries across Roman Britain. Its near equal representation of males and females is unusual as a preponderance of male burials is typical of many Romano-British cemeteries (Jones, 1987; Woodward, 1993; Davison, 2000; Mays, 2000; Quensel-von-Kalben, 2000) although reanalysis of the important sample from Lankhills (Winchester) suggests that for some older projects, this bias may depend on osteological methods used for recording (Gowland, 2001; Booth et al., 2010; Redfern and DeWitte, 2011a). The rates of grave good inclusions were markedly higher both for adults and for subadults in the non-Poundbury sample than at the Poundbury sites as was the number of grave goods included with individuals. Grave good patterning in relation to age also varied between the non-Poundbury and the Poundbury sites: containers, for instance, were more frequently recovered with subadults in the non-Poundbury population, whereas personal ornaments were found more often with subadults than adults at the Poundbury sites, but exhibited no age-related distributional variation in the non-Poundbury population. The presence of elaborate mausolea, with internal painted plaster, also differentiates the Poundbury sites from their neighbors. These differences, and others, between the two cemeteries led Hamlin (2007) to recommend that the Poundbury sites should not be considered as to be fully representative of mortuary behavior in Roman Dorset, as has been the case to date (Philpott, 1991; Woodward, 1993; Esmonde Cleary, 1999; Gale, 2003; Lewis, 2010).

Skeletal data

Our study used data from a total of 344 individuals, 150 from rural and 194 from urban cemeteries, who dated to the 1st–5th centuries AD, with the majority dating from the 4th century: 123 subadults (<20 years old), 116 adult males, 78 adult females, 10 ambiguous sex, and 3 indeterminate individuals (Table 1). For the Poundbury Camp cemetery, 115 skeletons were randomly selected by the first author as the total number of excavated individuals ($N = 1{,}442$) (Farwell and Molleson, 1993) could not be recorded during her doctoral research (Redfern, 2006). With the exception of those buried at Dorchester County Hospital, Little Keep, Poundbury Farm, and Wyke Regis, all of the individuals were recorded by the first author (Redfern, 2006) using the standards for data collection published by Buikstra and Ubelaker (1994) (see Redfern and DeWitte 2011a). The skeletons from the other sites were recorded by commercial archaeology units using the standards described by Brickley and McKinley (2004). As these two standards are compatible, it has been possible to include these data using the methodologies described below (see also, Redfern and DeWitte, 2011a).

Age-at-death for subadults was estimated using a combination of dental eruption, diaphyseal length, and epiphyseal fusion methodologies (Scheuer and Black, 2000). If both dental and skeletal estimates were present, dental age was used because it is a more reliable age estimate (Lewis and Garn, 1960). In adults, age-at-death was estimated using degenerative changes to the pubic symphyses (Brooks and Suchey, 1990), auricular surfaces (Lovejoy et al., 1985; Meindl and Lovejoy, 1989), and sternal rib end morphology (İsçan and Loth, 1986a,b). Sex was assessed using morphology of the skull and pelvis (Buikstra and Ubelaker, 1994). In the skull, the following features were scored by following the method described by Acsádi and Nemeskéri (1970): the nuchal crest, mastoid process, supraorbital margin and ridge, and mental eminence of the mandible. The os coxae were scored using Phenice's (1969) method based on the morphology of the ventral, dorsal, and medial aspects of the pubis region, the shape of the sciatic notch, and the expression of the preauricular sulcus (Buikstra and Ubelaker, 1994, 18). The sex and age-group divisions devised by Buikstra and Ubelaker (1994) were used to organize the data.

To investigate frailty and mortality risk, we examined the indicators of stress (cribra orbitalia, porotic hyperostosis, nonspecific periostitis, and enamel hypoplastic defects) (Lewis and Roberts, 1997), metabolic (rickets and scurvy) (Brickley and Ives, 2008), and infectious diseases (tuberculosis) (Roberts and Buikstra, 2003), and dental health (carious lesions and calculus) (Hillson, 1998).

Statistical methods

The differences in the frequencies of coffin burials (and thus higher-status individuals) and stress markers, and the differences in age-at-death distributions were tested using Chi-square analysis. To determine whether there were differences in mortality between the urban and the rural sites, "urban" was modeled as a covariate (rural = 0, urban = 1), affecting the parameters of the Siler model of mortality. The Siler model fits a wide range of human mortality patterns (Gage, 1988; Siler, 1979), and the hazard of dying at age a is specified as follows:

$$h(a) = \alpha_1 e^{-\beta_1 a} + \alpha_2 + \alpha_3 e^{\beta_3 a}$$

The first component of the Siler model, $\alpha_1 e^{-\beta_1 a}$, represents juvenile or immature mortality, which is typically very high at birth and then decreases rapidly with age. The α_1 parameter is the force of neonatal mortality, and β_1 is the rate at which neonatal mortality changes with age (Gage, 1988). The second component of the model, α_2, is an age-independent component associated with the causes of death that are unrelated to an individual's age (e.g., accidental causes of death). The last component of the Siler model, $\alpha_3 e^{\beta_3 a}$, represents the typical senescent pattern of mortality, which is low at birth and younger ages, but increases with adult age. The α_3 parameter is the force of mortality associated with senescence, and β_3 is the rate at which senescent mortality changes with age. Together, these three components of the Siler model can allow for the estimation of the typically observed U-shaped curve of human mortality, that is mortality that is high at birth, declines during childhood, and then increases again (often during or after adolescence) (Gage, 1988). However, the model is flexible enough that it does not impose that, or any other, pattern on the data. The three components are independent and competing hazards, and hence surviving one component of mortality does not affect one's risk of death from the others and the three components compete throughout life. As the Siler model requires the estimation of a small number of parameters, it can be applied to relatively small samples; it smoothes the random variation usually present therein without imposing any particular age pattern on the data (Gage, 1988; Wood et al., 2002a). This and similar parametric models are also suitable for use with data sets, such as ours, that include imprecise age estimates, particularly with respect to open-ended terminal age categories as they allow for the estimation of patterns at later adult ages that would otherwise be inaccessible (Milner et al., 2008). The age-independent component of the Siler model, α_2, is often difficult to estimate in paleodemographic studies (Herrman and Konigsberg, 2002), and hence we set the α_2 parameter equal to zero for these analyses.

Urban was modeled as a covariate affecting the Siler model in two ways: 1) affecting the entire Siler model and 2) affecting the juvenile and senescent components of the Siler model independently (to allow for some variation with age in the effect of urban context on the risk of mortality). In both cases, the covariates were modeled using a proportional hazard specification. Further, given the singular nature of the Poundbury sites, we also restricted the analysis to non-Poundbury urban cemeteries versus rural cemeteries and Poundbury sites versus non-Poundbury urban cemeteries. The model parameters and their 95% confidence intervals (CIs) were estimated using maximum likelihood analysis with the program *mle* (Holman, 2005). A negative estimate for the parameter representing the effect of the urban covariate on the hazard would suggest that people in the urban sites were at a decreased risk of death compared to rural individuals.

A likelihood ratio test (LRT) was used to assess the fit of the full model compared to a reduced model in which the value of the parameter representing the urban covariate was set equal to 0. Therefore, The LRT tests the null hypothesis that the urban setting was not associated with neither elevated nor decreased risks of death. The LRT was computed as follows: $\text{LRT} = -2[\ln(L_{\text{reduced}}) - \ln(L_{\text{full}})]$, where LRT approximates a χ^2 distribution with $df = 1$.

When the sample sizes are small, the estimation of the juvenile component of the Siler model has proven difficult (Herrman and Konigsberg, 2002; Wood et al., 2002b; Nagaoka and Hirata, 2007). Kaplan–Meier survival was used to verify that the results from the Siler model were indicative of a real trend rather than an artefact of the model's potential shortcoming with respect to paleodemographic samples. The nonparametric Kaplan–Meier analysis is used to test whether urban settings were associated with higher or lower survivorship compared to rural settings. The Kaplan–Meier analyses were performed using SPSS version 20.

The differences in survivorship and mortality risk between males and females were also examined separately in each of these samples: urban including Poundbury sites, urban excluding Poundbury sites, Poundbury sites, and rural. In each sample, the differences in survivorship were assessed using Kaplan–Meier analysis as described above. The differences between male and female mortality were assessed by modelling sex ($0 = \text{male}$, $1 = \text{female}$) as a covariate affecting the Gompertz model of adult mortality. A negative estimate for the parameter representing the effect of the sex covariate on the hazard would suggest that females were at a decreased risk of death compared to males.

RESULTS

Urban (including Poundbury sites) versus rural cemeteries

When the urban covariate was modeled as affecting the entire Siler model (Table 2), the results suggested that mortality risks did not differ between the cemetery types (the 95% CI for the parameter representing the urban covariate for includes both positive and negative values). However, when urban was modeled as a covariate separately on the subadult and senescent components of the model, the results indicated a significantly higher mortality for urban subadults, but no significant difference in risk between the urban and the rural adults (Table 2). Kaplan–Meier survival analysis (Table 3) revealed no difference in survivorship when all ages were evaluated or when only subadults or adults were considered. In all cases, the 95% CI for mean survival time overlaps between the urban and the rural samples. The comparison of the age-at-death distributions revealed significant demographic differences, with more 0–10 year olds and adults of >35 years old in urban cemeteries compared to rural ones (Table 4). Significantly higher frequencies of enamel hypoplastic defects, carious lesions, and rickets were found in urban cemeteries (Table 5), and no significant difference in status, as evidenced by coffin presence, was observed between the two cemetery types (Table 5).

Non-Poundbury urban cemeteries versus rural cemeteries

When the Poundbury sites were excluded from the analyses (Table 6), we found that there were significantly more coffined burials in rural cemeteries, and significantly higher frequencies of enamel hypoplastic defects, carious lesions, and calculus in urban cemeteries, with rural cemeteries having significantly higher frequencies of cribra orbitalia, porotic hyperostosis, and nonspecific periosteal lesions. The analysis of mortality risk only using non-Poundbury urban sites, and when urban was modeled as a covariate affecting the entire Siler model, revealed no significant difference in mortality risk between the urban and the rural sites. When subadults and senescent mortality were examined separately, there was significantly higher mortality for urban subadults, but significantly lower mortality for non-Poundbury urban adults compared to rural adults (Table 2). The results for age-at-death distribution were consistent with those estimated when the Poundbury sites were included. No significant difference in survivorship was observed between the two groups when all ages were considered simultaneously or when only subadults were included, but there was significantly higher survivorship in the non-Poundbury urban sites when only adults were included in the analysis (Table 3).

Poundbury sites versus non-Poundbury urban cemeteries

The Poundbury sites had significantly higher numbers of coffined burials than did the other urban cemeteries in our sample (Table 7). The risk of adult mortality was higher at the Poundbury sites, and survivorship was significantly higher in the non-Poundbury urban sample when only adults were included. There were no differences in the risk of mortality or survivorship when all age groups or only subadults were considered (Tables 2 and 3). However, age-at-death distributions were significantly different, with fewer older adults in the Poundbury sites (Table 4). The Poundbury sites also had significantly higher frequencies of cribra orbitalia, porotic hyperostosis, and nonspecific periosteal lesions

TABLE 2. Maximum likelihood estimates of the effect of the covariate on the hazard models (95% CIs for the covariate effect are shown in parentheses)

Samples	Siler hazard	−2LLR[a]	Juvenile mortality	Senescent mortality	−2LLR[a]
Urban[b] versus Rural	0.09 (−0.15, 0.32)	0.59 ($P = 0.44$)	1.32 (0.89, 1.67)	−0.18 (−0.52, 0.07)	8.76 ($P = 0.003$)
Urban (non-PB)[b] versus Rural	−0.07 (−0.44, 0.27)	0.2 ($P = 0.68$)	1.0 (0.37, 1.52)	−0.49 (−0.99, −0.06)	18.9 ($P < 0.001$)
Urban non-PB versus PB[b]	0.28 (−0.04, 0.58)	3.62 ($P = 0.05$)	0.31 (−0.30, 0.76)	0.65 (0.25, 01.02)	35.2 ($P < 0.001$)

[a] The covariates scored as 1 for these analysis.
[b] The −2LLR columns provide the χ^2 values and *P*-values for the likelihood ratio tests.

TABLE 3. Kaplan–Meier survival analysis results[a]

Samples	Mean survival time	95% CI	Mantel–Cox χ^2	*P*-value
Urban (all ages)	21.6	18.7–24.5	0.71	0.40
Rural (all ages)	24.9	21.4–28.4		
Urban (adults)	38.8	36.5–41.1	3.68	0.06
Rural (adults)	35.0	32.2–37.8		
Urban (children)	2.1	1.3–2.8	0.63	0.43
Rural (children)	2.8	1.5–4.1		
Urban (Non-PB) (all ages)	23.7	18.7–28.6	0.09	0.77
Rural (all ages)	24.9	21.4–28.4		
Urban (Non-PB) (adults)	42.4	39.0–46.0	8.24	0.004
Rural (adults)	35.0	32.2–37.8		
Urban (Non-PB) (children)	1.3	0.2–2.3	2.6	0.108
Rural (children)	2.8	1.5–4.1		
Urban Non-PB (all ages)	23.7	18.7–28.6	2.93	0.09
PB (all ages)	20.1	16.6–23.6		
Urban Non-PB (adults)	42.4	39.0–46.0	7.99	0.005
PB (adults)	36.1	33.3–38.8		
Urban Non-PB (children)	1.3	0.2–2.3	2.03	0.15
PB (children)	2.6	1.5–3.7		

[a] Mean survival times and 95% CIs are provided in years.

TABLE 4. Age-at-death distributions (the percentages of each sample that fall into each age interval are in shown parentheses)

Age	Rural	All urban	Urban (Non-PB)	PB
0–9.99	30 (0.286)	81 (0.435)	34 (0.43)	47 (0.439)
10–19.99	10 (0.123)	11 (0.059)	3 (0.038)	8 (0.075)
20–34.99	34 (0.324)	31 (0.167)	10 (0.127)	21 (0.196)
35–49.99	21 (0.20)	47 (0.253)	20 (0.253)	27 (0.252)
50+	10 (0.095)	16 (0.086)	12 (0.152)	4 (0.037)
Total	105	186	79	107

TABLE 5. Percentages of individuals with container burials and observable skeletal stress markers/pathologies within all urban sites versus rural sites[a]

	Urban	Rural	*P*-value
Container burial	0.59	0.67	0.13
Cribra orbitalia	0.23	0.26	0.53
Porotic hyperostosis	0.11	0.07	0.24
Periosteal lesions	0.34	0.35	0.83
EHD	0.28	0.17	0.05
Caries	0.55	0.35	0.002
Calculus	0.70	0.59	0.11
Tuberculosis	0.02	0	0.10
Rickets	0.04	0	0.02

[a] *P*-values are provided for Chi-square tests.

compared to the others, which had significantly higher frequencies of carious lesions and calculus (Table 7).

Male versus female survivorship and mortality

As summarized in Table 8, in each of the samples, female survivorship was higher and mortality risks were lower than those of males. However, the 95% CIs for the mean survival times and for the estimates of the parameter representing the sex covariate indicated considerable overlap in all cases, which means we did not detect a significant difference between the sexes under any circumstances. The results of the hazard analysis using the Gompertz model are summarized in Table 9. All 95% CIs for the estimated values of the parameter representing the sex covariate include both positive and negative values, indicating a lack of a significant difference in mortality risk between males and females for all comparisons.

DISCUSSION

The overall results of our study differ from the investigation of health inequality by Pitts and Griffin (2012), whereby rural populations had higher frequencies of disease compared to urban ones. Rural populations in Dorset experienced lower frequencies of indicators of stress, dental disease, and metabolic diseases compared to their urban counterparts, a result not observed by Pitts and Griffin (2012), although this varied to some degree

TABLE 6. Percentages of individuals with container burials and skeletal stress markers/pathologies for non-PB urban sites versus rural sites[a]

	Urban (non-PB)	Rural	*P*-value
Container burial	0.29	0.67	<0.001
Cribra orbitalia	0.07	0.26	0.001
Porotic hyperostosis	0	0.07	0.02
Periosteal lesions	0.16	0.35	0.004
Enamel hypoplastic defects	0.30	0.17	0.05
Carious lesions	0.69	0.35	<0.001
Dental calculus	0.82	0.59	0.008
Tuberculosis	0	0	Na
Rickets	0.02	0	0.16

[a] *P*-values are provided for Chi-square tests.

TABLE 7. Percentages of individuals with container burials and skeletal stress markers/pathologies for non-PB urban sites versus PB[a]

	Urban non-PB	Urban PB	*P*-value
Container burial	0.29	0.80	<0.001
Cribra orbitalia	0.07	0.34	<0.001
Porotic hyperostosis	0	0.18	<0.001
Periosteal lesions	0.16	0.46	<0.001
Enamel hypoplastic defects	0.30	0.26	0.62
Carious lesions	0.69	0.48	0.03
Dental calculus	0.82	0.63	0.03
Tuberculosis	0	0.03	0.14
Rickets	0.02	0.06	0.17

[a] *P*-values are provided for Chi-square tests.

TABLE 8. Kaplan–Meier analysis of sex differentials in survivorship[a]

Samples	Mean survival time	95% CI	Mantel–Cox χ^2	*P*-value
Urban male	38.9	36.3 – 41.4	3.41	0.07
Urban female	43.0	39.2 – 46.7		
Urban Non-PB male	41.5	37.6 – 45.3	3.8	0.05
Urban Non-PB female	48.8	43.1 – 54.4		
PB male	36.3	33.2 – 39.4	1.66	0.20
PB female	39.6	35.3 – 44.0		
Rural male	35.8	32.4 – 39.2	0.68	0.41
Rural female	38.1	33.7 – 42.4		

[a] Mean survival times and 95% confidence intervals are provided in years.

TABLE 9. Maximum likelihood estimates (with 95% CI in parentheses) of the effect of the sex covariate on the Gompertz model and the results of the likelihood ratio tests

Samples	Effect of "Female" on Gompertz Hazard	−2LLR
Urban	−0.42 (−1.03, 0.09)	3.7 ($P = 0.05$)
Urban non-PB	−0.59 (−1.67, 0.2)	3.12 ($P = 0.08$)
PB	−0.48 (−1.26, 0.14)	2.70 ($P = 0.10$)
Rural	−0.22 (−0.9, 0.33)	0.77 ($P = 0.38$)

depending on whether or not the Poundbury sites were included in the analysis.

Our examination of two variables not studied by Pitts and Griffin (2012)—mortality risk and survivorship—also demonstrated that the health of rural and urban populations is more complex than previously thought, especially when considered in relation to age. Crucially, there was significantly higher mortality risk for urban compared to rural subadults. The higher numbers of those <10 years old in the urban cemeteries may reflect lower infant mortality in rural settlements, perhaps owing to a stronger continuity of late Iron Age child-rearing traditions, which appear to have been less detrimental to health (Gowland and Redfern, 2010; Redfern and DeWitte, 2011a; Redfern et al., 2012), notwithstanding the inclusion of the Poundbury sites in this result and the potential bias of age-related funerary practices (see discussion in Scott, 1999; Pearce, 2001; Moore, 2009; Gowland et al., 2014).

The higher mortality risk, lower survivorship, and the smaller numbers of older adults in rural cemeteries are likely to be multifactorial in origin. The clinically attested differences in health and employment that influence life expectancy between urban and rural populations in modern settings may have a bearing on this pattern (Wadsworth, 1997a,b). The most significant contextual factor may be rural social inequality, as Pitts and Griffin (2012) argue, albeit when observing different characteristics. The legal status of the late Roman rural poor as enslaved or bonded labor is impossible to assess in Britain as it is in much of Roman northern Europe, in the absence of relevant textual evidence, but current scholarly consensus emphasizes the massive inequality of the late Roman countryside, a locale dominated by powerful landowners (Whittaker and Garnsey, 1997). The best testimonies of such status asymmetries in the Durotrigian *civitas*, as elsewhere in southern England and beyond, are the villas which reached the apogee of their scale and architectural sophistication in the 4th century AD (Scott, 2000; Putnam, 2007). These speak of an elite whose control of the fruits of the land enabled the acquisition of the cultural capital manifested in the mosaic repertoire of sites such as Hinton St Mary and Frampton, with their complex allusions to late Antique philosophy (Perring, 2003). The rural funeral monument of a probable retired magistrate from *Durnovaria* (Tomlin et al., 2009, N 3014) also provides an anecdotal illustration of the likely overlap between landowners and urban office-holders in Dorset. Although much less well attested, the same period also saw innovations to increase agricultural productivity, perhaps initiated by the same elites (Millett, 1992). In short, the rural data suggest an exploited and undernourished group, a Roman echo of the itinerant laborers forming the backcloth to many scenes in Thomas Hardy's novels set in the same landscape in the late 19th century (Bownas, 2012). In our case study, it is in the rural sample with higher mortality risk and lower survivorship that the Malthusian pressures observed in other Roman skeletal samples are most apparent (i.e., decreased stature; see Scheidel, 2010).

The health of the Dorset population in our study also conforms to the results observed in other Romano-British urban cemeteries (Redfern and Roberts, 2005; Bonsall, 2013), and for urban populations more generally (e.g., higher rates of markers of metabolic diseases) (Roberts and Cox, 2003). The higher rate of carious lesions in the urban sample conforms to a national trend observed post-Conquest, reflecting the significant dietary changes that occurred with the introduction of new foods and the continuity of food ways by different communities (e.g., military) (Cool, 2006; Peck, 2009; Redfern et al., 2010; Redfern and DeWitte, 2011a; Müldner, 2013). However, importantly, our study has been able to demonstrate that although there are higher frequencies of poor health indicators, urban dwellers had increased survivorship compared to their rural counterparts.

We propose that the increased survivorship and the greater presence of older adults in the urban cemeteries provides further evidence for the less hazardous nature of the living environment in British *civitas* capitals, because of their smaller population size and lower housing density. This supports the results of Bonsall's (2013) study which compared health between Winchester and Ancaster, and found that the population of Winchester, the larger settlement, had higher frequencies of indicators of stress and metabolic disease compared to the smaller town of Ancaster. As the regional hub, *Durnovaria* was the largest settlement in the territory, where the formal civic buildings were located, and by the late 3rd and early 4th centuries AD, the original timber buildings had been replaced by stone and included a forum (market), amphitheatre, and a large bathhouse possibly connected to a temple complex, with the town's water supplied via an aqueduct (Woodward et al., 1993; Putnam, 2007). The settlement evidence from *Durnovaria* has led Putnam (2007) to suggest a population estimate in the high hundreds or low thousands, which in combination with the archaeological evidence, perhaps typifies the scenario suggested by Scheidel (2004: 16) of "a small and generously laid out town of 1,000–2,000" which did not see the "urban graveyard effect" characteristic of larger and more densely occupied centers.

Excavations of houses in late Roman Dorchester have revealed that the dwellings were set within their own plots, with rubbish and cess disposed of in pits in backyards (Woodward et al., 1993; Putnam, 2007; Trevarthen, 2008). The evidence suggests a low occupation density within extensive walled areas interspersed with gardens and paddocks. The character of such housing is well illustrated by the Dorchester County Hospital, County Hall, and Greyhound Yard sites, revealing masonry-built buildings across the late Roman town (Smith, 1993; Woodward et al., 1993; Putnam, 2007; Trevarthen, 2008). There are uncertainties with this characterization, with the presence of "dark earth" perhaps masking small mass-walled structures interleaved with the grander and more spacious stone buildings (Rogers, 2011). Unfortunately, because very little organic remains survive from excavated sites from Dorchester, it has not been possible to use environmental indicator groups to understand the living conditions of the houses or the town (Bryant, 1990) although hair lice were discovered at Poundbury Camp (Farwell and Molleson, 1993). The limited environmental evidence from larger and higher-ranking settlements in Britain (York and London) show that there were areas of decomposing material created by food, faecal material, and other domestic waste, and that houses hosted black rats and house mice (Hall and Kenward, 1995; Hill and Rowsome, 2011). Overall, however, there is no environmental or archaeological evidence to suggest that living conditions in Britain were as unsanitary, polluted, or crowded as in larger cities in the Roman world (Scobie, 1986), or in better documented preindustrial urban settings (Morley, 2005).

Our key finding is the influence of the Poundbury sites data upon the results. The poor health, higher subadult mortality, lower survivorship, and higher adult mortality risk at this cemetery is atypical of the region in the late Roman period, and contrasts in these characteristics with the other urban and rural cemeteries in Dorset (see also data published by, Lewis, 2010, 2011, 2012; Lewis and Gowland, 2009; Melikian and Waldron, 2003). Our result supports an earlier study by Gowland and Redfern (2010), which found that subadult health at Poundbury Camp was more similar to cemeteries in London and Italy than urban cemeteries in Britain. In the case of London, established and settled by migrants from Britain and across the empire (Perring, 2002), this result was argued to reflect the adoption and/or continuation of Mediterranean-style childcare practices. We suggest that the very poor health of subadults from the Poundbury sites also reflects these behaviors, such as swaddling, which would have placed infants at greater risk of developing vitamin D deficiencies (Brickley and Ives, 2008), and also the shift to nonlocal breastfeeding and weaning strategies in this period (e.g., withholding of colostrum and the use of wet nurses) that negatively impacted health as evidenced by their dietary stable isotope data (Redfern et al., 2012).

Despite the late Iron Age origins of burial at the Poundbury sites, the funerary evidence is also somewhat atypical of the region and Britain (Hamlin, 2007); however, because we lack other regional funerary studies from Britain, it is not clear whether this result is unique to these sites or in actual fact common in urban cemeteries. Unfortunately, Anglo-Saxon and medieval Dorchester was constructed by robbing stone from *Durnovaria* and its cemeteries, meaning that little inscription evidence survives, and tombstones from the area do not provide evidence for the individuals of non-British origin (Tomlin and Hassall, 2000; Graham, 2007; Putnam, 2007; Tomlin et al., 2009). However, other characteristics of the human skeletal evidence from the Poundbury sites, including the presence of individuals with congenital anemias and lead isotope values, suggesting a Mediterranean origin, indicate that some people buried at Poundbury Camp came from the Continent (Richards et al., 1998; Redfern, 2007; Lewis, 2012). Mobility isotope studies have not yet been conducted elsewhere in Dorset, but the dietary stable isotope results from individuals buried in *Durnovaria's* other rural and urban cemeteries provide evidence for diverse food-ways, which we have interpreted as evidence for socio-cultural heterogeneity, in part to be attributed to the presence of migrants (Redfern et al., 2010, 2012). Additionally, it should be noted that these other cemeteries lack the evidence for congenital anemias and high frequencies of metabolic diseases observed at the Poundbury sites (Redfern, 2006, 2007; Redfern and DeWitte, 2011b).

Consequently, we propose that our results support the proposition that the Poundbury sites were to a substantial degree used by migrants (and their descendants) who had settled in *Durnovaria* from other regions of the empire including the Mediterranean. The impact of migrant health on data reported from Romano-British cemeteries appears to be very influential, as a pilot study undertaken by the first author and colleagues has shown. This compared frequencies of indicators of stress, metabolic, and infectious diseases between individuals identified as local or nonlocal to Britain based on stable isotope data, and found higher frequencies of these variables in the migrant sample (Redfern et al., 2014).

CONCLUSIONS

Our study demonstrated that there are health, demographic, and mortality differences between urban and rural populations in Roman Britain. The structured variability within the sample supports a recent observation by Scheidel (2012) that there is no standard "Roman" demographic pattern. Overall, it found that when age variables were pooled, there are no significant differences in survivorship or mortality risk between urban and rural populations, but when just adults are considered, urban populations in Dorset had higher survivorship and lower mortality compared to rural ones. Although our analysis differed in approach and key aspects from that of Pitts and Griffin (2012), both articles challenge the identification of rural environments as intrinsically healthier. Based on the preliminary results of our pilot study (Redfern et al., 2014), we propose that these differences can only be more fully understood through the increased use of mobility isotope analysis in bioarchaeological health studies.

The key finding of the study is that Poundbury Camp and the Pipeline cemeteries were anomalous within Dorset and Britain. Unfortunately, we are lacking other regional analyses of health and funerary practices in Roman Britain and such data are needed to more fully understand the extent to how and why the Poundbury sites are different. The present data suggest that migration may be a factor, and we recommend that the additional analysis of mobility and dietary stable isotopes from this and other groups within this sample is a future research priority to better understand such variation. Consequentially, we recommend that skeletal and funerary data from the Poundbury sites are used with discretion in future studies of Roman populations and burial rituals.

ACKNOWLEDGMENTS

The authors thank the reviewers and Associate Editor for their helpful comments on this research. They also thank HRH the Prince of Wales and The Duchy of Cornwall, Simon Mays, AC Archaeology, AOC Archaeology, Jacqueline McKinley and Wessex Archaeology, Peter Woodward, Jon Murden, Dorset County Museum, Dorset Natural History and Archaeological Society, The Natural History Museum (London), The Duckworth Laboratory (Cambridge University), and The Priest's House Museum (Wimborne Minster). The authors are also grateful to Katie Robbins (The British Museum) for the preparation of the figures.

LITERATURE CITED

Acsádi G, Nemeskéri J. 1970. History of human life span and mortality. Budapest: Akadémiai Kiadó.

Bonsall L. 2013. Variations in the health status of urban populations in Roman Britain: a comparison of skeletal samples from major and minor towns. Doctoral dissertation. Edinburgh: University of Edinburgh.

Booth P, Boyle A, Clough S, Cool HEM, and Poore D. 2010. The late Roman cemetery at Lankhills, Winchester: excavations 2000–2005. Oxford Monograph No. 10. Oxford: Oxford Archaeology.

Bownas JL. 2012. Thomas Hardy and empire: the representation of imperial themes in the work of Thomas Hardy. Farnham: Ashgate.

Breeze DJ, editor. 2014. The impact of Rome on the British countryside. A conference organized by the Royal Archaeological Institute, Chester, 11–13 October 2013. London: Royal Archaeological Institute Supplementary Publication.

Brettell RC, Schotsmans EMJ, Walton Rogers P, Reifarth N, Redfern RC, Stern B, and Heron CP. 2015. "Choicest unguents": molecular evidence for the use of resinous plant exudates in late Roman mortuary rites in Britain. J Archaeol Sci. 53:639–648.

Brickley M, Ives R. 2008. The bioarchaeology of metabolic bone disease. London: Academic Press.

Brickley M, McKinley J, editors. 2004. Guidance to the standards for recording human skeletal remains. Reading: Institute of Field Archaeologists, British Association of Biological Anthropology and Osteoarchaeology.

Brooks S, Suchey JM. 1990. Skeletal age determination based on the os pubis: a comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. Hum Evol 5.3: 227–238.

Bryant L. 1990. Dorset. In: Coles BJ, Bryant L, editors. Organic archaeological remains in southwest Britain. Exeter: University of Exeter. p 35–56.

Buikstra JE. 1977. Biocultural dimensions of archaeological study: a regional perspective. In: Blakely RL, editor. Biocultural adaptation in prehistoric America. Proceedings of the Southern Anthropological Society, No. 11. Athens, Georgia: University of Georgia Press. p 67–84.

Buikstra JE. 2006. Preface. In: Buikstra JE, Beck LA, editors. Bioarchaeology. The contextual analysis of human remains. London: Academic Press. p xvii–xxx.

Buikstra JE, Ubelaker DH. 1994. Standards for data collection from human skeletal remains. Proceedings of a seminar at the Field Museum of Natural History organized by Jonathan Haas. Arkanas: Arkansas Archaeological Survey Research Series No. 44.

Caldarini C, Caprara M, Caboni L, De Angelis F, Di Giannantonio S, Minozzi S, Pantano W, Preziosi P, Catalano P. 2006. Vivere a Roma in età Imperiale: evidenze antropologiche da recenti scavi nel suburbio. Medicina nei Secoli 18.3: 799–814.

Cool HEM. 2006. Eating and drinking in Roman Britain. Cambridge: Cambridge University Press.

Cucina A, Vargiu R, Mancinelli D, Ricci R, Santandrea E, Catalano P, Coppa A. 2006. The necropolis of Vallerano (Rome, 2nd–3rd century AD): an anthropological perspective on the ancient Romans in the Suburbium. Int J Osteoarch 16.2:104–117.

Davison C. 2000. Gender imbalances in Romano-British cemetery populations: a re-evaluation of the evidence. In: Pearce J, Millett M, Struck M, editors. Burial, society and context in the Roman World. Oxford: Oxbow Books. p 231–237.

Davies SM, Grieve D. 1986. The Poundbury pipeline: archaeological observations and excavations. Proc Dorset Nat Hist Archaeol Soc 107:81–88.

Davies SM, Thompson CN. 1987. Archaeological evaluation at Southfield House, Dorchester. Dorset Proc Dorset Nat Hist Archaeol Soc 107:101–110.

Davies SM, Bellamy PS, Heaton MJ, Woodward PJ. 2002. Excavations at Alington Avenue, Fordington, Dorchester, Dorset, 1984-87. Dorchester: Dorset Natural History and Archaeological Society Monograph Series 15.

Eckardt H, Müldner G, Lewis M. 2014. People on the move in Roman Britain. World Archaeol 46.4:1–17.

Egging Dinwiddy K. 2009. A late Roman cemetery at Little Keep, Dorchester, Dorset. Wessex Archaeology. Available at: http://www.wessexarch.co.uk/system/files/Little_Keep_Dorchester_64913.pdf. Accessed: October 5, 2014.

Egging Dinwiddy K, Bradley P. 2011. Prehistoric activity and a Romano-British settlement at Poundbury Farm, Dorchester, Dorset. Salisbury: Wessex Archaeology.

Esmonde Cleary AS. 1999. Roman Britain: civil and rural society. In: Hunter J, Ralston I, editors. The archaeology of Britain: an introduction from the Upper Palaeolithic to the Industrial Revolution. London: Routledge. p 157–175.

Esmonde Cleary S. 1987. Extra-mural areas of Romano-British towns. Oxford: BAR British Series 169.

Farmer P. 2004. On suffering and structural violence: a view from below. In: Scheper-Hughes N, Bourgois P, editors. Violence in war and peace an anthology. Oxford: Blackwell Publishing. p 281–289.
Farwell DE, Molleson TL. 1993. Excavations at Poundbury 1966-80, Volume II: the cemeteries. Dorchester: Dorset Natural History and Archaeological Society Monograph Series Number 11.
FitzGerald C, Saunders S, Bondioli L, Macchiarelli R. 2006. Health of infants in an Imperial Roman skeletal sample: perspective from dental microstructure. Am J Phys Anthropol 130:179–189.
Gage TB. 1988. Mathematical hazard models of mortality: an alternative to model life tables. Am J Phys Anthropol 76:429–441.
Gale J. 2003. Prehistoric Dorset. Stroud: Tempus Publishing Ltd.
Gerrard J. 2010. New radiocarbon dates from the cemetery at Bradley Hill, Somerton. Somerset Archaeology and Natural History 154:189–192.
Goodman P. 2006. The Roman City and its periphery: from Rome to Gaul. London: Routledge.
Gowland R. 2001. Playing dead: implications of mortuary evidence for the social construction of childhood in Roman Britain. In: Davies G, Gardner A, Lockyear K, editors. TRAC 2000 Proceedings of the Tenth Annual Theoretical Roman Archaeology Conference, London 2000. Oxford: Oxbow Books. p 152–168.
Gowland R, Chamberlain AT, Redfern R. 2014. On the brink of being: re-evaluating infanticide and infant burial in Roman Britain. J Roman Archaeol 96:69–88.
Gowland RL, Redfern RC. 2010. Childhood health in the Roman World: perspectives from the centre and margin of the Empire. Int J 3:15–42 (Series: Childhood in the Past).
Graham A, editor. 2007. The excavation of five beaker burials, the Iron Age and Romano-British settlements and the 4th century courtyard villa at Barton Field, Tarrant Hinton, Dorset, 1968–1984. Excavation by RG Tanner and AG Giles, Wimborne Archaeological Group. Dorchester: Dorset Natural History and Archaeological Society Monograph Series 17.
Hall AR, Kenward HK. 1995. Environmental evidence from the Colonia. The Archaeology of York. The Environment 14/6. York: Council for British Archaeology.
Hamlin C. 2007. The material expression of social change: the mortuary correlates of gender and age in late Pre-Roman Iron Age and Roman Dorset. 2 vols. Doctoral dissertation. Milwaukee: University of Wisconsin-Milwaukee.
Harrison GA, Gibson JB, editors. 1978. Man in urban environments. Oxford: Oxford University Press.
Hearne CM, Birkbeck V, editors. 1999. A35 Tolpuddle to Puddletown bypass DBFO, Dorset, 1996-8, incorporating excavations at Tolpuddle Ball. Salisbury: Wessex Archaeology Report Number 15.
Herrman NP, Konigsberg LW. 2002. A re-examination of the age-at-death distribution of Indian Knoll. In: Hoppa R, Vaupel JW, editors. Paleodemography: age distributions from skeletal samples. Cambridge: Cambridge University Press. p 243–257.
Hill J, Rowsome P. 2011. Roman London and the Walbrook stream crossing. Excavations at 1 Poultry and vicinity, City of London. London: Museum of London Archaeology Monograph Series 37.
Hillson S. 1998. Dental anthropology. London: Routledge.
Hin S. 2008. Counting Romans. In: De Ligt L, Northwood SJ, editors. People, land, and politics. Demographic developments and the transformation of Roman Italy, 300 BC-AD 14. Leiden: Brill. p 187–238.
Hingley R. 1989. Rural settlement in Roman Britain. London: B.A. Seaby Ltd.
Holman DJ. 2005. A programming language for building likelihood models. Version 2.1. Seattle, WA. Available at: http://www.faculty.washington.edu/djholman/mle/index.html.
Hurst H., editor. 1999. The coloniae of Roman Britain. New studies and a review. Papers of the conference held at Gloucester on the July 5–6, 1997. J Roman Archaeol Suppl. Ser. 36.
İşcan M, Loth S. 1986a. Determination of age from the sternal rib in white males: a test of the phase method. J Forensic Sci 31:122–132.
İşcan M, Loth S. 1986b. Determination of age from the sternal rib in white females: a test of the phase method. J Forensic Sci 31:990–999.
Jackson BL. 2013. Nutritional health status and urban food economies: the view from Roman Britain. Masters dissertation. Los Angeles: University of California Los Angeles.
Jones MJ. 2004. Cities and urban life. In: Todd M, editor. A companion to Roman Britain. Oxford: Blackwell Publishing Ltd. p 162–192.
Jones RF. 1987. A false start? The Roman urbanization of western Europe. World Archaeol 19:47–57.
Joshel SR. 2013. Geographies of slave containment and movement. In: George M, editor. Roman slavery and Roman material culture. London: University of Toronto Press. p 99–128.
Killgrove K, Tykot RH. 2013. Food for Rome: a stable isotope investigation of diet in the Imperial period (1st-3rd centuries AD). J Anthropol Archaeol 32:28–38.
King A. 2007. Rural settlement in southern Britain: a regional survey. In: Todd M, editor. A companion to Roman Britain. Oxford: Blackwell Publishing Ltd. p 349–370.
King AA. 2001. The Romanization of diet in the western Empire: comparative archaeozoological studies. In: Keay S, Terrenato N, editors. Italy and the West: comparative issues in Romanization. Oxford: Oxbow Books. p 210–223.
King AC. 1999. Animals and the Roman Army: evidence of animal bones. J Rom Archaeol Suppl. Ser. 34:139–150.
Laurence R, Cleary SE, Sears G. 2011. The City in the Roman West, c. 250 BC–c. AD 250. Cambridge: Cambridge University Press.
Leonard A. 2008. Late iron age and Romano-British burials and associated activity at the former allotments Church Knapp, Wyke Regis, Weymouth, Dorset. Proc Dorset Nat Hist Archaeol Soc 129:115–126.
Lewis AB, Garn SM. 1960. The relationship between tooth formation and other maturational factors. Angle Orthodont 30: 70–77.
Lewis M, Roberts C. 1997. Growing pains: the interpretation of stress indicators. Int J Osteoarch 7:581–586.
Lewis ME. 2010. Life and death in a Civitas Capital: metabolic disease and trauma in the children from late Roman Dorchester, Dorset. Am J Phys Anthropol 142:405–416.
Lewis ME. 2011. Tuberculosis in the non-adults from Romano-British Poundbury Camp, Dorset, England. Int J Paleopathol 1:12–23.
Lewis ME. 2012. Thalassaemia: Its diagnosis and interpretation in past skeletal populations. Int J Osteoarch 22:685–693.
Lewis ME, Gowland RL. 2009. Infantile cortical hyperostosis: causes, cases and contradictions. In: Lewis ME, Clegg M, editors. Proceedings of the Ninth Annual Conference of the British Association for Biological Anthropology and Osteoarchaeology, Department of Archaeology, University of Reading. Oxford: BAR International Series 1918. p 43–51.
Locker A. 2007. In piscibus diversis: the bone evidence for fish consumption in Roman Britain. Britannia 38:141–180.
Lovejoy CO, Meindl RS, Pryzbeck TR, Mensforth RP. 1985. Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of age at death. Am J Phys Anth 68:15–28.
Mattingly D. 2006. An imperial possession: Britain in the Roman Empire. London: Penguin Books Ltd.
Mays S. 2000. The archaeology and history of infanticide, and its occurrence in earlier British populations. In: Sofaer Derevenski J, editor. Children and material culture. London: Routledge. p 180–190.
McCarthy M. 2012. The Romano-British peasant: towards a study of people, landscapes and work during the Roman occupation of Britain. Oxbow: Windgather Press.

McIntyre L. 2013. Analysis of skeletal remains from Roman York: demography, diet and health. Doctoral Dissertation. Sheffield: University of Sheffield.

McKinley JI, Egging Dinwiddy K. 2009. "Deviant" burials from a late Romano-British cemetery at Little Keep, Dorchester. Proc Dorset Nat Hist Archaeol Soc 109:43–61.

Meindl RS, Lovejoy CO. 1989. Age changes in the pelvis: implications for palaeo-demography. In: İşcan M, editor. Age markers in the human skeleton. Springfield: Charles C Thomas. p 137–168.

Melikian M, Waldron T. 2003. An examination of skulls from two British sites for possible evidence of scurvy. Int J Osteoarchaeol 13:207–212.

Millett M. 1992. The Romanization of Britain: an essay in archaeological interpretation. Cambridge: Cambridge University Press.

Millett M. 1997. English Heritage book of Roman Britain. London: B.T. Batsford.

Millett M. 2001. Approaches to urban societies. In: James S, Millett M, editors. Britons and Romans: advancing an archaeological agenda. York: Council for British Archaeology Research Report. p 60–66.

Milner GR, Wood JW, Boldsen JL. 2008. Paleodemography. In: Katzenberg MA, Saunders S, editors. Biological anthropology of the human skeleton, 1st ed. New York: Wiley-Liss. p 561–600.

Minozzi S, Catalano P, Caldarini C, Fornaciari G. 2012. Palaeopathology of human remains from the Roman Imperial Age. Pathobiology 79:268–283.

Moore A. 2009. Hearth and home: the burial of infants within Romano-British domestic contexts. Int J 2:33–54 (Series: Childhood in the Past).

Morley N. 2005. The salubriousness of the Roman city. In: King H, editor. Health in antiquity. London: Routledge. p 92–305.

Müldner G. 2013. Stable isotopes and diet: their contribution to Romano-British research. Antiquity 87:137–149.

Nagaoka T, Hirata K. 2007. Reconstruction of paleodemographic characteristics from skeletal age at death distributions: perspectives from Hitotsubashi, Japan. Am J Phys Anthropol 134:301–311.

Nevett L, Perkins P. 2000. Urbanism and urbanization in the Roman world. In: Huskinson J, editor. Experiencing Rome Culture, identity and power in the Roman Empire. London: Routledge. p 213–244.

Paine RR, Storey GR. 2006. Epidemics, age at death, and mortality in Ancient Rome. In: Storey GR, editor. Urbanism in the preindustrial world. Cross-cultural approaches. Tuscaloosa: The University of Alabama Press. p 69–85.

Pearce J. 2000. Burial, society and context in the provincial Roman world. In: Pearce J, Millett M, Struck M, editors. Burial, society and context in the Roman world. Oxford: Oxbow Books. p 1–10.

Pearce J. 2001. Infants, cemeteries and communities in the Roman provinces. In: Davies G, Gardner A, Lockyear K, editors. TRAC 2000. Proceedings of the Tenth Annual Theoretical Roman Archaeology Conference, London 2000. Oxford: Oxbow Books. p 125–142.

Pearce J. 2010. Burial, identity and migrations in the Roman world. In: Eckardt H, editor. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. J Rom Archaeol Suppl. Ser. 78:79–98.

Pearce J. 2013a. Beyond the grave. Excavating the dead in the late Roman provinces. Late Antique Archaeol 9:441–482.

Pearce J. 2013b. Contextual archaeology of burial practice. Case studies from Roman Britain. Oxford: BAR British Series 588.

Pearce J, Millett M, Struck M, editors. 2000. Burial, society and context in the Roman world. Oxford: Oxbow Books.

Peck JJ. 2009. The biological impact of culture contact: a bioarchaeological study of Roman colonialism in Britain. Doctoral Dissertation. Ohio: Ohio State University.

Perring D. 2002. Roman London. London: Routledge.

Perring D. 2003. "Gnosticism" in fourth-century Britain: the Frampton mosaics reconsidered. Britannia 34:97–127.

Philpott R. 1991. Burial practices in Roman Britain: a survey of grave treatment and furnishing AD 43–410. Oxford: BAR British Series 219.

Pitts M, Griffin R. 2012. Exploring health and social well-being in late Roman Britain: an intercemetery approach. Am J Archaeol 116:253–276.

Prowse TL, Saunders SR, Schwarcz HP, Garnsey P, Bondioli L, Macchiarelli R. 2008. Isotopic and dental evidence for weaning and young child feeding practices in an Imperial Roman skeletal sample. Am J Phys Anthropol 137:294–308.

Putnam B. 2007. Roman Dorset. Stroud: Sutton Publishing Ltd.

Quensel-von-Kalben L. 2000. Putting late Roman burial practice (from Britain) in context. In: Pearce J, Millett M, Struck M, editors. Burial, society, and context in the Roman World. Oxford: Oxbow Books. p 217–230.

Redfern R, DeWitte S, Gowland R, Montgomery J, Loe L. 2014. Time for a change? New insights and challenges in understanding health, diet and mobility in Roman Britain. Roman Archaeology Conference. Reading University. Available at: http://www.reading.ac.uk/web/FILES/archaeology/RAC2014_Handbook__v13.pdf. Accessed: October 5, 2014.

Redfern RC. 2006. A gendered analysis of health from the Iron Age to the end of the Romano-British period in Dorset, England (middle and late 8th century B.C. to the end of the 4th century A.D.) Doctoral dissertation. Birmingham: University of Birmingham.

Redfern RC. 2007. The influence of culture upon childhood: an osteological study of Iron Age and Romano-British Dorset. In: Harlow M, Laurence R, editors. Age and ageing in the Roman Empire: J Rom Archaeol Suppl. Ser. 65:171–194.

Redfern RC. 2008. A bioarchaeological investigation of cultural change in Dorset, England (mid to late 4th century B.C. and to the end of the 4th century A.D.). Britannia 39:161–191.

Redfern RC, DeWitte S. 2011a. A new approach to the study of Romanization in Britain: a regional perspective of cultural change in late Iron Age and Roman Dorset using the Siler and Gompertz-Makeham models of mortality. Am J Phys Anthropol 144:269–285.

Redfern RC, DeWitte SN. 2011b. Status and health in Roman Dorset: the effect of status on risk of mortality in post-Conquest populations. Am J Phys Anthropol 146:197–208.

Redfern RC, Roberts CA. 2005. Health in Romano-British urban communities: reflections from the cemeteries. In: Smith DN, Brickley MB, Smith W, editors. Fertile ground: papers in honour of Susan Limbrey. Oxford: Oxbow Books. p 115–129.

Redfern RC, Hamlin C, Beavan Athfield N. 2010. Temporal changes in diet: a stable isotope analysis of late Iron Age and Roman Dorset, Britain. J Archaeol Sci 37:1149–1160.

Redfern RC, Hamlin C, Millard A. 2012. A regional investigation of subadult dietary patterns and health in late Iron Age and Roman Dorset, England. J Archaeol Sci 39:1249–1259.

Richards MP, Molleson TL, Vogel JC, Hedges REM. 1998. Stable isotope analysis reveals variations in human diet at the Poundbury Camp cemetery site. J Archaeol Sci 25:1247–1252.

Richmond I, editor. 1968. Hod Hill, Vol. 2. London: The Trustees of the British Museum.

Roberts CA, Buikstra JE. 2003. The bioarchaeology of tuberculosis. A global view on a reemerging disease. Florida: University Press of Florida.

Roberts CA, Cox M. 2003. Health and disease in Britain: from prehistory to the present day. Stroud: Sutton Publishing Ltd.

Rogers A. 2011. Late Roman towns in Britain: rethinking change and decline. Cambridge: Cambridge University Press.

Rogers A. 2013. Rural Settlement in Late Iron Age and Roman Britain: a Review of three recent archaeological fieldwork reports and their wider implications. Britannia 44:397–400.

Scheidel W. 1996. Measuring sex, age and death in the Roman empire: explorations in ancient demography. J Rom Archaeol Suppl. Ser. 21:184.

Scheidel W. 2001. Roman age structure: evidence and models. J Rom Archaeol Suppl. 91:1–26.

Scheidel W. 2004. Human mobility in Roman Italy, I: the free population. J Rom Stud 94:1–26.

Scheidel W. 2006. Stratification, deprivation and quality of life. In: Atkins M, Osborne R, editors. Poverty in the Roman world. Cambridge: Cambridge University Press. p 40–59.
Scheidel W. 2009. Diease and death in the ancient city of Rome. Princeton/Stanford Working Papers in Classics. Available at: http://www.princeton.edu/~pswpc/pdfs/scheidel/040901.pdf. Accessed: February 1, 2010.
Scheidel W. 2010. Physical wellbeing in the Roman world. Princeton/Stanford Working Papers in Classics. Available at: http://www.princeton.edu/~pswpc/pdfs/scheidel/011001pdf. Accessed: February 1, 2010.
Scheuer L, Black S. 2000. Developmental juvenile osteology. London: Academic Press.
Scobie A. 1986. Slums, sanitation, and mortality in the Roman world. Klio 68:399–433.
Scott E. 1999. The archaeology of infancy and infant death. Oxford: BAR International Series 819.
Scott S. 2000. Art and society in fourth-century Britain: villa mosaics in context. Oxford: Oxford University School of Archaeology.
Shaw BD. 2006. Seasonal mortality in Imperial Rome and the Mediterranean: three problem cases. In: Storey GR, editor. Urbanism in the preindustrial world. Cross-cultural approaches. Tucscaloosa: The University of Alabama Press. p 86–109.
Siler W. 1979. A competing-risk model for animal mortality. Ecology 60:750–757.
Smith RJC. 1993. Excavations at County Hall, Colliton Park, Dorchester, Dorset, 1988. Salisbury: Wessex Archaeology Report No. 10.
Smith RJC, Healy F, Allen MH, Morris EH, Barnes M, Woodward PJ, editors. 1997. Excavations along the route of the Dorchester by-pass, Dorset, 1986-8. Salisbury: Wessex Archaeology Report 11.
Soranus. 1991. Gynecology. Temkin O, Trans. Baltimore: The Johns Hopkins Press.
Sparey-Green C, Paterson M, Biek L. 1981. A Roman coffin-burial from the Crown building site, Dorchester: with particular reference to the head of well-preserved hair. Proc Dorset Nat Hist Archaeol Soc 103:67–94.
Sperduti A. 1997. Life conditions of a Roman Imperial age population: occupational stress markers and working activities in Lucus Feroniae (Rome, 1st-2nd century A.D.). Hum Evol 12:253–267.
Stacey, LC. 1987. The excavation of burials at 43 Cornwall Road, Dorchester: interim report. Proc Dorset Nat Hist Archaeol Soc 108:184.
Startin DWA. 1982. Excavations at the Old Vicarage, Fordington, Dorchester, Dorset. Proc Dorset Nat Hist Archaeol Soc 103:43–61.
Storey GR, editor. 2006. Urbanism in the preindustrial world. Cross-cultural approaches. Tuscaloosa: The University of Alabama Press.
Tacitus. 1973. The annals: Agricola and the Germania. Mattingly H, Handford SA, Trans. London: Penguin Books.
Taylor J. 2001. Rural society in Roman Britain. In: James S, Millett M, editors. Britons and Romans: advancing an archaeological agenda. York: CBA Research Report 125, Council for British Archaeology. p 46–59.
Taylor J. 2013. Roman urbanism: a view from the countryside. Oxford J Archaeol 32:413–432.
Tomlin RSO, Hassall MWC. 2000. Roman Britain in 1999, ii Inscriptions. Britannia 31:433–434.
Tomlin RSO, Wright RP, Hassall MWC. 2009. The Roman inscriptions of Britain volume III: inscriptions on stone found or notified between 1 January 1955 and 31 December 2006. Oxford: Oxbow Books.
Trevarthen M. 2008. Surburban life in Roman Durnovaria. Excavations at the former County Hospital Site, Dorchester, Dorset 2000–2001. Salisbury: Wessex Archaeology.
van der Veen M, Livarda A, Hill A. 2008. New plant foods in Roman Britain: dispersal and social access. Environ Archaeol 13:11–36.
Varro. 1934. De Re Rustica. Hooper WD, Ash HB, Trans. Harvard: Loeb Classical Library.
Wadsworth ME. 1997a. Changing social factors and their long-term implications for health. Br Med Bull 53:198–209.
Wadsworth ME. 1997b. Health inequalities in the life course perspective. Soc Sci Med 44:859–869.
Waldron T. 1989. The effects of urbanisation on human health: the evidence from skeletal remains. In: Serjeantson D, Waldron T, editors. Diet and crafts in towns. The evidence of animal remains from the Roman to Post-Medieval periods. Oxford: BAR British Series 199:55–73.
Whittaker CR, Garnsey P. 1997. Rural life in the later Roman empire. In: Cameron A, Garnsey P, editors. The Cambridge Ancient History 13. The Late Empire, AD 337–425. Cambridge: Cambridge University Press. p 277–311.
Wood JW, Holman DJ, O'Connor KA, Ferrell RJ. 2002a. Mortality models for paleodemography. In: Hoppa RD, Vaupel JW, editors. Paleodemography: age distributions from skeletal samples. Cambridge: Cambridge University Press. p 129–168.
Wood JW, Holman DJ, O'Connor KA, Ferrell RJ. 2002b. Mortality models for paleodemography. In: Hoppa RD, Vaupel JW, editors. Paleodemography: age distributions from skeletal samples. Cambridge: Cambridge University Press. p 129–168.
Woodward A. 1993. Discussion. In: Farwell DE, Molleson T, editors. Excavations at Poundbury 1966-80, Vol. II: the cemeteries. Dorchester: Proceedings of the Dorset Natural History and Archaeology Society Monograph No 11. p 215–239.
Woodward PJ, Davies SM, Graham AH, editors. 1993. Excavations at the Old Methodist Chapel and Greyhound Yard, Dorchester, 1981–1984. Dorchester: Dorset Natural History and Archaeological Society Monograph Series number 12.