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

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ABSTRACT This is the first study of health in the Roman Empire to use the Siler and Gompertz–Makeham models of mortality to investigate the health consequences of the 43 AD conquest of Britain. The study examined late Iron Age and Romano-British populations (N = 518) from Dorset, England, which is the only region of Britain to display continuity in inhumation burial practice and cemetery use throughout the two periods. Skeletal evidence for frailty was assessed using cribra orbitalia, porotic hyperostosis, periosteal lesions, enamel hypoplasia, dental caries, tuberculosis, and rickets. These health variables were chosen for analysis because they are reliable indicators of general health for diachronic comparison (Steckel and Rose: The backbone of history: health and nutrition in the western hemisphere (2002)) and are associated with the introduction of urbanism in Britain during the Roman period (Redfern: J Rom Archaeol Supp Series 64 (2007) 171–194; Redfern: Britannia 39 (2008a) 161–191; Roberts and Cox: Health and disease in Britain: from prehistory to the present day (2003)). The results show that levels of frailty and mortality were lower in the late Iron Age period, and no sex differences in mortality was present. However, post-conquest, mortality risk increased for children and the elderly, and particularly for men. The latter finding challenges received wisdom concerning the benefits of incorporation into the Empire and the higher status of the male body in the Roman world. Therefore, we conclude that the consequences of urbanism, changes in diet, and increased population heterogeneity negatively impacted health, to the extent that the enhanced cultural buffering of men did not outweigh underlying sex differences in biology that advantage women. Am J Phys Anthropol 144:269–285, 2011.

The gradual incorporation of Britain into the Roman Empire began after the 54–55 BC invasion by Caesar, which established client-kingdoms in the southeast (Creighton, 2000; Cunliffe, 2007), but this connection was limited to a few communities that did not practice inhumation or an archeologically recoverable burial rite or both (Mattingly, 2006; Whimster, 1981). Therefore, to examine the effects of cultural change, it is the larger-scale and more long-lasting conquest by the Emperor Claudius in 43 AD that must be investigated. The Iron Age communities (late 8th Century BC to 1st Century AD) of Britain show considerable regional variation in terms of material culture, settlement patterns, and burial practices, and these patterns continued into and underwent changes during the post-conquest Romano-British period, reflecting population movement and wider social trends (Haselgrove and Moore, 2008; Haselgrove and Pope, 2007; Mattingly, 2006; Pearce, 2008). On the basis of current archeological evidence, the majority of Britain (e.g., Yorkshire) displays a break in funerary and cemetery continuity (Mattingly, 2006). At present, Dorset county in the southwest of England (Fig. 1) is the only region to provide continuity in the practice of an inhumation burial rite and cemetery use from the late Iron Age to the end of the Romano-British period (1st Century BC to the late 4th Century AD) (Blackmore et al., 1979; Hamlin, 2007; Putnam, 2007; Whimster, 1981).

Health changes post-conquest have been investigated at the national level by Roberts and Cox (2003) and at the regional level in Yorkshire (Peck, 2009), where a recent diaspora study of individuals excavated from the city of York has shown to have been inhabited by people from many areas of the Empire (Leach et al., 2009) and, thus, reflects health statuses also influenced by ethnicity (LaVeist, 2002). In contrast, the study presented here is the first regional analysis of the relationship between patterns of health and mortality and colonization in Britain before and after the Claudian conquest, using bioarcheological data from the unique region of Dorset. Published evidence and on-going research by the first author (R.C.R.) has demonstrated that, in Dorset, the late Iron Age population were from Britain (confirming national trends) and the Romano-British communities

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Fig. 1. Location map of the county of Dorset in Britain.

were made up of locals and migrants from the Northern Mediterranean (Redfern et al., 2010; Richards et al., 1998). Therefore, the influence of population diversity on health should be nominal because these populations show very little genetic differentiation (Lao et al., 2008).

The relationships among cultural change, general health, and risk of death have been established by many studies (e.g., Hutchinson, 2006; Stodder, 1996). Considerable work has been undertaken in the Americas to assess the health statuses and demographic change within populations pre- and post-contact (15th Century AD) (i.e., Jones, 2010; Larsen and Milner, 1994; Snow and Lanphear, 1988; and Rose, 2002), which has demonstrated that this process can affect dental health, demography, and the prevalence of disease. Importantly, this work has also shown that a uniform response will not be observed, because many communities successfully adapted to significant cultural and environmental transformations (Larsen and Milner, 1994). Previous research by Redfern (2006, 2007, 2008a), Redfern et al. (2010), and Richards et al. (1998) on pre- and post-conquest communities in Dorset has demonstrated that post-conquest dietary patterns change. This is evidenced by the increased consumption of marine resources and the presence of multiple food-ways; the increased prevalence of dental disease, infectious and metabolic diseases; decreased evidence for trauma; the decline of subadult growth; and the fact that the average male stature did not increase over time. These health changes could be directly associated with the introduction of urban living, changes in diet, and greater population variation as evidenced by archeological and stable isotope data (Putnam, 2007; Redfern et al., 2010; Richards et al., 1998). To further examine these patterns and to incorporate new data from the region, the authors used the Siler and Gompertz–Makeham models of mortality to investigate the health consequences of the Roman conquest by examining demographic patterns and the risk of death associated with skeletal and dental markers of stress.

ARCHEOLOGICAL BACKGROUND

The Roman Empire (3rd Century BC to 5th Century AD), which at its height extended from North Africa into the Arab World and included most of Europe, incorporated existing communities by military conquest or political treaties (Wells, 1992). Integration into this sophisticated political and military system frequently resulted in changes to the agrarian system and living environment and implemented new social and economic structures (Todd, 2007; Wells, 1992). However, the Roman Empire was heterogeneous, i.e., communities were not uniform and instead continued to express their ethnic and cultural identities through material culture, funerary practices, and diet (e.g., Chenery et al., 2010; Hingley, 2005; King, 1999; Laurence and Berry, 1998; Williams, 2000). Recent archeological studies have shown that life within the Empire displayed intense inter-regional differences, reflecting underlying sociocultural variations (e.g., Keay and Terrenato, 2001; Pearce, 2000; Purcell, 2003; Revell, 2005).

In Britain, the Claudian conquest was traditionally viewed as a shift toward civilization—the end of prehistory—marked by the use of writing, formal government, and the building of metaled roads (e.g., Wacher, 1979). In more recent years, this view has become more nuanced and comprehensive because of studies that have examined environmental, funerary, and material culture evidence (e.g., Cool, 2006; Mattingly, 2006). The process of incorporation into the Roman world is known as Romanization, a now controversial term because of its imperialist and colonial connotations (Gosden, 2006; Hingley, 2005). Recent debates have challenged how the term is understood and used in Roman archeology; indeed, many scholars have suggested that more neutral terms, such as "globalization" (Hingley, 2005) or "creolization" (Webster, 2001) should be used instead. However, in this study we use the term Romanization but "...in its weakest sense, as a convenient denomination covering the events involved in the creation of Roman [Britain], with no cultural implications taken for granted" (Terrenato, 1998: 20).

During the Iron Age, Dorset formed part of the Durotriges tribal territory, a tribe that had probably lived in the region since the early Iron Age (9th to 7th Centuries BC) (Cunliffe, 2005; Gale, 2003). By the late Iron Age, the Durotriges had developed into a close-knit tribal confederacy centered on modern Dorset (Gale, 2003). The Durotriges were ethnically similar tribal groups, each of which had a hillfort or hillforts that served as trading or manufacturing centers, central storage facilities for cereal, and defensive structures in times of crisis (Cunliffe, 2005; Gale, 2003). These tribal units were represented by a common currency, had an extensive trade system for items of Durotrigian manufacture (both for regional use and for export), and likely banded together in defense of the confederacy's territory (Cunliffe, 2005; Sharples, 1991a). These units lived in wattle-and-daub roundhouses and practiced a mixed agricultural economy set in a landscape of grasslands, woods, heathlands, and fields (Dark and Dark, 1998). Faunal analysis of diet shows that chickens and pigs were kept in small numbers, but the majority of meat and dairy products were derived from cattle and sheep herds; wild resources only contributed a small part of the diet (Albarella, 2007; Hambleton, 1999). Stable isotope analyses of late Iron Age diet support these data and also demonstrate that no sex differences in dietary contributions existed (Redfern et al., 2010; Richards et al., 1998).

The Durotrigian use of an inhumation funerary rite developed from an earlier tradition of pit burial in the middle Iron Age (Whimster, 1981: 37). This rite was not practiced by all communities in the Durotrigian confederacy, as based on current evidence, it seems to have been used particularly by those living in the southern portion of the territory (Whimster, 1981). Because funerary rites were not homogenous across Dorset, it is not unexpected that the flat-grave cemeteries seem to have been used more frequently for men, with more women receiving an "invisible" burial (Hamlin, 2007). Inhumed individuals were accompanied by grave-goods of pottery, jewelry, cuts of meat and utilitarian items, for which men and women had comparable inclusion rates (Hamlin, 2007; Whimster, 1981). As with any archeologically derived sample, the extant Durotrigian sample available for research reflects the biases of their own funerary practices but also important factors such as cemeteries not being completely excavated in response to development (e.g., Dorchester and Tolpuddle bypasses) (see discussion by Waldron, 1994: 12–16). Despite these insoluble issues, demographic analysis of these cemeteries shows that they conform to an attritional profile (Redfern and Chamberlain, in press), with a male:female ratio of 1.2:1.

Dorset was conquered early in the 1st Century AD (ca. 43/44 AD) by the Roman army that established the first town in the region (Dorchester) in 65–70 AD, which also acted as the native capital of the Durotriges (Royal Commission on the Historical Monuments (England), 1970; Woodward et al., 1993). This event is also likely to represent the consolidation of Roman power in southern England (Mattingly, 2006) because there are no references in primary texts to show that the tribe continued to resist Roman occupation (Sharples, 1991a, 1991b). Dorchester

(*Durnovaria*) was built in a Roman style, with an aqueduct to provide water for the public bathhouse and fountain (Putnam, 2007), and the streets were aligned in a grid, providing order to the townhouses and forum (Woodward et al., 1993). The rectangular townhouses were built of wood or stone or both, with richer inhabitants incorporating drains and under-floor heating systems (hypocaust), small bathhouses, and latrines (Putnam, 2007).

Management of the landscape improved and agriculture continued to intensify, though these changes would not have been immediate (Dark and Dark, 1998; Grant, 2007). New technologies, such as the more efficient iron plough coulter, and developments in livestock size and management were implemented (Albarella et al., 2008; O'Connor and van der Veen, 1998). The consumption of cattle, sheep, and pigs continued, but the range of species in the diet increased to include more wild game, fish, and shellfish (Grant, 2007; Locker, 2007). Plant remains indicate the introduction of new species, and innovation in meat processing and cookery techniques are evident in new vessel types (Cool, 2006; van der Veen et al., 2007, 2008). Greater quantities of freshwater and marine species were incorporated into the diet, derived from local and imported sources (Hamliton-Dyer, 1993, 2001; Redfern et al., 2010; Richards et al., 1998).

Settlements outside *Durnovaria*'s walls continued their late Iron Age rural features, and the extent to which these communities were "Romanized" was not a simple reflection of their proximity to the town, but involved a broad range of variables (Putnam, 2007). Roundhouses continued to be built and occupied across Dorset, with Roman-style rectangular buildings constructed in some outlying settlements, whereas in other areas large tracts of the landscape were managed by villas, with their wealthy inhabitants also enjoying the similar luxuries of plumbing and hypocausts to their town-dwelling peers (Hingley, 1989; Putnam, 2007).

Unfortunately, there is a paucity of environmental evidence that prevents us from using indicator group data (Kenward and Hall, 1997) to reconstruct living environments in both periods, particularly the limited number of water-logged deposits recovered from the county (Bryant, 1990; Gale, 2003; Putnam, 2007). We do not know what living conditions in Iron Age roundhouses were like, as a range of activities (metalworking, cereal storage, and textile production) took place inside, and the deposits of rubbish that we do find, seem to have a ritual component and, therefore, are unlikely to be reflective of daily activities (Hill, 1995; Redfern, 2008b). In Roman *Durnovaria*, domestic and personal waste was buried in backyards (Woodward et al., 1993), although, as in the Iron Age, this might have had a ritual component (Woodward and Woodward, 2004). An insight into personal hygiene is possible because of studies undertaken on the gypsum burials at Poundbury Camp; analysis of head and facial hair samples indicates that people suffered from head lice (Farwell and Molleson, 1993: 205–206), and samples taken from the stomach area identified whipworm and roundworm ova (Jones, 1993).

Evidence for industrial activities has shown that metal and bone working, fabric making, and butchery all took place in the town, and an urban farmstead has been potentially identified, suggesting that the environs of the town were managed (Woodward et al., 1993). In settlements elsewhere in Dorset, we must assume that domestic rubbish and industrial waste was also buried or burnt (for elsewhere in Britain, see Hurst, 1999).

In the Roman period, the practice of inhumation continued in many cemeteries, and became more widespread throughout the region by the creation of new ones around settlements (Esmonde Cleary, 1987, 2000). The internment of individuals outside the official and religious boundary of a settlement served to uphold Roman law but also to avoid the ritual pollution of the community (Adkins and Adkins, 1998: 181). Infants (usually those aged $\leq$3 years) were not always placed in these cemeteries; instead they were often buried within settlements, particularly in rural areas (Scott, 1999: 110–120). Pearce's (2001) review of infant burials concludes that temporal differences exist, with the majority of cemetery inhumations occurring in the 3rd and 4th Centuries AD, and that intercemetery differences exist in the numbers of subadult internments excavated. In many Romano-British cemeteries, sex differences in the male-female ratio of burials has been identified, particularly those associated with urban centers, e.g., Cirencester (Gloucestershire) (Crowe, 2001; Davison, 2000). Because of the close association of the military with many of these towns (e.g., Colchester, Essex), this result may reflect the reality of a large male population. However, the extent to which these assertions are "real" or can be reliably investigated is problematic, because the majority of cemeteries have not been completely excavated; most date to the late Roman period (3rd to early 5th Century AD) (Pearce, 2008); and the ability to determine an individual's sex is not only influenced by the methods used, but is also influenced by skeletal completeness and preservation (Bello et al., 2006; Walker, 1995). Furthermore, ratio differences are based on inhumation data predominantly excavated from the southeast of England in response to commercial archeological projects (Pearce, 2008). Unfortunately, this has led to cemetery data being strongly biased toward urban centers, with very few cemeteries excavated from rural, villa, or military sites (Pearce, 2008).

In Dorset, the factors identified by Pearce (2008) have resulted in the majority of the cemeteries in the environs of Dorchester being excavated (Table 1), with only a few burials located in a rural setting. Additionally, as Table 1 shows, there are intersite differences in the numbers of subadults recovered, indicating that the youngest individuals were not always buried in formal burial grounds in either an urban or rural setting (e.g., County Hall vs. Alington Avenue). The demography of the sample available from Roman Dorset conforms to an attritional profile (Chamberlain, 2006; Redfern, 2008a), with the ratio of male-to-female being 1.5:1, a change of 0.2 from the preceding period.

The Romano-British period saw clearer evidence for status reflected in Dorset's funerary record, with individuals buried in an extended position, often within wood, stone, or lead containers, which were sometimes placed in decorated mausoleums (e.g., Poundbury Camp); additionally, decapitation, prone, and gypsum burial rites were practiced (Leech, 1980; Millett, 1997: 128). The range of grave-goods increases, reflecting cultural change, such as the inclusion of hobnail shoes and coins (Hamlin, 2007). Greater differences between the sexes in the number and variety of grave-goods increases in this period, with rural–urban disparities in the different type of grave-goods also apparent, and a trend for "dynamic conservatism" in rural female burials, with their emphasis on pre-Roman funerary traditions (Hamlin, 2007).

TABLE 1. Sample used in the study presented by date and site

Date	Site	Male	Female	Ambiguous sex	Undetermined sex	Subadult	Total *N*
M-LIA	1. Gussage All Saints	4	4	–	–	21	29
LIA	2. Alington Avenue	4	4	–	–	–	8
	3. Broadmayne	1	–	–	–	–	1
	4. Dorchester Bypass	4	6	2	–	5	17
	5. Hod Hill	–	1	–	–	–	1
	6. Kimmeridge	–	1	–	–	1	2
	7. Maiden Castle	30	24	–	1	9	64
	8. Newfoundland Wood	1	–	–	–	–	1
	9. Portesham	–	1	–	–	–	1
	10. Portesham (Manor Farm)	3	–	–	–	3	6
	11. Poundbury Camp	8	5	–	9	27	49
	12. Rope Lake Hole	–	–	–	–	1	1
	13. Tarrant Hinton	1	2	–	–	–	3
	14. Tolpuddle Bypass	3	2	1	–	3	9
	15. Whitcombe	6	2	–	–	2	10
	16. Wyke Regis	–	1	–	–	–	1
	Period total	65	53	3	10	72	203
RB	17. Albert Road (U)	8	2	–	1	10	21
	18. Alington Avenue (R)	24	15	5	–	13	58
	19. County Hall (U)	–	–	–	–	6	6
	20. Crown Building (U)	1	–	–	–	–	1
	21. Dorchester Bypass (R)	11	9	1	–	14	35
	22. Fordington Old Vicarage (U)	5	1	–	–	6	12
	23. Greyhound Yard (U)	–	–	–	–	8	8
	24. Gussage All Saints (R)	1	–	–	–	–	1
	25. Hod Hill (R)	1	–	–	–	2	3
	26. Little Keep (U/R)	17	9	–	–	3	29
	27. Littlewood Farm (R)	1	–	–	–	–	1
	28. Poundbury Camp (U/R)	33	23	4	–	55	115
	29. Poundbury Pipeline (U/R)	–	3	1	–	1	5
	30. Southfield House (U)	–	1	–	–	–	1
	31. Tarrant Hinton (R)	–	–	–	–	8	8
	32. Tolpuddle Bypass (R)	2	3	–	–	2	7
	33. Wyke Regis (R)	–	3	–	1	–	4
	Period total	104	69	11	2	128	315
	Total sample	169	122	14	12	201	518

1 and 24, Wainwright (1979); 2 and 18, Davies et al. (2002); 3, Young (1974); 4 and 21, Smith et al. (1997); 5 and 25, Richmond (1968); 6, O'Connell (unpublished report); 7, Wheeler (1943); 8, Toms (1970); 9, Fitzpatrick (1997); 10, Valentin (2004); 11 and 28, Farwell and Molleson (1993); 12, Maw (1976); 13 and 31, Graham (2007); 14 and 32, Hearne and Birkbeck (1999); 15, Aitken and Aitken (1991); 16, Leonard (2008); 17, Stacey (1987); 19, Smith (1993); 20, Sparey Green et al. (1981); 22, Startin (1982); 23, Woodward et al. (1993); 26, McKinley and Egging-Dinwiddy (2009); 27, Putnam (unpublished report); 29, Davies and Grieve (1986); and 30, Davies and Thompson (1987). M-LIA, middle and late Iron Age; LIA, late Iron Age; RB, Romano-British period; U, urban RB cemetery; R, rural RB cemetery; U/R, RB cemetery with urban and rural characteristics.

MATERIALS AND METHODS

The burial contexts are located throughout Dorset (Table 1, Figs. 2–4), but because the county remains rural in character, the majority of individuals are derived from the environs of Dorchester because this has been subject to most road and settlement redevelopment. Because the regional sample derives from Victorian to present-day excavations, it has not been possible to analyze the data set using a more nuanced chronology (Redfern, 2006, 2007, 2008a). Therefore, the samples are divided into mid-to-late Iron Age (mid-to-late 4th Century BC to 1st Century AD) and Romano-British (1st to 5th Centuries AD).

The sample consists of 518 inhumed individuals from the county of Dorset, England. Of these, 203 date from the middle and late Iron Age and 315 from the Romano-British period. These individuals derive from articulated inhumations and were between stages zero (excellent) to three (weathered compact bone) of preservation. For the Romano-British phase of the Poundbury Camp cemetery, 115 skeletons were randomly selected because the total number of excavated individuals (N = 1,442) (Farwell and Molleson, 1993) was too large to be recorded within the parameters of Redfern's (2006, 2007) doctoral studies. No such sampling was done for the Iron Age burials. In addition to subadult and sexed adult data previously published, ambiguous and indeterminate sex individuals are also included in some of the analyses done for this study. Furthermore, since the completion of Redfern's (2006) doctoral research, additional skeletal samples have been excavated and recorded using the widely accepted standards published by Brickley and McKinley (2004) and Buikstra and Ubelaker (1994). Therefore, because these were recorded similarly to Redfern (2006, 2007, 2008a), it has been possible to incorporate these data using the methodologies described below.

Age and sex estimation

Subadults (aged <20 years) were aged using a combination of dental eruption, diaphyseal length, and epiphyseal fusion methodologies (Scheuer and Black, 2000; Ubelaker, 1989). When both dental and skeletal estimates were available, the dental was used because this has the strongest correlation to chronological age and

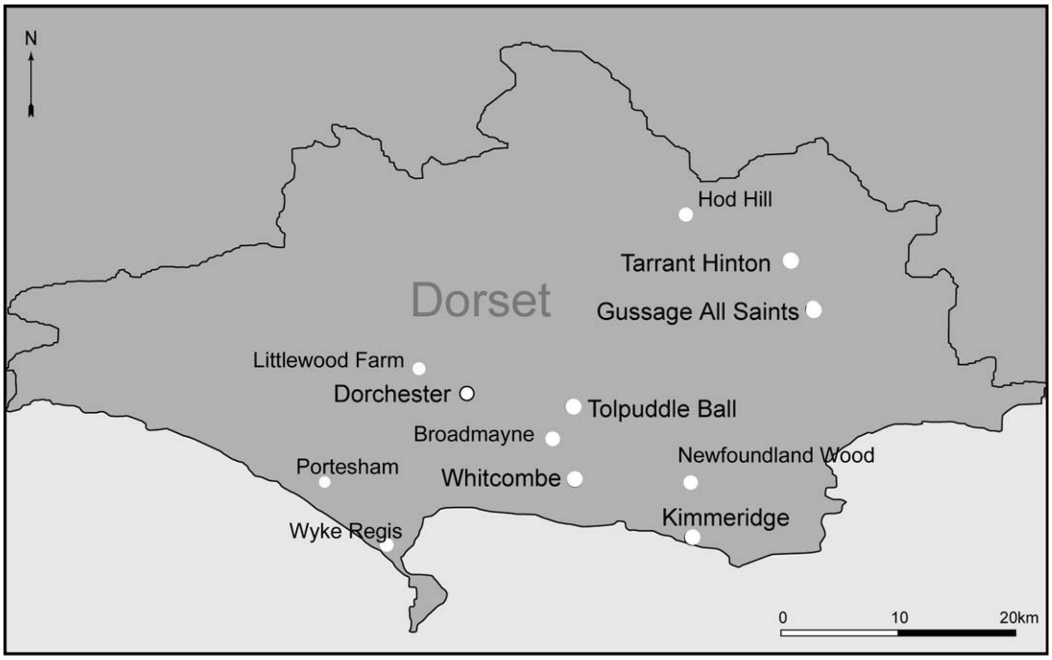

Fig. 2. Location of sites outside the environs of Dorchester after © 1998–2006 John Allen.

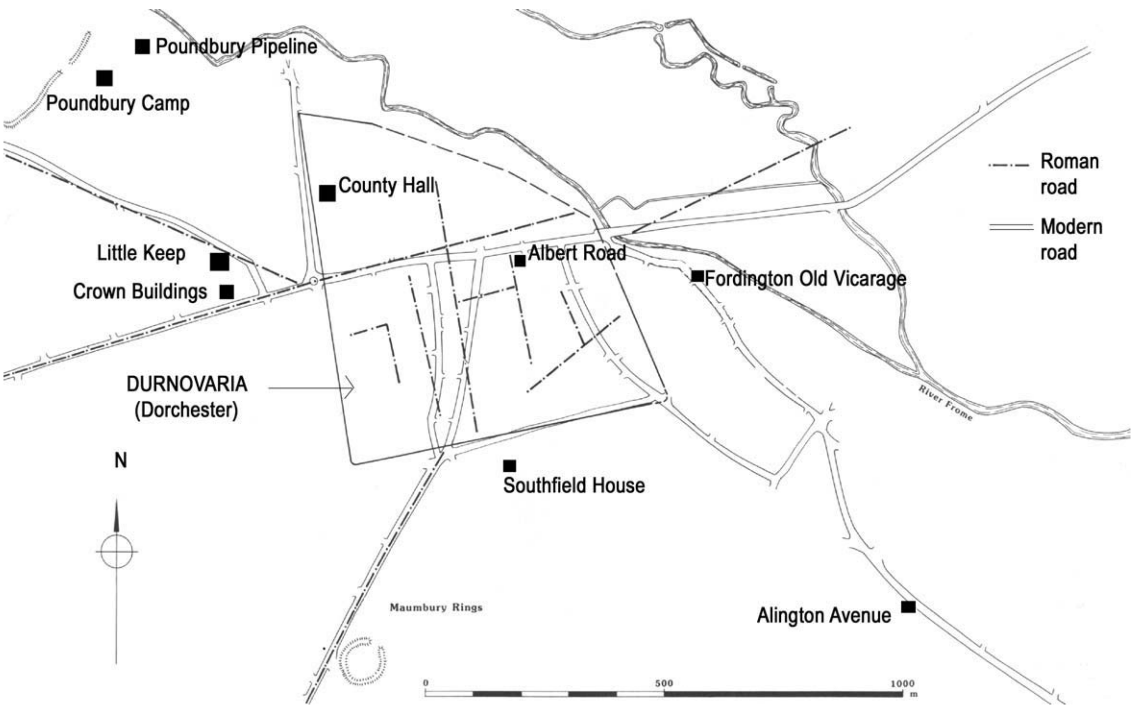

Fig. 3. Location of sites in the immediate environs of Dorchester (after Davies et al., 2002).

provides the most reliable estimates (Lewis and Garn, 1960). Age-at-death in adults was determined using degeneration of the pubic symphysis and iliac auricular surfaces, and sternal rib end morphology (Buikstra and Ubelaker, 1994; İşcan and Loth, 1986a, b). Sex was estimated using morphology of the skull and pelvis (Buikstra and Ubelaker, 1994), and the sex and age-group divisions devised by Buikstra and Ubelaker (1994) were used.

Age patterns of mortality

The age patterns of mortality within the Iron Age and Romano-British samples were assessed by using age-at-

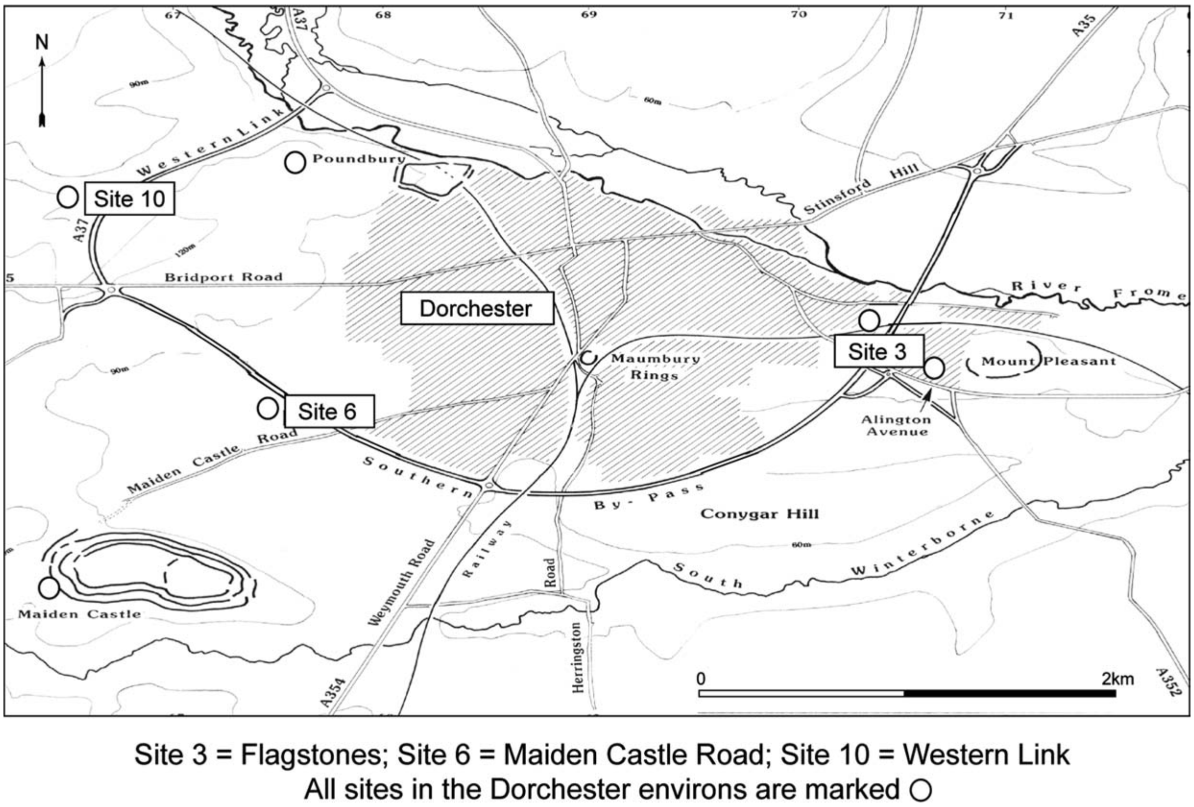

Fig. 4. Location of sites on the Dorchester Bypass and in the environs of Dorchester (after Smith et al., 1997).

death data to estimate the parameters of the Siler model of mortality, a parsimonious parametric model that fits a wide variety of human mortality patterns (Gage, 1991; Wood et al., 2002):

$$h_{13}(a) = \alpha_1 e^{-\beta_1 a} + \alpha_2 + \alpha_3 e^{-\beta_3 a}.$$

The first component of the Siler model, $\alpha_1 e^{-\beta_1 a}$, describes the exponentially decreasing juvenile risk, where α_1 is the risk of death at birth associated with immaturity and β_1 is the rate at which this risk decreases with age a. The second component of the model, α_2, is the constant age-independent risk that everyone within the population faces (i.e., the chance of dying from causes that are unrelated to aging). The third component of the model, $\alpha_3 e^{\beta_3 a}$, is the exponentially increasing senescent risk, where α_3 is the risk of death associated with senescence at birth and β_3 is the rate at which this risk increases with age (Gage, 1988). The three components of the Siler model are independent; thus, surviving one component of mortality does not affect the risk of death from the others (Wood et al., 2002).

This study uses the Siler model rather than a more traditional life-table approach because the model requires the estimation of only five parameters (Gage, 1990) and is therefore a more efficient way to use paleodemographic age-at-death data (Buikstra, 1997; Hoppa and Vaupel, 2002; Konigsberg and Frankenberg, 2002; Milner et al., 2008; Wood et al., 2002). Life tables require the estimation of the central mortality rate for every age interval used in the study, a task that is difficult without huge samples and information about the original population size at risk, neither of which is available for this study (Wood et al., 2002). The parameters of the Siler model were estimated separately for the Iron Age and Romano-British samples using maximum likelihood estimation with the program *mle* (Holman, 2005); maximum likelihood estimation, in general, finds values for model parameters that maximize the likelihood of the observed sample data.

Sex differentials in mortality

To determine whether sex patterns of mortality (i.e., whether men and women faced similar risks of dying) differed between the Iron Age and Romano-British time periods, sex was modeled as a covariate affecting adult mortality within the two samples. Because of the difficulties associated with determining sex in juvenile skeletal remains, the analysis of sex differentials only examines patterns of mortality among adults. Adult mortality was modeled using the Gompertz–Makeham mortality function, which fits the general human pattern of relatively low mortality during the young adult ages and an increasing risk of death with senescence (i.e., the second two terms of the Siler model) (Wood et al., 2002):

$$h(a_i) = \alpha_1 + \alpha_2 e^{\beta a}$$

In this model, a_i is the age of the ith skeleton in years, α_1 is the constant age-independent risk of mortality that everyone within the population faces, and $\alpha_2 e^{\beta a}$ is the exponentially increasing senescent risk of mortality (Gage, 1988).

To evaluate whether men and women differed in their risks of mortality within each of the samples, sex was modeled as a covariate acting on the parameters of the Gompertz–Makeham model. For this analysis, women were coded as 0, and men were coded as 1. Parameters were estimated using maximum likelihood analysis with the program *mle* (Holman, 2005). The model was fit separately to the data from the Iron Age and Romano-British samples. A significant positive estimate for the parameter representing the effect of the covariate on the hazard would suggest that men were at an increased risk of death compared with women. Conversely, a significant negative estimate would indicate the risk for men was lower than that for women.

Estimation of general health status

To evaluate the effect of Romanization on health patterns, the following pathologies were assessed in the Iron Age and Romano-British samples: cribra orbitalia, porotic hyperostosis, periosteal lesions, enamel hypoplasia, dental caries, tuberculosis, and rickets. The health variables chosen for analysis in this study were selected because they have been proven to be reliable indicators of general health for diachronic comparison and are associated with the introduction of urbanism in Britain during the Roman period (Redfern, 2007, 2008a; Roberts and Cox, 2003; Steckel and Rose, 2002). Several of these health variables reflect the impact of subadult stress events on health and longevity in adulthood, such as enamel hypoplastic defects (Humphrey and King, 2000). Additionally, the dental health variables were found to be statistically significantly different between pre- and post-conquest communities in Dorset (Redfern, 2008a).

The presence of cribra orbitalia and porotic hyperostosis in archeological populations is believed to reflect subadult episodes of iron deficiency because of factors such as parasitism and poor diet (Stuart-Macadam and Kent, 1992); however, a recent study concluded that it could reflect a maternal and childhood deficiency in folic acid (vitamin B_9) and vitamin B_{12} (Walker et al., 2009). Tuberculosis is an infectious disease caused by members of the genus *Mycobacterium* and is transmitted by the consumption of infected meat and dairy products, between people via the respiratory route, or to nursing infants from their mother or wet-nurse (Roberts and Buikstra, 2003). Although the disease is found in both rural and urban populations, it has become synonymous with urban environments because the nature of these locales influences its prevalence (Roberts and Buikstra, 2003). Rickets is a disease of childhood (Lewis, 2007). It is a metabolic disease caused by a deficiency in vitamin D, which is usually obtained by exposing the skin to sunlight and the consumption of certain foods, such as oily fish (Brickley and Ives, 2008).

A person's dental health reflects their diet and status, which dictates the range, quality, and quantity of foods prepared and eaten (Roberts and Manchester, 2005). To provide an overview of dental health, this study focuses on carious lesions and enamel hypoplastic defects. Carious lesions are caused by dental plaque, and their prevalence is related to the consumption of carbohydrates and dairy products and dental hygiene practices (Hillson, 1998). Enamel hypoplastic defects have multifactorial origins and are considered to be a nonspecific indicator of systemic physiological stress (Guatelli-Steinberg and Lukacs, 1999). Nonspecific indicators of stress include periosteal new bone formation, cribra orbitalia and porotic hyperostosis, and enamel hypoplastic defects (Goodman and Martin, 2002). The etiology of these indicators has undergone revision in recent years (e.g., Walker et al., 2009), but they continue to be used by many researchers as reliable indicators of the general health of a population (Belcastro et al., 2007; Steckel and Rose, 2002).

The frequencies of these various pathologies within the late Iron Age and Romano-British samples were compared using χ^2 analysis to determine whether Romanization was associated with significant changes in markers of health, which might indicate improvements in or deterioration of general levels of health within the population. Analysis of the frequencies of skeletal pathologies might not, by itself, be totally informative about health differences between two populations because we often do not know how those pathologies were associated with risks of death in the populations. A higher frequency of pathologies in one sample might mean lower general levels of health compared with another sample. However, such an interpretation might not be correct if the risks of death associated with skeletal pathologies are not the same in two populations. Perhaps, in one population, general levels of health were so poor that many people died from various physiological stressors before skeletal pathologies formed in response to those stressors. In such a case, the resulting skeletal sample would have a lower frequency of those pathologies than one from a comparatively healthier population in which people survived the stressors long enough to form skeletal pathologies (Wood et al., 1992). Without evaluating the risk of death associated with pathologies, one would conclude that the sample with the lower frequencies of pathologies was healthier, when in fact the opposite was true.

The possibility of variation among populations in the association between skeletal pathologies and risk of mortality requires the use of models that allow one to explicitly evaluate those associations. For these reasons, the multistate model of morbidity and mortality developed by Usher (2000) was used in this study to determine whether the excess mortality associated with skeletal pathologies differed between the late Iron Age and Romano-British samples as a means of assessing differences in frailty between the two populations. Frailty refers to an individual's relative risk of death compared with other members of the population (Vaupel et al., 1979). If average frailty was lower during the Iron Age, individuals might have developed skeletal pathologies yet still resisted death more successfully than did Romano-British individuals. The effects of exposure to physiological stress on risk of dying might have been stronger and, thus, increased risks of mortality to a greater extent in the Roman-British population than in the late Iron Age population. If so, the excess mortality associated with skeletal pathologies is expected to be higher in the Romano-British sample than the late Iron Age sample.

The Usher model, shown in Figure 5, has three, nonoverlapping states: State 1 includes all those individuals in the sample without any visible skeletal pathology; State 2 includes those with visible pathology; and State 3 is death. Everyone in the skeletal sample used for this study is observed in State 3, and States 1 and 2 represent the possible living states the individuals could have been in immediately before they died. In the Usher

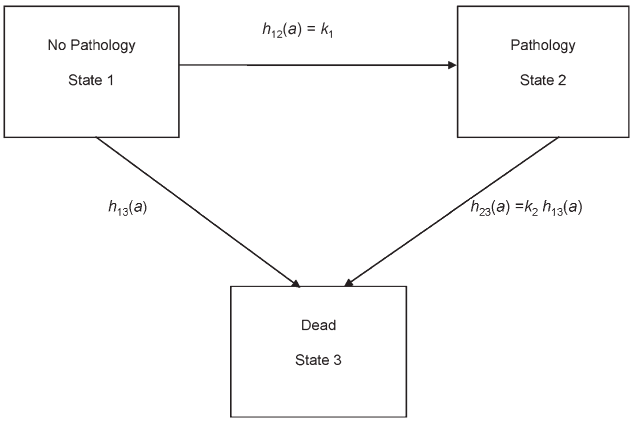

Fig. 5. Usher three-state model of morbidity and mortality (redrawn from Usher, 2000).

model, individuals can move from State 1 to State 2 (i.e., suffer physiological stress and consequently develop a skeletal pathology) and individuals can die from either of the two living states (i.e., with or without skeletal pathology). The transitions from either of the two living states to death are determined by age-specific hazard rates. The model allows for (but does not require) variation in the hazard rates between each of the two living states and death; i.e., the hazard of making the transition from State 2 to death can be higher or lower than, or the same as the hazard of making the transition from State 1 to death. Thus, the model can be used to estimate the differential risk of death associated with the living states. Even though everyone in a cemetery sample is observed in State 3, data on age-at-death and the presence of skeletal pathologies can be used to estimate all of the parameters of the model described below.

For this study, the baseline risk of death from State 1, $h_{13}(a)$, was specified as the Siler model described above. The hazard of moving from State 1 to State 2, i.e., of developing a skeletal pathology, $h_{12}(a)$, was estimated as a constant k_1. For this study, an age-specific hazard of moving from State 1 to State 2 was not included in the model because, for most skeletal pathologies, one does not know the age at which an individual became ill or suffered some other physiological stress sufficient to cause the pathology, nor does one know precisely how long it took for skeletal pathology to develop. For simplicity, in this study, the age of onset of skeletal pathology was modeled as an exponential random variable. The hazard of dying from State 2, $h_{23}(a)$, was modeled as proportional to the baseline age-specific risk of dying from State 1. Under the proportional hazards specification, k_2, is a proportional term on the Siler function and is, thus, independent of age. The k_2 parameter value indicates the proportional difference in risk of death between individuals with and without skeletal pathologies. Estimated k_2 values significantly greater than 1 indicate that individuals with skeletal pathologies were at higher risks of dying compared with peers without them. Estimated k_2 values significantly lower than 1 indicate that individuals with skeletal pathologies face decreased risks of death compared with their peers. Estimated k_2 values equal to 1 indicate that individuals with and without skeletal pathologies were at approximately equal risks of dying.

TABLE 2. Maximum likelihood estimates of the Siler model parameters with associated standard errors (SEs)

Parameter	Iron Age (SE)	Romano-British (SE)
α_1	0.41 (0.06)	0.34 (0.05)
β_1	0.9 (0.20)	0.9 (0.21)
α_2	0.0005 (0.008)	0.02 (0.004)
α_3	0.004 (0.003)	3.6×10^{-5} (0.0001)
β_3	0.07 (0.02)	0.16 (0.07)

For this analysis, the Usher model was fit to data on age, time period (i.e., late Iron Age or Romano-British), and the presence of skeletal pathologies using a pooled sample of all individuals in the late Iron Age and Romano-British samples. To evaluate differences in the excess mortality associated with skeletal pathologies between the late Iron Age and Romano-British samples, and thus whether previous exposure to stressors had the same effect on risk of death within the two samples, time period was modeled as a covariate affecting the k_2 parameter in the Usher model. In this analysis, late Iron Age individuals were coded as 0, and Romano-British individuals in the sample were coded as 1. A significant positive or negative estimate for the parameter representing the effect of the time period covariate would suggest that the excess mortality associated with stress markers was higher or lower, respectively, for Romano-British individuals compared with late Iron Age individuals.

The model was fit separately to data on the presence of each of the following stress markers: cribra orbitalia, porotic hyperostosis, periosteal lesions, enamel hypoplasia, and dental caries. The model was not applied to data on tuberculosis and rickets because there were too few individuals with those pathologies within the late Iron Age and Romano-British samples to allow for informative parameter estimation. Parameters were estimated using maximum likelihood analysis with the program *mle* (Holman, 2005).

RESULTS

Age patterns of mortality

The Siler model parameter estimates for the late Iron Age and Romano-British samples are shown in Table 2, and graphs of the corresponding hazard functions are shown in Figure 6. For both samples, the highest risks of mortality were faced by infants and by older adults. However, as can be seen in Figure 6, the hazards for children, adolescents, and older adults (individuals above the age of 50) are higher in the Romano-British sample than in the late Iron Age sample; the hazard for younger adults (aged 30–50) is slightly higher in the late Iron Age sample.

Sex differentials in mortality

The estimated values of the parameter representing the effect of the sex covariate within the late Iron Age and Romano-British samples are shown in Table 3. The estimate for the late Iron Age sample is not significantly different from zero, which suggests that in the late Iron Age population, sex did not affect risk of death (i.e., men and women faced approximately equal risks of mortality). However, the estimate of the parameter representing the effect of the sex covariate within the Romano-British sample is significantly higher than zero. This

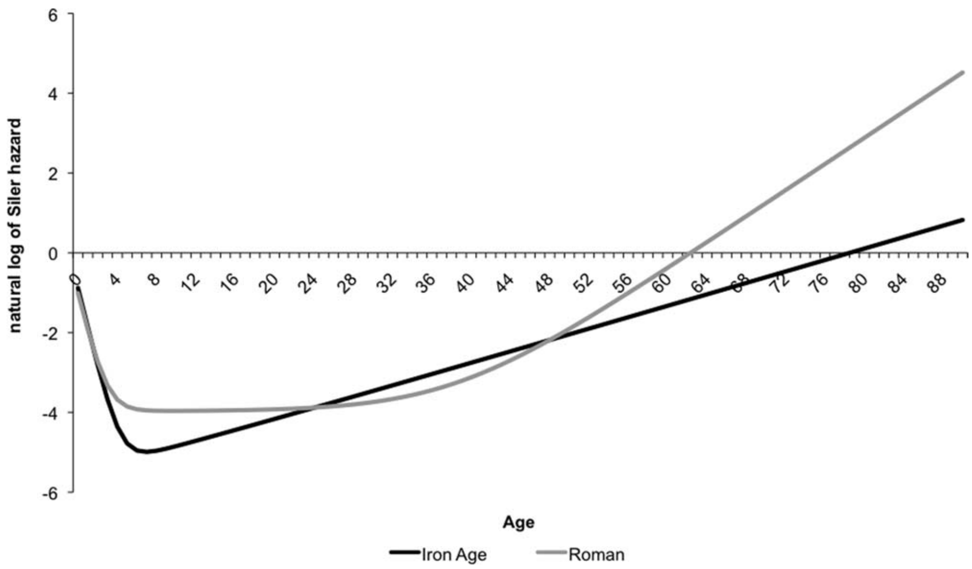

Fig. 6. Siler hazard model of mortality.

TABLE 3. Maximum likelihood estimates of the effect of the sex covariate with associated standard errors (SEs)

	Iron Age (SE)	Romano-British (SE)
Sex covariate	0.07 (0.19)	0.38 (0.17)

TABLE 4. Frequencies of skeletal pathologies in each sample and results of the χ^2 tests (df = 1)

Pathology	Iron Age (%)	Romano-British (%)	χ^2	*P*
Cribra orbitalia	35	25	5.56	0.02
Porotic hyperostosis	25	10	17.3	<0.001
Periosteal lesions	49	36	5.99	0.01
Enamel hypoplasia	18	20	0.33	0.57
Dental caries	43	46	0.35	0.55
Rickets	0.5	3	3.29	0.07
Tuberculosis	0.5	1.3	0.88	0.35

TABLE 5. Maximum likelihood estimates of k_2 and the effect of the time period covariate with associated standard errors (SEs)

Pathology	$\hat{k}_2$ (SE)	Time period (SE)
Cribra orbitalia	1.80 (0.29)	0.18 (0.17)
Porotic hyperostosis	2.69 (0.55)	0.06 (0.22)
Periosteal lesions	1.64 (0.25)	0.19 (0.15)
Enamel hypoplasia	1.30 (0.21)	0.31 (0.20)
Dental caries	1.25 (0.19)	0.03 (0.16)

suggests that within the Romano-British population, men were at higher risk of mortality than women.

Health status

Table 4 shows the frequencies of skeletal pathologies within the late Iron Age and Romano-British samples, and the results of the χ^2 tests for each pathology. The maximum likelihood estimates of k_2, the estimated values of the parameter representing the effect of the time period covariate, and the standard errors associated with these estimates are shown in Table 5.

The results of the χ^2 tests indicate that cribra orbitalia, porotic hyperostosis, and periosteal lesions were at significantly higher frequencies ($P < 0.05$) in the late Iron Age sample. Enamel hypoplasia, dental caries, rickets, and tuberculosis were more common in the Romano-British sample, but the differences between the two samples are not statistically significant. Overall, analysis of the frequencies of these skeletal variables does not reveal a consistent pattern with respect to changes in general health status from the late Iron Age to the Romano-British periods.

However, the estimates of the excess mortality associated with the skeletal pathologies do indicate a change in health patterns after Roman conquest. The maximum likelihood estimates of k_2 and the excess mortality associated with the pathologies used in this study (with the exception of rickets and tuberculosis, for reasons provided above) are all greater than 1 and, thus, indicate that these pathologies are associated with increased risks of death in the pooled sample of both late Iron Age and Romano-British individuals. These results suggest that in both time periods, individuals with these pathologies were at higher risks of death than their peers without them. Furthermore, the estimated values of the parameter representing the effect of the time period covariate are positive for all pathologies analyzed (note, however, that for porotic hyperostosis and dental caries, the estimated value is not significantly different from zero). These results suggest that the excess mortality associated with stress markers was higher for individuals in the Romano-British sample than for late Iron Age individuals.

DISCUSSION

The age patterns of mortality within the late Iron Age and Romano-British samples, as revealed by the Siler model parameter estimates, suggest that Romanization had deleterious effects on the age groups that are typically the most vulnerable, i.e., very young children and the elderly. In the Roman world, these age groups were on the margins of society, because of the way age and gender hierarchies were structured over the life course, and bound up in legislation and public duties (Harlow and Laurence, 2002; Parkin, 2003). In addition to the well-established health risks of infancy (Kelmar et al., 1995), it has been proposed by the first author (Redfern, 2007) that the introduction of new settlement types increased mortality risk in this period, as evidenced by a lower burden of disease in the late Iron Age subadults and the lower mortality risk of the adult population in that period. Additionally, we also suggest that a change in cultural buffering, such as the use of wet-nurses, choice of weaning foods, and practices such as swaddling, put in place by many care givers, actually increased the risk of developing metabolic and infectious diseases during this period, as evidenced by the presence of these skeletal changes in the infant sample (Rawson, 2003; Redfern, 2007; Wiedemann, 1989). Although this study examines the consequences of Romanization at the broad regional view, it should be noted that subadult health in Roman Dorset shows considerable intercemetery differences, with the majority of those with evidence for disease buried at Poundbury Camp (Redfern, 2007; compare Lewis, 2010). Therefore, it is considered that the results obtained in this and other studies of health in Dorset underscore the nature and variability of Romanization in the region, and by extension Britain, reflecting both underlying cultural traditions, including childrearing choices, as seen today in societies where indigenous and Western/European practices co-exist (e.g., Abel et al., 2001), and also variations in population origin, settlement type, and living environment (Gowland and Redfern, 2010)

For older individuals during the Romano-British period, the primary sources such as censuses, legislation, letters, and dramatic texts allow us to understand the cultural factors beyond the normal processes of senescence (Masoro and Austad, 2001), which can influence mortality risk (Parkin, 1992; Scheidel, 2006). It is recognized that these sources are biased toward large urban Mediterranean communities and elite men; however, because individuals from the Mediterranean were buried in Dorset (Richards et al., 1998) and in the absence of evidence specific to Britain, they are used to provide an insight into factors potentially influencing male health outcomes in this study. Men over 45 "retired" from military service, and after the age of 60 their role as citizens changed because they were no longer able to vote, but were still expected to undertake their public duties and offices until roughly the age of 70. Those who were too poor or without family help had to support themselves and, thus, continued to work at late ages or became reliant on charity for survival (Parkin, 2003). Because of the male bias in primary sources, our knowledge of the lives of older women, especially those who lived without a family and were unable to support themselves, is very limited, leading Harlow and Laurence (2002:129) to conclude that, "without the resources or children to care for [them] once the infirmities of age arrived [women] probably did not survive for long."

The estimates of the parameter representing the effect of the sex covariate indicate that in the late Iron Age population, men and women did not differ significantly in their risks of mortality. This result conforms to status information derived from funerary evidence, which shows parity between the sexes in Dorset during this period (Hamlin, 2007). This, in turn, supports primary textual information about Iron Age communities, whereby women were active social agents, able to own property and other goods, and were not barred from positions of authority (Green, 1997). However, after the Roman conquest, men were apparently at significantly higher risks of dying than women. This finding questions many traditional and often implicit assumptions about Romanization and life in the Roman Empire, fundamentally that this cultural change and social environment would be more advantageous for men (Birley, 1964; Scheidel, 1996, 2006; Watts, 2005). It also identifies a mismatch between the Roman concept and ideal of maleness, masculinity, and corporeality, which ranked male status and bodies higher than those of females (Flemming, 2000; Foxhall and Salmon, 1998) and the realities of male health-statuses (compare Scheidel, 2009, 2010). Consequentially, the proposed cultural buffering afforded by having a male body in the Roman world (Foxhall and Salmon, 1998) may not have been sufficient protection, particularly for nonelite men against factors such as migration (forced and economic), hazardous male occupations (e.g., soldier or metalworker), and the nature of Roman/Romanized living environments (Birley, 1979; Scobie, 1986). Furthermore, this finding may potentially reflect differences in the nature of Romanization between locales (Gowland and Redfern, 2010; Keay and Terrenato, 2001; Laurence and Berry, 1998).

Other factors that may have influenced the higher risk for men include male risk-taking behavior, dietary differences, and underlying biological differences between the sexes. Clinical studies demonstrate that men are more likely to engage in risky activities, such as violence, that increase their mortality and morbidity risk (Courtenay, 2002; Wilson and Daly, 1985)—this aspect of male behavior is attested in the Roman world, particularly in military contexts (e.g., Baker, 2009). However, in post-conquest Dorset, the overall frequency of trauma decreases, although healed assault fractures (Johansen et al., 2008) and weapon injuries are present in a minority of male individuals who potentially may have been retired army veterans (Dobson, 1995; Mann, 2002; McKinley and Egging Dinwiddy, in press; Redfern, 2006, 2010). Therefore, we do not believe that violence played a significant factor in male mortality patterns in Roman Dorset (see Chamberlain, 2006).

Post-conquest, stable isotope evidence of dietary changes does not suggest that either sex was more privileged or that diet improved in such a way that enhanced underlying female biological advantages (Redfern et al., 2010); however, stable isotopes are not informative about the quantity or quality of foods eaten. No adults included in the first author's doctoral study (Redfern, 2006) showed evidence for osteomalacia or scurvy (Brickley and Ives, 2008), although the presence of cribra orbitalia and porotic hyperostosis may suggest that some adults continued to suffer from childhood dietary deficiencies (Walker et al., 2009).

Although sex differences in risk of mortality were likely multifactorial, we argue that the observed differences in risk were strongly influenced by underlying biological differences between the sexes, such as enhanced female immune response, increased male environmental sensitivity, and genetic differences that lead to the sexes showing variations in disease prevalence and severity, particularly with respect to infectious disease (Langley, 2003; Ortner, 1998; Stinson, 1985). Such biological advantages may have provided women with a buffer that was sufficient enough for them to more successfully adapt to Romanization in Dorset, despite the cultural buffering suggested to exist for men in the Roman world (Stinson, 1985). This hypothesis is supported by the funerary, dietary, and wider health data indicating that female status in Dorset did not decline under Roman rule (Hamlin, 2007; Redfern, 2006; Redfern et al., 2010), as has been suggested by many authors (Allason-Jones, 2005; Watts, 2005).

The results of the χ^2 analyses of the differences in the frequency of various pathologies failed to reveal a consistent pattern of changes in these health markers from the late Iron Age to Romano-British period. However, the results from analyses using the Usher model are more informative about health patterns in the two populations. The k_2 estimates (i.e., the excess mortality associated with skeletal pathologies) for all pathologies analyzed using the Usher model (i.e., cribra orbitalia, porotic hyperostosis, periosteal lesions, enamel hypoplasia, and dental caries) are greater than 1. These results indicate that individuals in both the late Iron Age and Romano-British samples with these skeletal pathologies were at elevated risks of death compared with their peers without them. These results are consistent with findings from previous studies, using the same model, that such pathologies are informative about frailty (DeWitte and Bekvalac, 2010; DeWitte and Wood, 2008).

As shown in Table 5, the estimates of the parameter representing the effect of the time period covariate for cribra orbitalia, periosteal lesions, and enamel hypoplasia are significantly different from zero. The positive estimated values of the covariate effect indicate that the excess mortality associated with these pathologies was even higher for individuals in the Romano-British sample compared with the late Iron Age sample. These results suggest that previous physiological stress increased the risk of death for individuals after the Roman conquest to a greater extent than was true before it. Late Iron Age individuals might have been less frail and, thus, able to resist death better than Romano-British individuals, despite development of skeletal pathologies in response to physiological stressors. We suggest that this finding reflects their pre-urban living conditions, particularly the low density of settlements, a smaller and less mobile population, parity in cultural buffering between the sexes, and better health during childhood.

It should be noted that the survival of a greater proportion of a population to later ages and, thus, the accumulation of more age-associated skeletal pathologies could potentially elevate the estimates of the excess mortality associated with some pathologies. This could occur if the risk of death associated with these pathologies was higher for older adults than for younger individuals. For this study, we used the proportional hazards specification, where k_2 is a proportional term on the baseline mortality function and is, thus, independent of age. By using the proportional hazards specification, we did not explicitly examine whether, within each sample, the excess mortality with pathologies varied with age. It is possible that such variation with age does occur, and that is a phenomenon that deserves further study. However, this is beyond the scope of this study given that it would require much larger sample sizes for each pathology (because of the addition of parameters that this type of analysis would necessitate) than we currently have available. We are confident, however, that such a possible effect does not explain the difference observed between the Iron Age and Romano-British samples used for this study because there is actually a higher proportion of adults over the age of 20 (particularly in the 50+ age category) in the Iron Age sample compared with the Romano-British sample.

The greater difference in the risks of death between those with and without skeletal pathologies in the Romano-British sample compared with the late Iron Age sample might indicate that disparities in health within the population increased after conquest. This might, in turn, suggest that Romano-British individuals were frailer, on average, than late Iron Age individuals. The reasons for this increase in frailty we consider to be multifactorial and derive from three main sources: living environment, migration, and social status. The introduction of urban settlements, increase in population density, and new living environments would have impacted health, because these changes would have altered the type and degree of exposure to environmental stressors and, because of greater population density in settlements, increased the ability of diseases to be transmitted and to thrive (MacMahon and Price, 2005; Scheidel, 2010; Storey, 1992, 2006). It should also be noted that post-conquest, an additional influence on frailty would have been a change in the quality and size of living environment with greater evidence for status differences in housing in terms of size, construction materials (stone vs. wood), and the use of plumbing/sanitation.

We suggest that the apparent increased level of frailty in the Romano-British period also reflects a rise in population heterogeneity. The small number of carbon and nitrogen stable isotope studies from Iron Age Britain shows that their diets relied on local food contributions, and it is considered that this reflects a population that was not highly mobile and did not contain many (if any) individuals from outside the United Kingdom, despite accessing continentally derived food and material culture (Jay, 2006, 2008; Jay and Richards, 2007; Redfern et al., 2010). Currently, only one faunal study has published strontium isotope data from Britain, and this raises the possibility for greater human mobility than expected. Bendrey et al.'s (2008) pilot study of horse remains in southern Britain identified locally bred animals but also one horse that potentially could have traveled from Wales, Scotland, or Continental Europe.

Post-conquest, Britannia became home to people from all over the Empire, as attested by material culture, stable isotopes, and epigraphic evidence (i.e., Adams and Laurence, 2005; Birley, 1979; Leach et al., 2009). Exposure to new environments and to people and products from other regions increases the risk of exposure to diseases and parasites that have never before been encountered (McMichael, 2004). Individuals native to Britain could have been immunologically naïve and, thus, at elevated risk of morbidity and mortality from pathogens brought by immigrants to Britain, and similarly, the new immigrants to Britain were exposed and potentially vulnerable to pathogens to which they were immunologically naïve. An exchange of pathogens might have increased frailty in the post-conquest population of Britain. Further, people who migrated to Britain might have been adapted to different environmental conditions elsewhere in Europe, and once living in Britain, they might not have been as well adapted to the new environment and suffered increased risks of morbidity and mortality as a result.

In Dorset, stable isotope evidence from Poundbury Camp has identified people from the Mediterranean, and dietary analysis shows that multiple food-ways existed, supporting the limited isotope evidence for migration (Redfern et al., 2010; Richards et al., 1998) and potentially suggests that frailty may also be linked to dietary practices. Dietary data also shows evidence for status differences in food consumption, with the higher-status individuals buried in mausoleums at Poundbury Camp having greater quantities of marine resources in their diet (Richards et al., 1998). Importantly, this pattern has yet to be established in other cemeteries in the region (Redfern et al., 2010), and, therefore, the extent to which status, as evidenced through diet, influenced frailty in Roman Dorset is not clear. If in the Romano-British population, diet varied by social status to a greater degree than in the Iron Age population, this could have increased the differences in general health between those with and without access to certain foods in the post-conquest population. Differential access to certain foods might have made the individuals with limited access even more vulnerable to death after physiological stress than they would have been under the conditions existing in the Iron Age population. This would increase the differences in risk of death between those with and without skeletal pathologies in the Romano-British sample compared with the Iron Age sample. Unfortunately, it was not possible to test the relationship between frailty, diet, and funerary status in this study because the number of individuals with stable isotope results was too small to be measured. In Roman Dorset, the increase in population mobility, combined with the creation of new settlement types, introduction of new foods, and the adoption and hybridization of Roman culture could all have contributed to increased frailty heterogeneity.

In addition to clarifying the consequences of Romanization in Britain, the results of our analyses contribute to an understanding of the health effects of major societal transitions in general. Romanization seems to have negatively impacted health, and negative effects on general levels of health within populations have also been observed in societies that made the transition from foraging to sedentary agriculture (e.g., Cohen and Armelagos, 1984; Keita, 2003; Oxenham et al., 2005; Papathanasiou, 2005; Starling and Stock, 2007) and those that experience urbanization and industrialization (e.g., Armelagos et al., 2005; Lewis, 2002; Lewis and Gowland, 2007; Mays et al., 2008; Nagaoka and Hirata, 2007; Saunders and Keenleyside, 1999; Schell, 1991).

CONCLUSIONS

To understand the health consequences of Romanization, we used the Siler and Gompertz–Makeham models of mortality for data derived from the only region of Britain to show archeological continuity from the late Iron Age to the end of the Roman period, using a population that had not been subject to client-kingdom status in the late Iron Age and, therefore, had little to no contact with Roman culture before the Claudian conquest in 43 AD (Creighton, 2000; Cunliffe, 2005). The results of the study conformed to the findings of previous studies by the first author, which could not identify risk, but did observe a post-conquest decline in health, particularly for subadults, which was considered to relate to cultural change, migration, and the introduction of urban environments (Redfern, 2006, 2007, 2008b). The results of this more nuanced study have enhanced these conclusions and raised five important findings: it supported other funerary and bioarcheological evidence for parity between the sexes in the late Iron Age Durotriges tribe; demonstrated that Romanization negatively impacted health; showed that subadults and older adults were more vulnerable to the Romanized living environment; provided further data indicating that female status did not decline in Roman Dorset; and for the first time in Romano-British studies, statistically established that men had a higher risk of morbidity and mortality in this period, a finding that conflicts with many perspectives on life in the Roman Empire (e.g., Scheidel, 1996).

In conclusion, we consider that the detrimental health impacts on the late Iron Age communities in Britain were primarily caused by the introduction of new settlements and living environments, and the adoption of "Roman" cultural practices. Our findings suggest that the impact of Romanization on these and other communities in the Empire were not limited to the period of conquest and colonization, but continued throughout the time of incorporation, reflecting the diverse environments and ways in which people experienced the Roman world.

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