– ARTICLE –

Skeletal and Dental Health: the bioarchaeology of the human skeletons from the Sigatoka Sand Dunes Site, VL 16/1, Viti Levu, Fiji

Michael Pietrusewsky,[1] Michele Toomay Douglas,[2] & Rona M. Ikehara-Quebral[3]

ABSTRACT

In this paper, we examine the health, diet, and lifestyle of the early inhabitants of Fiji using non-specific and specific indicators of health recorded in 42 adult and six subadult skeletons excavated at the Sigatoka Sand Dunes site, VL 16/1, on Viti Levu, one of the largest samples of prehistoric skeletons from Fiji. Because the dates of the Sigatoka cemetery may coincide with contact with later intrusions of people from regions located to the west of Fiji, our research has the potential to inform on the health of prehistoric Fijians during a time of potential stress. Limited comparisons with skeletal series from Remote Oceania for understanding the health of the early inhabitants of tropical Pacific Islands are also made. This is the first study that focuses exclusively on the health of the people interred in the Sigatoka cemetery. With some notable exceptions, few differences were observed in comparisons of skeletal and dental indicators of health in adult males and females from Sigatoka, differences that can be attributed to gender-related cultural practices (e.g., kava use in males), dietary differences, and age. Regional comparisons indicate the early inhabitants of Fiji were relatively healthy and robust people. Unexpectedly, no evidence of yaws was found in the Sigatoka skeletons, a disease that was highly prevalent in Fiji and the western Pacific when the first Europeans arrived. Limited observations of deciduous dental pathology indicate good health *in utero* and during infancy.

Keywords: Bioarchaeology, dental pathology, deciduous dental pathology, indicators of health, Fiji

INTRODUCTION

The Sigatoka Sand Dunes, encompassing more than 6.5 km², are located at the mouth of the Sigatoka River on the southwestern coast of Viti Levu, Republic of Fiji (Figure 1). The dunes, the highest and most extensive in tropical Remote Oceania, have formed through long-term erosion of iron sands from the inland slopes of the Sigatoka River Valley and coastal dune forming processes (Dickinson 1968; Dickinson *et al.* 1998). Extensive erosion of the dunes' shoreline in the last half century has exposed a rich archaeological record, prompting intense archaeological and geological investigations that began in the mid-1960s (e.g., Best 1989; Birks 1973; Burley 2005; Dickinson *et al.* 1998). The extensive Sigatoka Dunes archaeological site VL 16/1 occupies an approximately 1 km section of the shoreline in the eastern end of the dune at the mouth of the Sigatoka River, approximately 3 km west of the town of Sigatoka. The site, which includes one of the largest burial sites (N = 52) in the Pacific, encompasses a complex series of cultural deposits representing the main phases of Fijian culture history from approximately 2700 years BP to historic times (Burley 2003). Three distinct occupational layers have been identified for the VL 16/1 site. Level 1, which corresponds to the lower Lapita layers of the site, dates to approximately 2800–2600 cal yr BP (Anderson *et al.* 2006; Petchey *et al.* 2011). Level 2 occupation (Navatu Phase) dates from 1700 to 1300 cal yr BP with several paleosols between the two (Anderson *et al.* 2006; Petchey *et al.* 2011). Radiocarbon dates for Level 3 (Vuda Phase) converge in the 600–500 cal yr BP range (Anderson *et al.* 2006: 147).

SKELETAL RECORD AND BIOARCHAEOLOGY FOR FIJI

There are very few archaeological sites in Fiji that contain human skeletons. With the exception of a single poorly preserved skeleton from Naitabale on Moturiki Island (Nunn *et al.* 2007), which most likely has a post-2650 cal yr BP date, or Late Lapita (Petchey *et al.* 2011: 11), most of the human skeletons from Fiji date to the post-Lapita pe-

1 Department of Anthropology, University of Hawai'i at Mānoa, 2424 Maile Way, Saunders 346, Honolulu, Hawaii 96822–2223 USA

2 Department of Anthropology, University of Hawai'i at Mānoa, 4020 Edgehill Road, Fort Worth, TX 76116–7325 USA

3 International Archaeological Research Institute, Inc. 2081 Young Street, Honolulu, Hawaii 96826–2231 USA

Corresponding author: mikep@hawaii.edu

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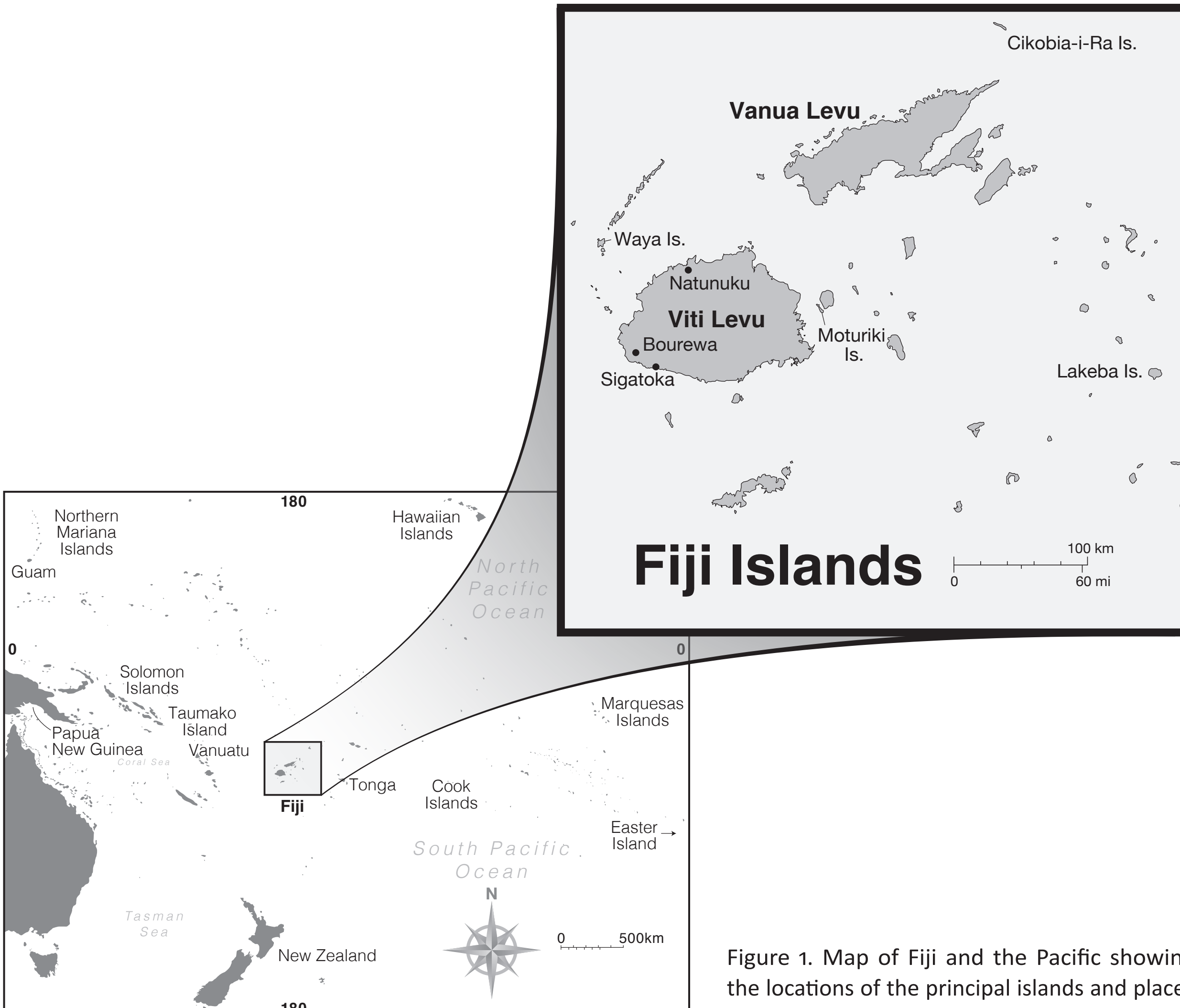

Figure 1. Map of Fiji and the Pacific showing the locations of the principal islands and places mentioned in the paper.

riod (Table 1). A few of the remaining skeletons from Fiji are immediately post-Lapita in age while others are much more recent. With the exception of the Sigatoka VL 16/1 site, the number of skeletons represented in archaeological sites from Fiji is generally restricted to a single individual. In addition to the scarcity of individuals represented, the skeletal remains from Fiji are often incomplete and poorly preserved. With some exceptions, previous studies of Fijian skeletons provided limited and often incomplete data on the health and lifestyle of prehistoric Fijians. Earlier studies of human skeletal remains from Fiji focused on mortuary and burial practices (e.g., Cochrane *et al.* 2004; Pietrusewsky *et al.* 2007; Valentin *et al.*, 2001), cannibalism (e.g., DeGusta 1999, 2000; Jones *et al.* 2015), reconstruction of paleodiet (e.g., Field *et al.* 2009; Jones and Quinn 2009, Phaff *et al.* 2016; Stantis & Buckley *et al.* 2016; Valentin *et al.* 2006), and biodistance studies (e.g., Pietrusewsky 1985, 1989, 2010). We briefly summarize the isotope studies for Fiji when we introduce the Sigatoka Sand Dunes burials. The Sigatoka Sand Dunes burials constitute one of the largest samples of prehistoric human skeletons from Fiji that provide direct biological evidence of the lives of the post-Lapita inhabitants.

Objectives

Using non-specific and specific indicators of health recorded in 1992 in adult skeletons excavated in 1988 and 1989 from the VL 16/1 site in the Sigatoka Sand Dunes site, Viti Levu, Fiji, we assess the health, diet, and lifestyle of the early inhabitants of Fiji. Although the emphasis of this paper is adult health, we also provide limited information on a small sample of subadult skeletons from the Sigatoka Sand Dunes. Because the dates of the Sigatoka cemetery may, according to Best (1987: 13, 1989: 63), coincide with contact with later intrusions of people from regions located to the west of Fiji, our research has the potential to inform on the health of prehistoric Fijians during a time of potential stress. In addition to examining whether differential health patterns exist between males and females

Table 1. *Archaeological sites in Fiji with human skeletons.*

Site	Location	No.	Date	Reference
Sigatoka (VL 16/1)	Viti Levu	52	1700–1300 BP	Anderson *et al*. 2006; Pietrusewsky *et al*. 1994; this study
Naitabale	Moturiki Is. Fiji	1 adult female	post 2650 cal BP	Kumar *et al*. 2004; Nunn *et al*. 2007; Petchey *et al*. 2011: 11
Olo (Burial Y2–25–1)	Waya Is., Fiji	1 adult male	2440–2330 cal BP	Pietrusewsky, Hunt, & Ikehara-Quebral 1997; Petchey *et al*. 2011
Qaranipuqa (Site 197)	Lakeba, Lau Group, Fiji	fragments	2290–2100 cal BP	Best 1984; Petchey *et al* 2011
Navatu (Site 17)	North coast Viti Levu	midden	2000–50 BP	Gifford 1951; DeGusta 1999
Natunuku (VL1/1)	Viti Levu, Fiji	1 adult male	1896 ± 85 BP	Davidson & Leach 1993; Pietrusewsky 1989
Naselala	Cikobia-i-Ra Island, northeast Fiji	1 adult	1730 ± 40 BP	Valentin *et al*. 2008
Sigatoka Valley (7 sites)	Viti Levu	primary and secondary burials	1350–150 BP	Kyle *et al*. 2009
Vunda (Site 26)	Western Viti Levu	midden	1150–350 BP	Gifford 1951; DeGusta 2000
Qaranicagi Site (Y2–39)	Waya Is., Fiji	1 adolescent	720–670 cal BP	Cochrane *et al*. 2004; Pietrusewsky *et al*. 2007
Bourewa	Southwest Viti Levu, Fiji	~25	750–0 BP[1]	Nunn *et al*. 2004; Nunn & Petchey 2013
Wakea (Site 196)	Lakeba, Lau Group, Fiji	1 adult male	530–450 cal BP	Best 1984; Houghton 1989; Petchey *et al*. 2011

1. Although the earliest occupation at the Bourewa site began at least 2800 BP and ended ca 2500 BP, the burials are from a later (intrusive) period.

from the Sigatoka Sand Dunes site, we make limited comparisons with skeletal series from Remote Oceania (Polynesia, Micronesia, and islands of eastern Melanesia) to increase understanding of the health of early inhabitants of tropical Pacific Islands. This is the first study that focuses on the health of the people buried in the Sigatoka cemetery.

SIGATOKA SAND DUNES SKELETONS

Simon Best excavated the human skeletons examined in this study in 1987 and 1988 as part of an archaeological conservation project (Best 1987, 1989). The burials are from a series of low coral mounds eroding out of the Sigatoka Sand Dunes site, VL 1/16, located at the eastern extent of the dunes on the south coast of Viti Levu, Fiji. The majority of the burials were interred in twenty coral rock cairns, several with multiple interments, while others were scattered within and around the perimeter of the main cemetery without cairns. The differential size and elaboration of the cairn-burials, their position in the dunes, and associated material culture suggest the cemetery had been used over a period of time by a highly stratified society (Best 1989; Burley 2005). The apparent hierarchical ranking of the burials at this site further indicates the possibility that many of the individuals buried in the Sigatoka dunes were related during life (Best, 1989). Likewise, according to Best, cairns with multiple interments laid side-by-side may represent a single burial event associated with a high-ranking individual, implying not all deaths were due to natural causes and many of those buried at the site were put to death because of their relationship with another individual (Best 1989: 53–54). Multiple simultaneous fatalities could also be the result of epidemics, accidents, natural disasters, warfare, mass murders, or ritualized killings. Ritualized killing of wives and/or other individuals (e.g., mothers, servants etc.) who had a special relationship to the deceased during life has been documented historically in Fiji (Patterson 1817; Wallis 1851; Wilkes 1845; Williams 1858, 1982).

The Sigatoka burials have been attributed to Level 2 occupation (Navatu Phase) of the VL 1/16 site whose radiocarbon dates extend from 1700 to 1300 cal BP (Anderson *et al*. 2006; Petchey *et al*. 2011). Burley's later excavations at the Sigatoka Sand Dunes suggested the presence of two discrete and superimposed settlements within Level 2, Fijian Plainware (ca.1750 to 1550 BP) and Navatu (ca. 1500 to 1400 BP) Phases, respectively (Burley 2003, 2005). Burley further maintains the transition to the Navatu Phase occurred rapidly, suggesting the arrival or influence of a new people from central Melanesia (Vanuatu-New Caledonia) and that the Plainware community was responsible for the main cairn burial cemetery at Sigatoka (Burley 2003, 2005). Clark (2009), however, has questioned the sharpness of the ceramic differences described by Burley for the Plainware and Navatu Phases and also his contention that the Navatu assemblages were the result of ceramic influences from central Melanesia. Attempts to obtain additional dates from the human skeletons from this site have proven unsuccessful and an earlier date for one of skeletons, Burial FC1, has now been questioned (Petchey *et* *al.* 2011). Although there are uncertainties concerning the radiometric dates for the Sigatoka skeletons and different ceramic chronologies proposed for Sigatoka and Fiji, the burials examined in this paper are associated with median ages that extend from 1700–1300 cal yr BP (Anderson *et al.* 2006). Others (e.g., Burley 2003, 2005; Marshall *et al.* 2000: 71) suggest a slightly more compressed age (1750–1550 BP) for the Sigatoka burials.

The Sigatoka burials were flexed, some tightly, and oriented east/west with heads to west. With the exception of two burials that were placed on their sides, all burials were supine. Associated cultural materials were identified for a few of the burials from the largest and highest mounds in the cemetery. For example, a small greywacke adze on top of a conus-shell armband and a perforated cowrie shell were located to the west of Burial 10A (Best 1989: 35). According to Best (1989), a total of fifty-five burials were recovered from the cairn burial cemetery. Five more burials, recovered outside the main cemetery, are not included in this study (Best 1987: 6). Likewise, burials recovered from the Sigatoka dunes after Best's excavations (e.g., Burley 1997; Crosby 1991; Hudson 1994; Marshall *et al.* 2000) are not included in this study.

Previous Studies of Sigatoka Sand Dunes Skeletons

Previous studies of the Sigatoka skeletons are restricted to an unpublished doctoral thesis (Visser 1994a), a short paper on kava use (Visser 1994b), a technical report (Pietrusewsky *et al.* 1994), studies that examine biological relationships (Pietrusewsky 1993, 2010; Visser and Green 1999), and a study of dietary and mobility patterns based on isotope analysis of human and faunal material from the Sigatoka Sand Dunes (Phaff 2012; Phaff *et al.* 2016). Biometric analysis of the most complete and best-preserved male crania from the Sigatoka cemetery demonstrated biological affinities with cranial series from western Remote Oceania (e.g., New Caledonia, Loyalty Islands, and Vanuatu) and Australia, suggesting post-Lapita intrusions of people from regions of Near and Remote Oceania located to the west of Fiji by the third century AD (Pietrusewsky 2010).

Isotopic Studies of Sigatoka Sand Dunes and Fiji

Stable isotope studies of human and faunal (non-human) skeletal and dental remains from Fiji are summarized in this section. The isotopic samples were obtained from numerous archaeological sites on Viti Levu, Waya Island, Cikobia Island, and the Lau Group. These studies provided the baseline isotopic data used to reconstruct dietary practices and analyze social relationships in ancient Fiji. None of these studies identified any sex difference in diet.

At the Sigatoka Sand Dunes site, the analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopes in bone collagen from 22 human and nine faunal samples from the Fijian Plainware phase (1435–1300 cal BP) indicated a mixed diet high in C_3 plants, but with a key marine component (Phaff *et al.* 2016: 680). C_3 plants such as taro were a staple food source throughout Fiji based on ethnographic data (Phaff *et al.* 2016: 684). Many of the Sigatoka individuals buried in elaborate coral rock cairns tended to have higher carbon values than the simple pit burials or limited coral rock features, suggesting cairn individuals had a greater access to marine foods. At least 25 per cent of protein consumption at Sigatoka appears to have derived from marine sources likely foraged from sites 2–5 km away due to unsuitability of reef foraging/fishing and limited shell midden in occupational refuse, suggesting a social and economic network existed between neighboring communities (Phaff *et al.* 2016: 685, 687). According to Burley (2003: 312), the faunal remains associated with the Sigatoka Sand Dunes sample included shellfish, fish, terrestrial birds, bat, sea turtle, rat, pig and chicken, which denote a horticultural-based village occupation not unlike that associated with traditional villages in Fiji today. Isotopic analysis revealed that the diet of the sampled fauna did not match their human consumers, suggesting humans had a varied diet from multiple food sources including terrestrial and marine environments (Phaff *et al.* 2016: 684).

In bone collagen sampled from nine late prehistoric/early historic (*ca.* AD 1850) burials from the Korotuku burial mound, Cikobia Island, northern Fiji, $\delta^{13}C$ and $\delta^{15}N$ values overlap with Sigatoka Sand Dunes values (Phaff *et al.* 2016: 685). Carbon analysis revealed marine fish contributed to 25 per cent of the dietary protein at Cikobia with a significant reliance on C_3 plants (Valentin *et al.* 2006: 1406). Isotopic analysis of a canid sample indicated a diversified range of food resources was available, suggesting cultural values influenced a more focused food selection for humans that may further signify social stratification (Valentin *et al.* 2006: 1406). Some of the Sigatoka Sand Dunes individuals buried in cairns had relatively elevated levels of marine proteins in their diet compared to individuals buried at Cikobia (Phaff *et al.* 2016: 685).

Isotopic analysis was conducted on bone collagen and bone apatite from nine prehistoric human samples and 15 faunal samples from various archaeological sites in the Lau Group, Fiji, with dates ranging from 2760–2700 cal BP to 540–420 cal BP (Jones & Quinn 2009). Results indicated a C_3 plant-based diet comprising 60–70 per cent of the total diet with reef resources (i.e., reef fish, reptiles, and marine shellfish) comprising the remaining 30–40 percent (Jones & Quinn 2009: 2748–2749). Zoological and ethnographic data suggested this diet was supplemented by diverse inshore marine foods, which would have buffered the Lau groups during climate change affecting marine resources (Jones & Quinn 2009: 2753). Of the isotopic data derived from human bone collagen samples for Fiji, the Sigatoka Sand Dunes $\delta^{13}C$ (-16.3±0.9‰) and $\delta^{15}N$ (9.3±0.6‰) mean values are most similar to the Lau Group ($\delta^{13}C$=-16.3±1.4‰; $\delta^{15}N$=9.4±0.8‰).

Field *et al.* (2009: 1550) analyzed 26 isotopic samples from western Fiji, including prehistoric bone collagen sampled from midden and burials from Waya Island (14 human and 3 faunal samples) and fortifications in the Sigatoka Valley (3 human and 2 faunal samples), and four modern fish samples. Results highlighted a geographic trend that Waya Island groups living in coastal areas on smaller islands had a primarily marine-based diet throughout 2000 years of prehistory, which persisted despite a (likely gradual) shift to incorporate more terrestrial foods over time. Although based on a small Sigatoka sample, the Sigatoka Valley groups living on the larger islands had a more terrestrial-based diet (*ca.* 1500 BP), which was relatively stable for 900 years (Field *et al.* 2009: 1554–1555).

Bourewa is a multi-period site on the southwest coast of Viti Levu, approximately 25 km to the west of Sigatoka. Isotopic analysis of bone and tooth collagen sampled from 25 individuals from the later Vudu Phase (750–150 BP) indicated marine organisms from lower trophic levels (e.g., inshore and reef environments) were a major dietary component at Bourewa, with a lesser reliance on terrestrial plants and/or mangrove fish in the adult diet compared to childhood diets (Stantis & Buckley *et al.* 2016: 491). Strontium ($^{87}Sr/^{86}Sr$) ratios suggested one individual, who had the lowest ratio in the assemblage, may have spent her childhood inland, while two other individuals spent their childhood elsewhere but in an environment similar to the Bourewa inhabitants. Compared to other prehistoric samples from Fiji and the Pacific, Bourewa individuals had a relatively greater reliance on marine foods.

Mean values of the human isotopic data for carbon and nitrogen are most similar between the Sigatoka Sand Dunes and the Lau Group samples, with a diet high in C3 plants supplemented by marine foods. There were no significant differences in isotope values between males and females. Isotopic studies revealed considerable dietary diversity in Fiji and neighboring Pacific Islands, even between the two Sigatoka sites, possibly due to environmental, geographical, and temporal differences (see Stantis & Buckley *et al.* 2016: 488–489) but it is beyond this paper's scope to expand this discussion to the broader Pacific region. Kinaston & Buckley (2013) provide an overview of the variable isotope results from the Pacific region, and call for more site-specific isotopic baseline data for the Pacific Islands.

SKELETAL SAMPLES

Sigatoka Sample

Although the number of individuals differs slightly for each category of data used in this study, the total number of adult skeletons used in this study is 42 (Tables 2 & 3). The number of male and female skeletons is nearly identical. The majority of the individuals were middle-aged (35–49.9 years) at the time of their deaths. We further report limited information on the dental remains of six subadults (aged 1–11.9 years) in this study. The age distribution of the deciduous tooth sample is summarized in Table 4. Due to unknown sex and/or lack of data the remains of two adults and two individuals aged between newborn and 0.9 years were not included in this study. More detailed information on the Sigatoka skeletons is provided in Pietrusewsky *et al.* (1994).

Preservation and Treatment of the Sigatoka Skeletons

Because of the fragile and moist condition of the human skeletons, the excavators applied several layers of a water-based *acrylic* adhesive (Acrylic WS-24) to these remains prior to lifting and transport (Best 1989: 16). In the laboratory (Department of Anatomy of the University of Otago Medical School), a solvent spray and careful mechanical brushing and picking were used to remove this preservative and adhering sand and soil. After cleaning, additional preservatives were applied to stabilize the bones. Preparation of the human skeletal and dental remains was undertaken by Mr. Edward Visser in the Department of Anatomy at the University of Otago Medical School in Dunedin, New Zealand prior to the examination of the Sigatoka skeletons in 1992 by Pietrusewsky and Douglas.

Skeletal preservation and completeness was affected by the continuously wet sand conditions as well as the significant weight of the overlying dune and the coral rock mounds, often resulting in crushing of the cranium. Preservative applied in the field fixed sand in the apertures, foramina, etc., and often necessitated excavation *en block* of hands, feet, ribs, and subadult remains, affecting the quantity and quality of observations. Often the cancellous portions of the long bones and the vertebrae were degraded or missing.

Comparative Samples

The comparative series used in this study are from Remote Oceania, including Polynesia, the Mariana Islands, and Taumako Island in the southeastern Solomon Islands (Table 5, Figure 1). Five of the eleven series compared were

Table 2. *Age and sex distribution of adult skeletons from the Sigatoka Sand Dunes used in this study.*

Age (years)	Male	Female	Total
Adolescent (15–19.9)	2	0	2
Young (20–34.9)	3	1	4
Mid-aged (35–49.9)	8	15	23
Old (50+)	6	6	12
Adult	1	0	1
Total	**20**	**22**	**42**

Table 3. *Age*[1] *and sex of the individual data recorded in the adult skeletons from the Sigatoka Sand Dunes.*

	Adol.	Young	Mid-aged	Old	Adult	Total
LEH[2]-M[3]	2	3	7	6	0	**18**
LEH-F[4]	0	2	13	6	0	**21**
LEH-Total (M+F)	**2**	**5**	**20**	**12**	**0**	**39**
CO[5]-M	0	3	6	2	0	**11**
CO- F	0	2	4	3	0	**9**
CO-Total (M+F)	**0**	**5**	**10**	**5**	**0**	**20**
Fracture[6]-M	0	3	7	6	1	**17**
Fracture-F	0	2	13	6	0	**21**
Fracture-Total (M+F)	**0**	**5**	**20**	**12**	**1**	**38**
Spondylolysis-M	0	2	7	6	1	**16**
Spondylolysis-F	0	2	8	3	0	**13**
Spondylolysis-Total (M+F)	**0**	**4**	**15**	**9**	**1**	**29**
Osteoarthritis[7]-M	0	3	8	6	1	**18**
Osteoarthritis-F	0	2	12	6	0	**20**
Osteoarthritis-Total (M+F)	**0**	**5**	**20**	**12**	**1**	**38**
Dental pathology-M	2	3	7	6	0	**18**
Dental pathology-F	0	2	13	6	0	**21**
Dental pathology-Total (M+F)	**2**	**5**	**20**	**12**	**0**	**39**

1. See Table 2 for explanation of age categories.
2. LEH = Linear enamel hypoplasia.
3. M = Male
4. F = Female
5. CO = Cribra orbitalia.
6. Fractures in the postcranial skeleton.
7. Osteoarthritis in the postcranial skeleton.

Table 4. *Age distribution of the Sigatoka Sand Dunes deciduous tooth sample.*

Age[1] (Years)	Total Sample	
	Individuals	Teeth[2]
<1	0	0
1–2.9	1	20
3–3.9	0	0
4–5.9	2	39
6–7.9	2	29
8–9.9	0	0
10–11.9	1	3
Total	**6**	**91**

1. Placement in age interval is based on individual's mean age estimate.
2. Includes teeth observed as present, root only, erupting, or unerupted.

examined by Pietrusewsky and/or students trained by him. Although dating of some of the comparative series may now be in doubt, the majority of the series represent pre-contact era skeletons that date between 1000 and 500 years BP. The absence of artifacts indicating European contact for the majority of these samples strengthens this assertion.

METHODS

The methods used to determine age-at-death and sex follow those described in Buikstra and Ubelaker (1994) and Pietrusewsky and Douglas (2002). Non-specific indicators of health (e.g., LEH, cribra orbitalia, stature), which are acquired during growth and development, and more specific indicators (e.g., trauma, infection, dental disease) are examined in this study. Because sample sizes are small, Fisher's Exact Test (FET) was used to test for statistical significance of frequency data (Thomas 1986).

Stature

It is now recognized that a strong correlation exists between adult stature and the suppression of growth in childhood due to poor environmental conditions such as malnutrition and disease (Larsen 2015). Individuals who are adequately nourished during childhood tend to achieve their growth potential while those who are subjected to inadequate diets often do not. While not as universal, differences in adult stature have also been correlated with changes in subsistence patterns and the genetic background of individuals (Bogin 2001).

The maximum lengths of the major long limb bones were recorded using an osteometric board following standard procedures (Buikstra & Ubelaker 1994). Given

Table 5. *The main comparative skeletal series used in this study.*

Skeletal Series	Location	Size	Dates (BP[1])	References
Bourewa	Southwest Viti Levu, Fiji	~25	750–0 BP[2]	Nunn *et al*. 2004; Nunn & Petchey 2013; Stantis & Buckley *et al*. 2016; Stantis & Tayles *et al*. 2016
'Atele (To-At-1 & To-At-2)	'Atele, Tongatapu, Tonga	99	ca. 460–0 cal BP[3]	Pietrusewsky 1969; Buckley 2016; Stantis *et al*. 2015; Stantis & Tayles *et al*. 2016
Rima Rau	Atiu Island, Southern Cook Islands	42	Pre-/Proto Historic	Stantis & Tayles *et al*. 2016
Toruapuru Cave	Mangaia, Southern Cook Islands	40	pre-173 BP	Katayama 1988
Hane	Hane Dune, Uahuka, Marquesas Islands	42	*ca*. 950–350 BP	Pietrusewsky 1976; Conte & Molle 2014; Sinoto 1970
Honokahua	Maui, Hawaiian Islands	712	pre-172 BP	Pietrusewsky *et al*. 1991; Pietrusewsky & Douglas 1994
Easter Island	Ahu Tepeu, Ahu Hekii & Vinapu, Easter Island	33	850 – 80 BP	Murrill 1968
Wairau Bar	North Coast, South Island, New Zealand	~42	*ca*. 662 – 650 BP	Buckley *et al*. 2010
Apotguan (Apurguan)	Guam, Mariana Islands	152	950 – 429 BP	Pietrusewsky *et al*. 2003; Douglas *et al*. 1997
Mariana Islands	Guam Rota, Tinian, & Saipan Islands	333/385	Latte Period 1050 – 250 BP	Pietrusewsky, Douglas & Ikehara-Quebral 1997; Pietrusewsky *et al*. 2014, 2016
Taumako	Duff Islands, S.E. Solomon Islands	~190	750 – 450 BP	Leach & Davidson 2008; Buckley 2016

1. BP = Years Before Present (before AD 1950).
2. Although the earliest occupation at the Bourewa site began at least 2800 BP and ended *ca*. 2500 BP, the burials are from a later (intrusive) period.
3. Although recent recalibration of AMS dates indicates the 'Atele burial mounds were in use *ca*. 460–0 cal BP during the Chiefdom Period in Tonga (*ca*. 750–150 BP), mound use 150–0 BP (early historic period) is unlikely, based on no recollection of the burials by the Keeper of the Palace Records at the time and present-day villagers in the vicinity, and absence of artifacts indicating European contact (Stantis *et al*. 2015:2-3).

the absence of Fijian formulae, regression formulae for New Zealand Maori (Houghton *et al*. 1975) were used to estimate adult stature. If more than one stature was estimated, the estimate having the least error was the one used. Only complete bones were used to estimate stature.

Linear Enamel Hypoplasia (LEH)

Linear enamel hypoplasia (LEH), observable as one or more transverse lines or grooves of varying depths on the crown surfaces of teeth, is generally linked to the disruption of enamel development during infancy and early childhood (Goodman & Rose 1990, 1991). A variety of stressors, including malnutrition, metabolic disorders, acute and chronic infections, physical trauma, and hereditary conditions that affect the mother and/or growing child can disrupt enamel production (Goodman & Rose 1990, 1991; Goodman *et al*. 1984; Hillson 2008). Because defects are more frequent in the incisors and canines than in the other teeth, we report any manifestation of LEH, regardless of the number of defects or their severity, for canines and incisors on a per tooth and per individual basis.

Cribra Orbitalia (CO)

Cribra orbitalia (CO), are sieve-like lesions observed in the orbital roof. The condition, which results from an increase in red blood cell production, is commonly attributed to iron deficiency anemia resulting from nutritional deficiencies, especially during early childhood, infectious diseases, gastrointestinal parasitic infections associated with infant diarrheal disease, as well as hereditary hemolytic anemias (Larsen 2015; Oxenham & Cavill 2010; Stuart-Macadam 1985, 1989; Walker *et al*. 2009). In this study the frequency of CO is reported on a per orbit and per individual basis.

Infection

Each of the skeletons in the Sigatoka sample was assessed for pathology, including evidence for degenerative joint disease, trauma, infectious lesions, hematological disease, metabolic and nutritional disorders, malformations, tumors, and skeletal changes attributable to cultural or behavioral practices (Ortner & Putschar 1981; Steinbock 1976). In this analysis pathological changes in bone were described and photographed and appear as part of the individual burial description (Pietrusewsky *et al*. 1994) as well as in summary form for the entire series where similar changes were noted in more than one individual. Diagnosis of any bone abnormality relies upon a recognizable pattern of occurrence in the individual skeleton, as well as a recognizable pattern of occurrence within a population. Ethnohistorical accounts at first European contact in the 17th and 18th centuries AD suggested infectious diseases were present in the Western Pacific including yaws, malaria, leprosy, parasitic and fungal infections (Buckley & Tayles 2003; Miles 1997; Trembly 1996). Yaws, caused by the spirochete *Treponema pallidum* subsp. *pertenue*, has been implicated in many of the bony lesions observed in archaeological skeletons from Fiji and western Polynesia (Buckley & Oxenham 2016; Rothschild & Heathcote 1993). Other infectious diseases that leave evidence in the skeleton, including leprosy, syphilis, tuberculosis, gout, and scurvy have also been identified in Pacific skeletal series.

In this study, we report the incidence of infection in the major limb bones of the postcranial skeleton on a per bone and per individual basis.

Limb Bone Fractures

Fractures of the major limb bones (clavicle, humerus, radius, ulna, femur, tibia, and fibula) provide an indication of the frequency and type of traumatic, accidental, or deliberate injury in past groups (Lovell 2008; Merbs 1989; Walker 1989). While healed fractures of other bones in the skeleton, including the skull, are observed in archaeological skeletons, because of difficulties in establishing frequencies for these regions of the skeleton, we focus on fractures of the major long limb bones. The frequency of fractures is estimated using the corresponding number of complete, or nearly complete, bones available for observation and on the number of individuals observed. We report the frequency of bone fractures on a per bone and per individual basis.

Spondylolysis

Spondylolysis, found mostly in the lower lumbar vertebrae, is a defect or stress fracture of the vertebrae within the pars interarticularis, the narrow area between the inferior and superior facets of the neural arch. Spondylolysis has been related to repeated stress in the lower back during physical activities requiring flexion of the lumbar spine with the legs extended (Merbs 1996; Ortner 2003). The frequency of spondylolysis is reported on a per lumbar vertebra and per individual basis.

Degenerative Joint Disease/Osteoarthritis

Degenerative joint disease (DJD), or osteoarthritis of the limb (diarthrodial) joints is characterized by the progressive formation of osteophytes, or lipping marginal to the articular joint surfaces, porosity of the joint surfaces, and eburnation (Brothwell 1981; Ortner & Putschar 1981; Ubelaker 1989). These changes are associated with the normal aging process and are distinguished from other forms of arthritis such as traumatic arthritis that is related to the disruption of the biomechanical functioning of a joint (Brothwell 1981; Ortner & Putschar 1981: 419; Ubelaker 1989). Each of the articular surfaces of the appendicular skeleton was systematically scored for DJD on a none, slight, moderate, and marked scale of increasing severity (Pietrusewsky & Douglas 2002: 144). These categories incorporate observations of lipping, porosis, and eburnation and were augmented with written descriptions of instances of moderate and marked observations. We report only the frequency of advanced (moderate and marked expressions) DJD in the larger joints of the skeleton (sternoclavicular, glenoid fossa, humeral head, radial head, proximal ulna, sacro-iliac joint, acetabulum, femoral head and condyle, proximal tibia, calcaneus and talus) and in the mandibular fossa of the temporal bone of the temporomandibular joint (TMJ) on a per articular surface and per individual basis.

Dental Pathology

In this study, we report data for six dental pathological conditions observed in the Sigatoka skeletons. Frequencies of dental pathology are reported on a per tooth and/or per tooth socket basis.

Antemortem tooth loss (AMTL)

The loss of teeth before death (antemortem tooth loss–AMTL) can be attributed to a number of pathological processes including periodontal disease, carious lesions, and alveolar defects (Lukacs 2007). The main criterion for recognizing AMTL is alveolar bone remodeling following the loss of teeth during life. Frequencies of AMTL were observed on the number of teeth or tooth sockets available for observation.

Dental caries

Dental caries is a demineralization of the tooth structures caused by organic acids produced by bacterial processes involved in the fermentation of dietary carbohydrates (Hillson 2008: 313). Dental caries were scored on a presence or absence basis per tooth.

Alveolar bone loss: alveolar resorption and alveolar defects

Two distinct types of alveolar bone loss were recorded in the skeletons from the Sigatoka Sand Dunes. The first, designated alveolar resorption, is related to the loss of alveolar bone due to inflammation of the supporting tissues of the teeth associated with periodontal disease (Hildebolt & Molnar 1991; Hillson 2008). The second type of alveolar bone loss, here referred to as alveolar defect, is the one concentrated around the apex of the tooth roots that originates from infections of the pulp; sometimes referred to as periapical dental abscess, or periapical cavity (Dias and Tayles 1997; Hillson 2008; Steckel & Rose 2002).

In this study, alveolar resorption is scored as the amount (none, slight, moderate, or marked) of tooth root exposed above the alveolar bone margin (Brothwell 1981: 155). The frequencies of advanced (moderate and marked) alveolar bone resorption are reported in this study on a per tooth/socket basis. Alveolar defects were scored on a present/absent basis per tooth/socket.

Dental calculus

Dental calculus is calcified or mineralized dental plaque (Hillson 2008, Lieverse *et al*. 2007), which is influenced by a number of variables including diet, attrition, oral environment, and salivary flow rate, among others (Lieverse 1999; Lieverse *et al*. 2007: 332). Of the two forms of dental calculus generally recognized, we report supragingival calculus, which is observed on the tooth crowns and sometimes roots. In the skeletons from the Sigatoka Sand Dunes, dental calculus was mainly confined to the tooth crown and cemento-enamel junction and recorded as none, slight, moderate, or marked following Brothwell (1981: 155). For adults we report the overall frequency of advanced (moderate and marked) calculus on a per tooth basis.

Dental attrition

Dental attrition results from tooth-on-tooth contact, which produces wear facets on the occlusal and proximal surfaces of the teeth in function (Hillson 1996). Occlusal attrition was recorded on a none, slight (enamel wear), moderate (dentin exposure), and marked (pulp exposure) gradient following more detailed patterns described in Brothwell (1981: 72) and Smith (1984). For adults we report only moderate and marked expressions of dental attrition that expose large areas of the dentin or exposure of the pulp cavity on a per tooth basis.

RESULTS

Subadult Health

Before reporting the indicators of health recorded in the adult skeletons, we summarize limited data in six subadult skeletons from the Sigatoka Sand Dunes. Most of the subadult skeletons are incomplete and fragmentary, with poor to fair preservation. The oldest subadult (10–12 years) is moderately complete and the best preserved (good to fair). For the six Sigatoka subadults observed, none of the permanent teeth (5 individuals, 51 teeth) and skeletal elements (6 individuals) exhibits pathology, so the following discussion is limited to the deciduous dental pathology and subadult cribra orbitalia. Most teeth (74.7%, 68/91) belong to individuals between four and eight years old. Very few deciduous teeth were recovered for individuals over eight years, due to displacement by erupting permanent teeth, compounded by small sample size.

Deciduous dental pathologies are presented by tooth class in Table 6. Alveolar defects (0/64 alveoli) and dental calculus (0/76 teeth) are absent and are not discussed further. Sex differences could not be assessed as all Sigatoka subadults are of undetermined sex.

Table 6. *Summary of* LEH *and dental pathology in the deciduous teeth*[1] *from the Sigatoka Sand Dunes (right and left sides combined).*

Trait/ Variation	Maxilla								Mandibular								Total	
	Molars		Canines		Incisors		Total		Molars		Canines		Incisors		Total			
	O[2]		O		O		O		O		O		O		O		O	
	A	%	A	%	A	%	A	%	A	%	A	%	A	%	A	%	A	%
Hypoplasias	20		10		15		45		22		8		13		43		**88**	
None	20	100.0	10	100.0	12	80.0	42	93.3	22	100.0	8	100.0	13	100.0	43	100.0	**85**	**96.6**
Present	0	0.0	0	0.0	3	20.0	3	6.7	0	0.0	0	0.0	0	0.0	0	0.0	**3**	**3.4**
Alveolar defect	20		7		8		35		17		6		6		29		**64**	
Present	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	**0**	**0.0**
Calculus	20		9		13		42		18		7		9		34		**76**	
None	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	**0**	**0.0**
Caries	20		10		15		45		22		8		13		43		**88**	
Absent	20	100.0	10	100.0	13	86.7	43	95.6	22	100.0	8	100.0	13	100.0	43	100.0	**86**	**97.7**
Present	0	0.0	0	0.0	2	13.3	2	4.4	0	0.0	0	0.0	0	0.0	0	0.0	**2**	**2.3**
Attrition	20		10		15		45		22		8		9		39		**84**	
None	11	55.0	6	60.0	2	13.3	19	42.2	12	54.5	5	62.5	1	11.1	18	46.2	**37**	**44.1**
Enamel	7	35.0	2	20.0	13	86.7	22	48.9	8	36.4	1	12.5	7	77.8	16	41.0	**38**	**45.2**
Dentin	2	10.0	2	20.0	0	0.0	4	8.9	2	9.1	2	25.0	1	11.1	5	12.8	**9**	**10.7**

1. 6 subadults are represented. See Table 4.
2. O = observed, A = affected; frequencies per tooth or alveolus.

Deciduous dental hypoplasia

The deciduous teeth from the Sigatoka site were assessed for enamel hypoplastic defects, including linear enamel hypoplasias (LEH) and pits (linear, non-linear, and single pit formations). LEH is present in 3.4 per cent (3/88) of the deciduous teeth and 16.7 per cent (1/6) of the subadult individuals, occurring only in the maxillary incisors (20.0%, 3/15). Burial 15, a 4–6 year old, has LEH defects visible in the maxillary left central and lateral incisors, which are also associated with horizontal carious lesions in the labial groove of the hypoplastic defects. There were no observed cases of localized hypoplasia of the primary canine (LHPC), a circular defect that suggests poor nutritional status in the womb, genetic influences, or mild trauma to the developing tooth shortly after birth (Skinner & Hung 1989).

Deciduous dental caries

Carious lesions are rare, occurring in 2.3 per cent (2/88) of the deciduous teeth and 16.7 per cent (1/6) of the individuals. Lesions are slightly more common in the maxillary teeth (4.4%, 2/45) than the mandibular teeth (0%, 0/43), occurring only in the upper incisors (13.3%, 2/15). Caries only occurs as elongated lesions in the weakened enamel bands encircling the incisors affected by LEH, discussed in the previous section. There were no cases of circular (pit) caries and no multiple lesions in the same tooth.

Deciduous dental attrition

The degree of dental attrition in this sample ranges from none to dentin exposure. Overall, 44.1 per cent (37/84) of the teeth have no wear, 45.2 per cent (38/84) have enamel wear, and 10.7 per cent (9/84) have dentin exposure. There was no difference in frequencies when analyzed by jaw. The incisor (87.5%, 21/24) was the most common tooth class affected by wear, as expected in the teeth that erupt earliest and are potentially used as tools (e.g., biting and holding objects). All subadults (100.0%, 6/6) exhibit teeth with enamel wear but only one individual (16.7%, 1/6), a 6–8 year old, has dentin exposure.

Subadult cribra orbitalia

Cribra orbitalia is absent in the Sigatoka subadults (0/2 orbits, 0/2 individuals).

Developmental pathology

The mandibular right deciduous central and lateral incisors of a 4–6 year old are congenitally fused at their crown-root interface but remain in their anatomical positions.

Summary of subadult health

The low rates of LEH and caries, and the absence of cribra orbitalia, LHPC, alveolar defects, and calculus in the Sigatoka deciduous tooth sample indicate good health *in utero* and during infancy, as well as good maternal health and adequate nutrient intake. The absence of pathology in the permanent teeth and skeletons suggests good childhood health as well.

Adult Health

Stature

Estimates of living stature, based on the maximum lengths of limb bones, for 12 males and eight females from the Sigatoka Sand Dunes, using Polynesian regression formulae (Houghton *et al.* 1975), are presented in Tables 7 and 8, respectively. Male statures range from 166.6 cm to 179.8 cm (mean = 174.1 cm) and female statures range from 153.0 cm to 174.8 cm (mean = 164.6 cm). Comparisons of these stature estimates with other skeletal series are discussed later.

Linear enamel hypoplasia (LEH)

The frequency of LEH in the maxillary and mandibular incisor and canine teeth in the Sigatoka adult skeletons, sexes combined, is 3.6 per cent (Table 9). The difference in per tooth frequencies of LEH in males (5.8%) and females (1.6%) is statistically significant, suggesting males were subjected to more disruption of enamel development dur-

Table 7. *Bone measurements and estimated stature (Houghton* et al. *1975) for adult male skeletons from the Sigatoka Sand Dunes.*

ID	Stature (cm)	Side[1]	Bone	Length (mm)
1A	177.7 ± 0.47	R	tibia	385
1B	174.2 ± 1.44	R	fibula	360
1C	173.6 ± 1.57	R	femur	448
4C	171.9 ± 1.57	R	femur	440
10C	177.3 ± 0.71	L	tibia	385
10B	179.8 ± 0.71	L	tibia	397
13A	174.6 ± 0.71	L	tibia	372
16	166.6 ± 0.47	R	tibia	335
17A	173.4 ± 1.57	R	femur	447
17B	173.4 ± 1.57	R	femur	447
19	174.2 ± 0.71	L	tibia	370
20	172.3 ± 0.71	L	tibia	361
	Average = 174.1			
	Range = 166.6 –179.8			

1. R = right, L = left.

Table 8. *Bone measurements and estimated stature (Houghton* et al. *1975) for adult female skeletons from the Sigatoka Sand Dunes.*

ID	Stature (cm)	Side[1]	Bone	Length (mm)
3D	168.0 ± 0.71	L	tibia	313
13/1	162.7 ± 1.57	R	femur	421
13B	174.8 ± 0.71	L	tibia	400
14	166.0 ± 0.47	R	tibia	356
21/22A	154.4 ± 2.84	R	humerus	260
23A	163.2 ± 0.47	R	tibia	343
24	153.0 ± 2.15	L	humerus	260
25	174.4 ± 0.71	L	tibia	398
	Average stature: 164.6			
	Range: 153.0–174.8			

1. R = right, L = left

Table 9. *Frequency of* LEH *(by tooth and individual) in canine and incisor teeth in adult skeletons from the Sigatoka Sand Dunes.*

	Male (N[1]=18)		Female (N=21)		Total (N=39)		
	A/O[2]	%	A/O	%	A/O	%	P-Value[3]
By tooth	9/154	5.8	3/184	1.6	12/338	3.6	0.0429*
By Individual	5/18	27.8	2/21	9.5	7/39	17.9	0.2155

1. N = Number of individuals.
2. A/O = affected/observed.
3. P-values obtained when Fisher's Exact Test (FET) was used to compare male and female frequencies; * indicates a statistically significant difference.

ing infancy and childhood than females. However, when analyzed per individual, the difference in male and female frequencies of LEH is not statistically significant.

Cribra orbitalia (CO)

Cribra orbitalia is absent in 11 male and 9 female adult crania from Sigatoka (Table 10).

Infection

Evidence of infection in the limb bones is equally low in male (1.7%) and female (0.6%) skeletons from the Sigatoka Sand Dunes site, a difference that is not statistically significant (Table 11). Based on the number of individuals observed, the frequency of infection was 11.8 per cent in males and 4.8 per cent in females, a difference that is not statistically significant. The overall frequency of bone infection in the Sigatoka skeletons is 1.1 per cent (by bone) and 7.9 per cent (by individual).

The skeletons of two males and one female that range in age from middle-aged to old, exhibit evidence of non-specific bone infection. This type of infection may be the result of injury, infection of the surrounding or overlying soft tissue, or the result of the introduction of bacteria into the joint or bone by a penetrating wound or spread via the bloodstream (Resnick and Niwayama 1981). Coarse porosity and remodeled periostitis with destruction of the articular surfaces noted in the poorly preserved left distal femur and proximal tibia in one male suggests severe infection of the left knee. Irregular remodeled cortex in two fibular shaft fragments with normal tibiae occurs in another male, and a lesion of healed periosteal bone occurs at the distal tibia above the articular facet in a female. Poor preservation in these skeletons, and the presence of dense, lacquered sand within the bones, prohibited the use of radiographs to illuminate the interior of these affected bones. Application of preservative over sand also complicates observations of the cortical surfaces in all the elements.

These examples of bone infection do not suggest treponematosis but are consistent with the presence of infection as a health hazard.

Long bone fractures

Identical frequencies of limb bone fractures (0.6%), based on the number of limb bones, are observed in males and females (Table 12). Based on the total number of individuals, the difference between the observed frequency of limb

Table 10. *Frequency of cribra orbitalia (by orbit and individual) in adult skeletons from the Sigatoka Sand Dunes.*

	Male (N[1]=11)		Female (N=9)		Total (N=20)		
	A/O[2]	%	A/O	%	A/O	%	P-Value[3]
By orbit	0/21	0.0	0/16	0.0	0/37	0.0	1.0000
By individual	0/11	0.0	0/9	0.0	0/20	0.0	1.0000

1. N = Number of individuals.
2. A/O = affected/observed.
3. P-values obtained when Fisher's Exact Test (FET) was used to compare male and female frequencies; * indicates a statistically significant difference.

Table 11. *Frequency of limb bone infection (by bone and individual) in adult skeletons from the Sigatoka Sand Dunes.*

	Male (N[1]=17)		Female (N=21)		Total (N=38)		
	(A/O)	%	(A/O)	%	(A/O)	%	P-Value[2]
By bone[3]	3/175	1.7	1/179	0.6	4/354	1.1	0.6229
By individual	2/17	11.8	1/21	4.8	3/38	7.9	0.5768

1. N = Number of individuals.
2. P-values obtained when Fisher's Exact Test (FET) was used to compare male and female frequencies; * indicates a statistically significant difference.
3. The bones include clavicle, humerus, radius, ulna, femur, tibia, and fibula.

Table 12. *Frequency (by bone and individual) of limb bone fractures in adult skeletons from the Sigatoka Sand Dunes.*

	Male		Female		Total		
	(N[1]=17)		(N=21)		(N=38)		
	A/O[2]	%	A/O	%	A/O	%	P-Value[3]
By bone	1/175	0.6	1/179	0.6	2/354	0.6	1.0000
By individual	1/17	5.9	1/21	4.8	2/38	5.3	1.0000

1. N = Number of individuals.
2. A/O = affected/observed.
3. P-values obtained when Fisher's Exact Test (FET) was used to compare male and female frequencies; * indicates a statistically significant difference.

Table 14. *Frequency of advanced osteoarthritis (by articular surface and individual) in adult postcranial skeletons from the Sigatoka Sand Dunes.*

	Male		Female		Total		
	(N[1]=18)		(N=20)		(N=38)		
	A/O	%	A/O	%	A/O	%	P-Value[2]
By articular surface	7/193	3.6	6/156	3.8	13/349	3.7	1.0000
By individual	3/18	16.7	3/20	15.0	6/38	15.8	1.0000

1. N = Number of individuals.
2. P-values obtained when Fisher's Exact Test (FET) was used to compare male and female frequencies; * indicates a statistically significant difference.

bone fractures in males (5.9%) and females (4.8%) is not statistically significant. The combined frequency of limb bone fractures in the Sigatoka skeletons is low when reported by bone (0.6%) or individual (5.3%), suggesting that accidental or deliberate injury is rare in the individuals buried in the Sigatoka Sand Dunes. The bones involved include a humerus (male) and radius (female).

Spondylolysis

A single lumbar vertebra in a single Sigatoka male exhibits spondylolysis. The frequencies of spondylolysis, based on the number of lumbar vertebrae available for observation, in males (1.5%) and females (0.0%) are not statistically different (Table 13). Likewise, the difference between the frequency of this stress fracture of the lower spine, based on the number of individuals observed in males (6.3%) and females (0.0%) is not statistically significant. These findings suggest the early inhabitants of Fiji were not subjected to repeated stress in the lower back.

Degenerative joint disease-osteoarthritis

Equally low frequencies (per surface) of advanced osteoarthritis are observed in male (3.6%) and female (3.8%) articular surfaces of the postcranial skeleton (Table 14). The overall frequency of advanced osteoarthritis, per surface, is 3.7 per cent. The frequencies of advanced osteoarthritis in the male and female postcranial skeletons (calculated per individual) are 16.7 per cent and 15.0 per cent, respectively, a difference that is not statistically significant. The articular surfaces exhibiting advanced DJD include the humeral head, proximal ulna, acetabulum, femoral condyle, proximal tibia, calcaneus, and talus.

The higher frequency of advanced osteoarthritis (calculated per articular surface) observed in the mandibular fossa of the temporal bone in males (33.3%) compared to females (3.4%) is statistically significant (Table 15). However, per individual frequencies of mandibular fossa osteoarthritis in males (33.3%) and females (6.3%) are not statistically significant. The overall frequencies of advanced osteoarthritis in the mandibular fossa of the temporal bone are 16.0 per cent (per surface) and 15.8 per cent (per individual).

Dental pathology

Frequencies of adult dental pathology in male and female teeth, based on the number of teeth or tooth sockets observed, are reported in Table 16. Three indicators have statistically significant differences between the sexes.

The difference in the frequencies of AMTL in females

Table 13. *Frequency of spondylolysis (by lumbar vertebra and individual) in adult skeletons from the Sigatoka Sand Dunes.*

	Male		Female		Total		
	(N[1]=16)		(N=13)		(N=29)		
	A/O[2]	%	A/O	%	A/O	%	P-Value[3]
By lumbar vertebra	1/66	1.5	0/46	0.0	1/112	0.9	1.0000
By individual	1/16	6.3	0/13	0.0	1/29	3.4	1.0000

1. N = Number of individuals.
2. A/O = affected/observed.
3. P-values obtained when Fisher's Exact Test (FET) was used to compare male and female frequencies; * indicates a statistically significant difference.

Table 15. *Frequency of advanced osteoarthritis (by articular surface and individual) in the mandibular fossa of the temporal bone in adult skeletons from the Sigatoka Sand Dunes.*

	Male		Female		Total		
	(N[1]=12)		(N=16)		(N=38)		
	A/O[2]	%	A/O	%	A/O	%	P-Value[3]
By articular surface	7/21	33.3	1/29	3.4	8/50	16.0	0.0067*
By individual	4/12	33.3	1/16	6.3	6/38	15.8	0.1331

1. N = Number of individuals.
2. A/O = affected/observed.
3. P-values obtained when Fisher's Exact Test (FET) was used to compare male and female frequencies; * indicates a statistically significant difference.

Table 16. *Frequency of dental pathology for permanent teeth (by tooth/tooth socket) in adult skeletons from the Sigatoka Sand Dunes.*

	Male		Female		Total		
	(N[1]=18)		(N=21)		(N=39)		
	A/O[2]	%	A/O	%	A/O	%	P-Value[3]
AMTL[4]	34/517	6.6	80/607	13.2	114/1124	10.1	0.0002*
Dental caries	24/446	5.4	33/496	6.7	57/942	6.1	0.4942
Alveolar defect	5/420	1.2	9/469	1.9	14/889	1.6	0.4303
Dental calculus[5]	0/362	0.0	10/406	2.5	10/768	1.3	0.0021*
Alveolar resorption[6]	39/229	17.0	31/286	10.8	70/515	13.6	0.0518
Dental attrition[7]	272/437	62.2	426/496	85.9	698/933	74.8	0.0001*

1. N = Number of individuals.
2. A/O = affected/observed.
3. P-values obtained when Fisher's Exact Test (FET) was used to compare male and female frequencies; * indicates a statistically significant difference.
4. AMTL = antemortem tooth loss scored by tooth.
5. Moderate and extreme expressions of dental calculus scored by tooth.
6. Moderate and marked resorption of the alveolus scored by toothy/tooth socket.
7. Moderate (reaching the dentin) and marked (pulp exposure and root only) attrition scored by tooth.

(13.2%) and males (6.6%) is statistically significant. The overall frequency of AMTL, sexes combined, is 10.1 per cent. Differences in frequencies of carious teeth in males (5.4%) and females (6.7%) are not statistically significant. The overall frequency of carious teeth in the Sigatoka skeletons is 6.1 per cent. The overall frequency of alveolar defects in the Sigatoka skeletons is 1.6 per cent. The difference between the frequencies of alveolar defects observed in males (1.2%) and females (1.9%) is not statistically significant.

Advanced (moderate and marked) dental calculus is noted in 1.3 per cent of the Sigatoka teeth. A significantly higher frequency of calculus is observed in female teeth (2.5%) compared male teeth (0.0%). The overall frequency of advanced (moderate and marked expressions) levels of alveolar resorption in the Sigatoka skeletons is 13.6 per cent. Though the frequency of alveolar resorption is greater in males (17.0%) than in females (10.8%), the difference is not statistically significant.

The overall incidence of advanced dental attrition, tooth wear that exposes the dentin (moderate) and pulp cavity (marked), is 74.8 per cent in the Sigatoka remains. The difference in the frequencies of advanced attrition in females (85.9%) and males (62.2%) is statistically significant. The incisors and canines exhibit the highest frequencies of advanced attrition, suggesting tooth wear may be attributed to non-dietary behaviors in females.

DISCUSSION

Sex Differences

As expected, the average stature of Sigatoka adult males was greater (by 9.5 cm) than the average stature for adult Sigatoka females, a difference that corresponds to sexual dimorphism in modern humans. For the majority of the skeletal indicators examined, there were very few statistically significant differences between the frequencies reported for males and females (Figure 2). Although the frequencies of LEH (per individual), bone fractures, stress fracture in the lower back, and infection were slightly higher in males, the differences between sexes were not statistically significant. Only when frequencies of LEH are based on the number of teeth, is there a statistically significant difference between male (greater) and female frequencies for this indicator of childhood stress. Cribra orbitalia, an indicator of childhood stress, was not observed in any of the skeletons from Sigatoka. The low frequencies of bone infection in both sexes suggest those buried in the Sigatoka burial mound were not greatly impacted by diseases that affect the skeleton. Likewise, the low frequencies of bone fractures and spondylolysis in Sigatoka skeletons suggest accidental or deliberate injury in males and females was equally rare.

Similar frequencies of advanced DJD in male and female appendicular skeletons suggests there were no marked gender differences in activities, in contrast to the male-female division of labor observed at contact. The ethnographic and ethnohistoric literature for indigenous Fijians at the time of European contact in the nineteenth century document gender differences in subsistence activities (Waterhouse 1866; Williams 1858, 1982)—women engaged in reef fishing and foraging while men were primarily responsible for crop maintenance, activities which could contribute to sex differences in advanced DJD in the postcranial skeleton.

The significantly higher frequency of DJD of the mandibular fossa (per side) in males could be attributed to gender differences in tool use or food processing, including kava. The processing and use of domesticated kava in

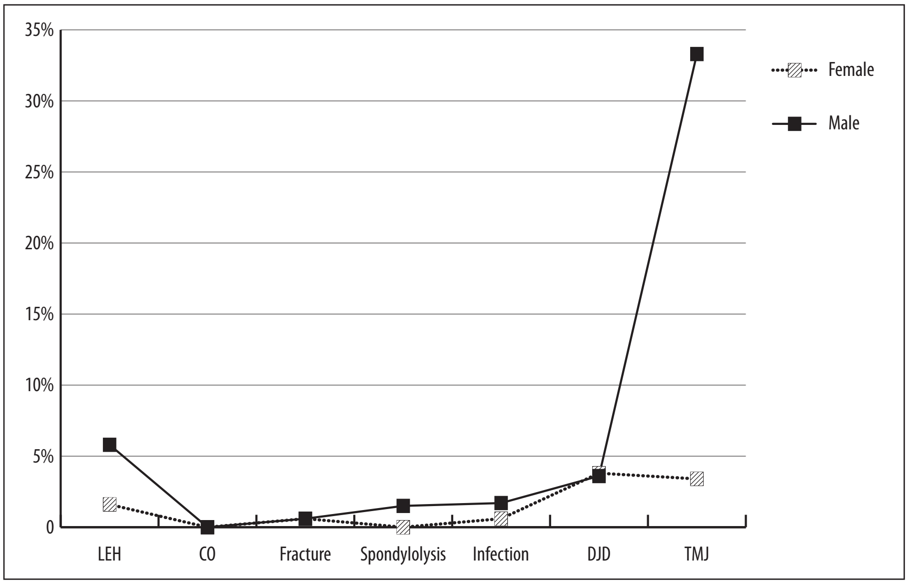

Figure 2. Comparison of skeletal indicators of health in male and female adult skeletons from the Sigatoka Sand Dunes.

Fiji has considerable antiquity and continues to the present (Lebot & Levesque 1989). Despite the fact that the kava plant (*Piper methysticum*) is grown and used throughout much of the Pacific, its social importance in Fiji was noted by some of the first early visitors to Fiji in the 19th century (e.g., Williams 1858, 1982). These accounts indicate that kava was used primarily by males who were also responsible for its preparation, a procedure that involved continual and repetitive chewing of the kava root (Williams 1858, 1982). Visser (1994b) has made a convincing argument that the repetitive, forceful, and shearing movements experienced by Sigatoka males in kava processing and use are correlated to TMJ dysfunction (Visser 1994b).

Examining dental pathology in the Sigatoka adult skeletons, no significant differences in the frequencies of dental caries, alveolar defect, or alveolar resorption were observed in the male and female Sigatoka dentitions. However, statistically significant differences were observed for three dental pathologies. Higher frequencies of AMTL, dental calculus, and dental attrition were observed in female compared to male dentitions (Figure 3).

Although gender differences in subsistence activities

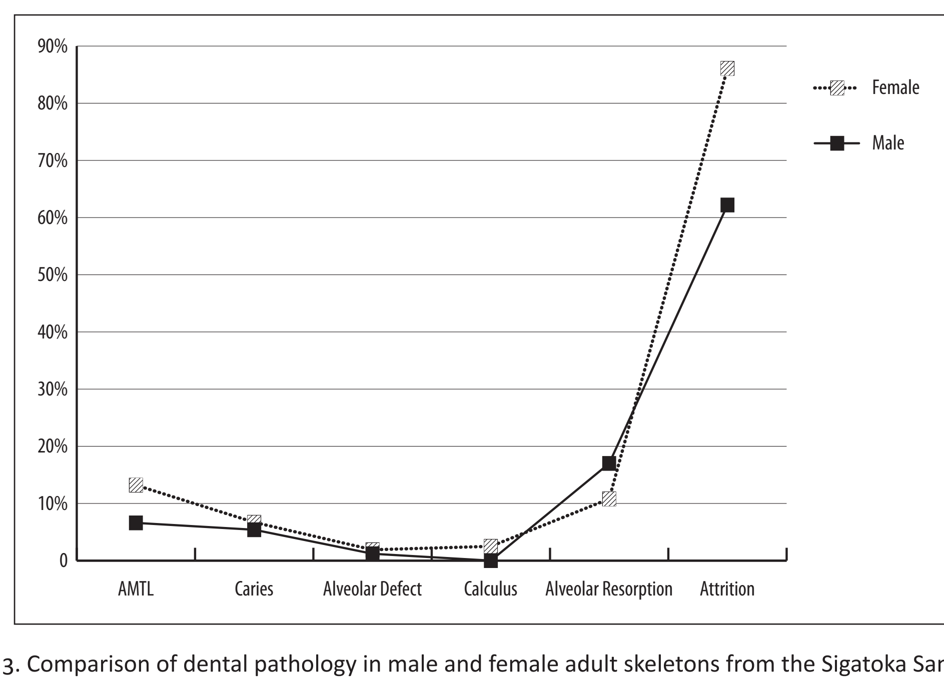

Figure 3. Comparison of dental pathology in male and female adult skeletons from the Sigatoka Sand Dunes.

are noted in the ethnographic and ethnohistoric literature (e.g., Waterhouse 1866; Williams 1858, 1982) and in modern ethnoarchaeological studies (e.g., Jones 2009), reconstructions of paleodiets based on isotopic studies of prehistoric skeletons from Fiji (Phaff 2012; Phaff *et al.* 2016; Valentin *et al.* 2006) found no clear pattern of dietary differences with respect to gender.

Although gender differences in diet cannot be ruled out, a number of other factors may be responsible for the higher frequency of AMTL observed in Sigatoka females including physiological effects of pregnancy and lactation, and the higher prevalence of dental caries, alveolar defect, dental calculus, and tooth attrition (see e.g., Lukacs 2007)—all of which may ultimately cause tooth loss. It is noteworthy that two of the factors that may lead to premature tooth loss, dental calculus and attrition, are significantly greater in females. The higher frequency of tooth wear observed in female Sigatoka skeletons may be linked to gender-related behaviors such as processing fibrous plant material for fishing nets and lines by females. Also, a higher percentage of middle-aged and old females (90.5%, 19/21), compared to males (72.2%, 13/18), may have contributed to the higher frequency of advanced attrition, dental calculus, and AMTL observed in females.

Several previous studies reported that tooth wear was positively correlated with degenerative changes of the TMJ (e.g., Hodges 1991; Richards 1988) while other studies (e.g., Lovell 2014; Sheridan *et al.* 1991; Whittaker *et al.* 1990) failed to find a positive correlation between tooth wear and DJD of the TMJ. Although a higher frequency of DJD of the TMJ was observed in Sigatoka males, the frequency of dental attrition in males was significantly less than the frequency observed in the Sigatoka females, an association that suggests tooth wear and DJD of TMJ are not correlated.

Summary of sex differences

The absence of cribra orbitalia and low frequencies of LEH, bone infection, fractures, and DJD suggest relatively good health for the early inhabitants of Fiji, a finding that will be corroborated when the Sigatoka skeletons are compared with other Pacific Island skeletal series in the next section. Only one indicator, LEH (per tooth), suggests that males experienced more stress than females during infancy and childhood, a difference that did not seem to affect the adult stature in males. With the exception of dental attrition, the frequencies of dental pathology observed in the Sigatoka dentitions are moderately low. Some of the observed differences in dental pathology may be due to differences in diet, gender-related activities, and age.

Regional Comparisons

In this section, we assess the health and lifestyle of the adult skeletons from the Sigatoka Sand Dunes by making limited comparisons with precontact skeletons excavated from other regions of the Pacific (Table 5). Several variables are responsible for the general paucity of comparative data from this region of the world. Most importantly, relatively few excavations have resulted in the recovery of substantially large numbers of human skeletons from the Pacific. Furthermore, some of the largest skeletal series from this region—for example skeletal series from Oahu, Hawaiian Islands (Snow 1974), Easter Island (Murrill 1968), and Tonga (Pietrusewsky 1969) were analyzed by different investigators using varying methods. The general lack of standardized reporting of bioarchaeological data among different investigators working in the Pacific continues to the present, although efforts to standardize some aspects of paleopathology have been made (e.g., Buckley & Tayles 2003). Finally, as discussed elsewhere (Pietrusewsky & Douglas 2012, 2016), the implementation of strict burial laws and repatriation issues has further compromised studies of bioarchaeology in the Pacific. Many skeletal series, including some examined in this paper, are no longer available for scientific investigation. Before summarizing the regional comparisons of health in the adult skeletons from Sigatoka and comparative series, we summarize regional comparisons of subadult deciduous dental pathology.

Subadult Health

While the Sigatoka subadult sample size for cribra orbitalia (CO) is quite small, the absence of CO (0%, 0/2) contrasts with the relatively greater (per individual) frequencies at Taumako (40.4%, 23/57) and 'Atele (20.7%, 6/29) (Buckley 2016), two skeletal series with the highest frequencies of treponemal disease. Comparative LEH data in the Taumako and 'Atele deciduous tooth samples were reported in Buckley (2016). When only the observed canines and incisors are included, the Sigatoka sample has the highest rate of affected teeth (6.5%, 3/46), followed by Taumako (2.9%, 4/138) and 'Atele (1.7%, 2/117). The higher rate of LEH at Sigatoka could be attributed to the small sample size as only one individual is affected.

Comparative deciduous dental data from neighboring regions is sparse and includes the two burial mounds (To-At-1 and To-At-2) at 'Atele, Tonga, dated to *ca.* 460–0 cal BP; a burial mound on Taumako, Solomon Islands, in use from 750–450 BP; one subadult from the Bourewa site along southwest coast of Viti Levu, 750–0 cal BP; and Rima Rau, a pre-/proto-historic site on Atiu Island, Cook Islands (Buckley 2016, Stantis & Tayles *et al.* 2016: 570).

When all deciduous teeth are included in comparisons, 2.5 per cent (7/286) of 'Atele teeth were affected by caries, a low rate very similar to Sigatoka (2.3%, 2/88) and slightly higher than Bourewa (0/19) and Rima Rau (0/52) (Stantis & Tayles *et al.* 2016). When comparisons are limited to circular caries present and include only the observed canines and incisors, the rate drops to 0 per cent (0/46) at Sigatoka, remains identical at 'Atele (2.6%, 3/117), and allows comparisons with Taumako subadults (21.7%, 30/138) (Buckley 2016). These frequencies suggest a dietary difference at Taumako, such as more sticky starches or a relatively less abrasive diet that does not remove developing caries. Dental wear was present in 'Atele teeth (6.2%, 5/81) and absent at both Bourewa (0/19) and Rima Rau (0/24) (Stantis & Tayles *et al*. 2016). These relatively low dental pathology rates suggest that Sigatoka subadults made greater use of their teeth as tools or had a coarser diet (which would also help prevent and remove caries formation).

Adult Health

Stature

Adult stature for males shows limited differentiation in the seven Pacific Island skeletal series examined, including Sigatoka (Table 17, Figure 4). The mean stature for Sigatoka males (174.1 cm) is closest to skeletal series from Tonga. The average stature for Sigatoka males is very similar to Polynesian males who are considered to be uniformly tall statured (Howells 1973: 34, 1979: 273). There is more variation in the average statures for adult females for Pacific Island groups (159.7–167.5 cm). The average stature for Sigatoka females (164.6 cm) is most similar to the average stature reported for the skeletons from Taumako Island in the southeastern Solomon Islands whose present day inhabitants speak a Polynesian language. Only Tongan females have average statures greater than the Sigatoka females. Small and uneven sample sizes may account for some the variation observed in mean statures reported here.

LEH

The frequencies of adult LEH (Table 18) reveal considerable variation for Pacific Island skeletal series available for comparison. Frequencies of this indicator of childhood

Table 17. *Comparison of average statures (cm) for adult males and females for Pacific Island skeletal series.*

Skeletal Series[1]	Male				Female				Reference
	N	Mean	Min.	Max.	N	Mean	Min.	Max.	
Sigatoka	13	174.1	166.6	179.8	8	164.6	153.0	174.8	this study
'Atele	17	173.7	168.7	180.1	10	167.5	160.9	178.7	Pietrusewsky 1969
Honokahua	100	173.3	164.7	182.0	221	163.1	149.8	172.0	Pietrusewsky *et al.* 1991; Pietrusewsky & Douglas 1994
Easter Island[1]	11	172.4	167.2	179.2	8	159.7	149.8	164.2	Murrill 1968
Wairau Bar	5	175.0	173.5	176.6	1	160.6			Buckley *et al.* 2010
Mariana Islands	58	173.2	166.1	182.1	45	160.6	153.9	170.6	Pietrusewsky *et al.* 2014
Taumako	52	175.5			19	164.3			Houghton 2008

1. Stature estimates based on Polynesian stature regression formulae (Houghton et al. 1975) obtained using long bone measurements in Murrill (1968).

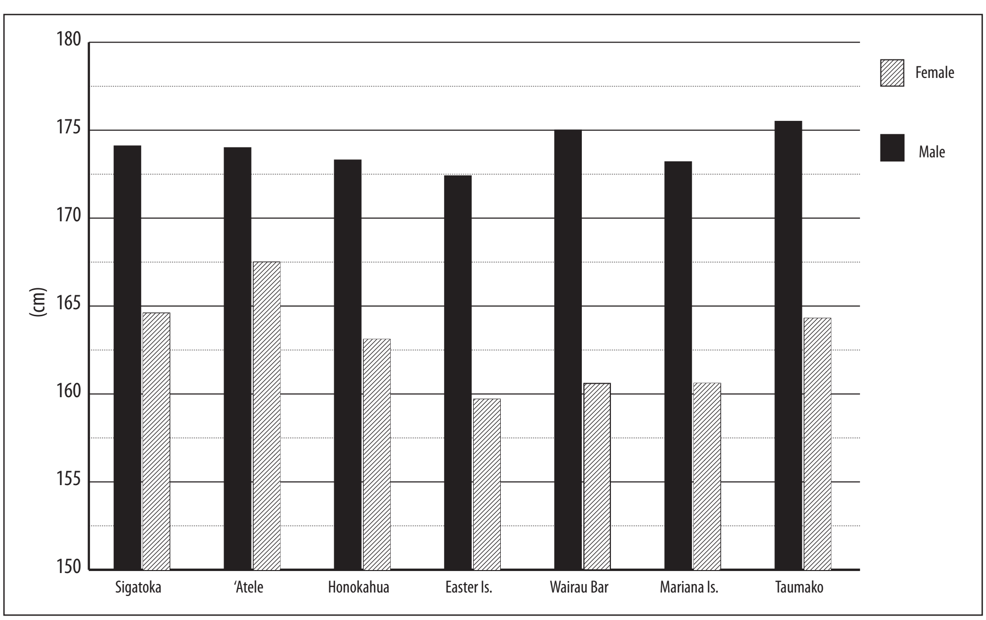

Figure 4. Comparison of average male and female statures for the adult skeletons from the Sigatoka Sand Dunes and six Pacific Island samples.

Table 18. *Comparison of* LEH *(by tooth) in permanent canine and incisor teeth in adult Pacific Island skeletons.*

Skeletal Series[1]	A/O[2]	%	Reference	P-Value[3]
Sigatoka	12/338	3.6	this study	
'Atele	12/155	7.7	Pietrusewsky[4]	0.1060
Honokahua	102/1718	5.9	Pietrusewsky *et al.* 1991; Pietrusewsky & Douglas 1994	0.0904
Mariana Islands	259/882	29.4	Pietrusewsky *et al.* 2014, 2016	0.0001*
Taumako	110/514	21.4	Buckley 2016	0.0001*

1. See Table 5 for information on skeletal series.
2. A/O = Affected/Observed.
3. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.
4. Data recorded by Pietrusewsky in 1992.

Table 19. *Comparison of cribra orbitalia (by individual) in adult skeletons from the Pacific Islands.*

Skeletal Series	Adults		Reference	P-Value[1]
	n/N	%		
Sigatoka	0/20	0.0	this study	
'Atele	5/30	16.7	Buckley 2016:127	0.0746
Honokahua	19/312	6.1	Pietrusewsky *et al.* 1991; Pietrusewsky & Douglas 1994	0.6164
Mariana Islands	20/132	15.2	Pietrusewsky *et al.* 2014, 2016	0.0765
Wairau Bar	7/21	33.3	Buckley *et al.* 2010	0.0086*
Taumako	38/111	34.2	Buckley 2016:127	0.0008*

1. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.

health range from 3.6 per cent (Sigatoka) to 29.4 per cent (Mariana Islands). The relatively low frequency of LEH observed in the Sigatoka skeletons suggests that malnutrition, metabolic disorders, and acute and chronic infections did not adversely affect the health during infancy and childhood among those buried in the Sigatoka Sand Dunes. Equally low frequencies of this childhood indicator of health are reported for the series from Tonga and Hawaii. Higher frequencies of LEH for two series, Mariana Islands and Taumako, were found to be statistically significant when compared to the frequency of LEH in the Sigatoka series.

Cribra orbitalia

The frequencies of adult cribra orbitalia (CO) in six Pacific Island series, including the Sigatoka series, range from 0.0 per cent (Sigatoka) to 34.2 per cent (Taumako) (Table 19). The complete absence of this indicator of health in the Sigatoka and relatively low frequencies are reported for the series from Tonga, Hawaii, Guam, and the Mariana Islands. Compared to the frequency observed in the Sigatoka skeletons, significantly higher frequencies of CO were observed in Wairau Bar and Taumako skeletons, suggesting relatively compromised health during early childhood for these series.

Infection

With the exception of Taumako, the frequencies of bone infection in the postcranial skeletons from Sigatoka and five other Pacific Island series are generally low (Table 20). While yaws was widespread in the western Pacific Islands, including Fiji and Tonga prior to European contact (Buckley & Tayles 2003; Miles 1997), none of the cases reported

Table 20. *Comparison of infection (by individual) in adult postcranial skeletons from the Pacific Islands.*

Site/Series	A/O[1]	%	Reference	P-Value[2]
Sigatoka	3/38	7.9	this study	
'Atele	8/38	21.1	Pietrusewsky 1969	0.1908
Hane	0/24	0.0	Pietrusewsky 1976	0.2766
Honokahua	11/356[3]	10.3	Pietrusewsky and Douglas 1994	0.1431
Taumako	41/71[4]	57.7	Buckley & Tayles 2003	0.0001*
Mariana Islands	40/350	11.4	Pietrusewsky *et al.* 2014	0.7846

1. A/O = Affected/Observed
2. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.
3. This frequency is based on the total number of adult male and female skeletons for which postcranial measurements were recorded.
4. The prevalence of postcranial pathology in adults from Taumako is reported as 38/71, or 53.5% in Buckley (2016).

for the Sigatoka series is likely indicative of yaws. This is particularly noteworthy since, prior to the establishment of a national yaws control program in 1955, Fiji was reported to have the highest prevalence of infectious yaws in the central Pacific (Capurano & Ozaki 2011). Buckley *et al.* (2008) also report the absence of evidence for yaws in some of the very early inhabitants of Remote Oceania at the Teouma site in Vanuatu. A diagnosis of yaws has been made for skeletons from the ʻAtele, Tuamako, and Mariana samples included in these comparisons.

The frequencies of LEH, CO, and infection in the Sigatoka skeletons are most similar to those reported for the skeletal series from Hawaii and neighboring Tonga (Figure 5), frequencies that suggest overall good health for the prehistoric inhabitants of these islands. Generally higher frequencies for these three indicators are found in the skeletons from the Mariana Islands and Taumako Island. Some of the highest frequencies of CO and bone infection are observed in the Taumako series, a series found to have one of the highest expressions of yaws in the Pacific (Buckley & Tayles 2003).

Limb bone fractures and spondylolysis

Frequencies of limb bone fractures in six Pacific Island skeletal series, including Sigatoka, are generally low, ranging from 0.1 per cent (Taumako) to 3.9 per cent (Tonga) (Table 21). The frequency of bone fractures in the Sigatoka skeletons (0.6%), one of the lowest reported, is significantly lower than that reported here for the skeletons from the To-At-1 and To-At-2 (henceforth ʻAtele) burial mound sites on Tongatapu in Tonga, skeletons that generally post-

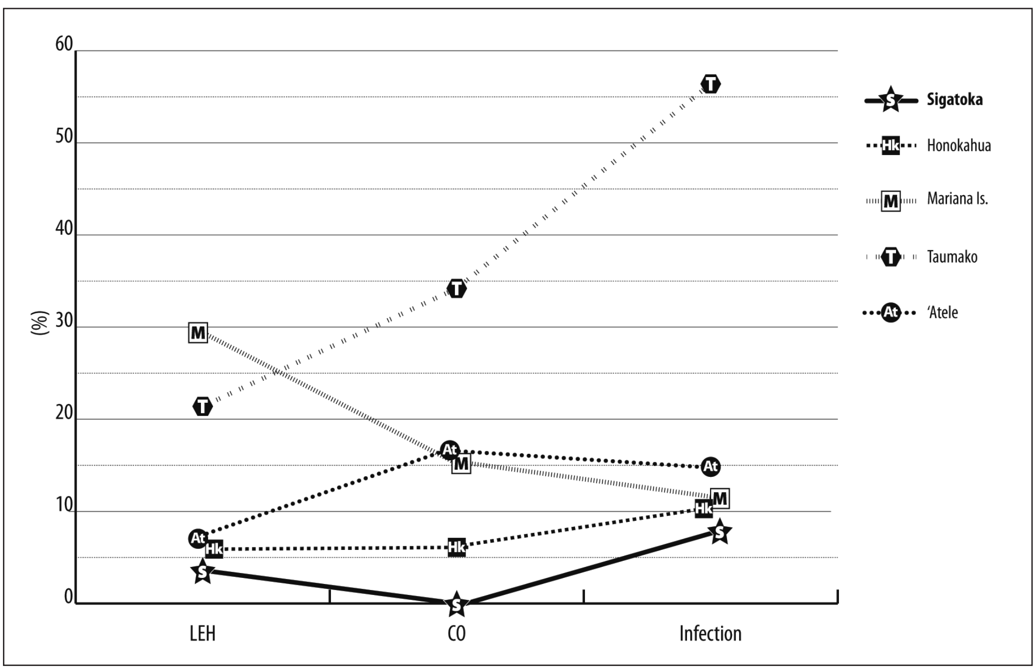

Figure 5. Comparison of linear enamel hypoplasia (LEH), cribra orbitalia (CO), and bone infection in the adult (male and female combined) skeletons from the Sigatoka Sand Dunes and four Pacific Island samples

Table 21. *Comparison of limb bone fractures (by bone) in adult skeletons from the Pacific Islands.*

Series	A/O[1]	%	Reference	P-Value[2]
Sigatoka	2/354	0.6	this study	
ʻAtele	6/115	3.9	Pietrusewsky 1969	0.0116*
Hane	3/122	2.5	Pietrusewsky 1976	0.1092
Honokahua	107/6555	1.6	Pietrusewsky *et al.* 1991; Pietrusewsky & Douglas 1994	0.1819
Mariana Islands	11/1185	0.9	Pietrusewsky *et al.* 2014, 2106	0.7440
Taumako	4/4000[3]	0.1	Scott and Buckley 2010	0.0794

1. A/O = Affected/Observed
2. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.
3. Frequency based on the total number of clavicles, humeri, ulnae, radii, femora, tibiae, and fibulae.

date those from Sigatoka. A very similar frequency of limb bone fractures in the ʻAtele skeletons (3.7%) was reported by Scott and Buckley (2014). Based on the skeletal pattern of trauma these authors have suggested that the injuries observed in prehistoric Tonga were most likely the result of ritualized violence or sporting activities rather than the result of warfare (Scott & Buckley 2014).

The highest frequencies of stress fracture of the lower back (spondylolysis) are found in skeletal series from the Mariana Islands, a condition that may have contributed to lower back trauma in ancient Chamorro related to transporting heavy *latte* stones for the construction of archaeological structures by the same name (Arriaza 1997) (Table 22). The frequency of stress fracture in the lumbar region is very low in the Sigatoka skeletons (0.9%) with no statistically significant differences with the frequencies reported for four additional Pacific Island series. Overall, these data suggest a relatively injury- and trauma-free existence for the early inhabitants of the Pacific Islands.

Degenerative joint disease (DJD)

Limited comparisons reveal low frequencies of advanced DJD in the postcranial skeletons from Sigatoka and four additional Pacific Island skeletal series (Table 23). None of the frequencies, which range from 3.4 per cent (Hane) to 6.5 per cent (Apotguan), is significantly different relative to the frequency of advanced osteoarthritis observed in the Sigatoka skeletons (3.7%). Frequencies of advanced osteoarthritis in the major articular surfaces of the postcranial skeleton indicate relatively conservative levels of biomechanical wear and tear and functional stress in the Sigatoka and Pacific Island series. Degenerative joint disease in the temporomandibular joint (sexes combined), on the other hand, is two times higher in the Sigatoka skeletons (Table 24).

With the exception of DJD of the TMJ, the skeletal series from Sigatoka, Tonga, Hawaii, and the Marquesas have very similar frequencies of limb bone fractures, spondylolysis, and DJD (Figure 6).

Dental pathology

Frequencies of AMTL, dental caries, and alveolar defect for six Pacific Island adult skeletal series are available for comparison with those for Sigatoka (Table 25). The frequency of AMTL ranges from 5.8 per cent (Mariana Islands) to 23.1 per cent (Bourewa). The frequency of AMTL in the Sigatoka series (10.1%) is significantly lower than one reported for Bourewa. Compared to the frequency of AMTL in the Sigatoka skeletons, a significantly lower frequency of AMTL was observed in the Mariana Islands and ʻAtele series.

The frequency of dental caries ranges from 4.8 per cent (Wairau Bar) to 16.2 per cent (Bourewa), with the frequency of this dental pathology in Sigatoka (6.1%) falling in the middle range. Comparing the frequency of

Table 22. *Comparison of spondylolysis (by bone) in lumbar vertebrae in adult skeletons from the Pacific Islands.*

Series	A/O[1]	%	Reference	P-value[2]
Sigatoka	1/112	0.9	this study	
ʻAtele	0/55[3]	0.0	Pietrusewsky 1969	1.0000
Hane	1/59	1.7	Pietrusewsky 1976	1.0000
Honokahua	21/1396	1.5	Pietrusewsky *et al*. 1991; Pietrusewsky & Douglas 1994	1.0000
Mariana Islands	14/355	3.9	Pietrusewsky *et al*. 2014, 2106	0.1336

1. A/O = Affected/Observed
2. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.
3. The total number of lumbar observed (O) was estimated from the total number of lumbar vertebrae measured.

Table 23. *Comparison of advanced degenerative joint disease (by articular surface) in adult postcranial skeletons from the Pacific Islands.*

Skeletal Series	A/O[1]	%	Reference	P-Value[2]
Sigatoka	13/349	3.7	this study	
ʻAtele	9/255	3.5	Pietrusewsky 1969	1.0000
Hane	10/296	3.4	Pietrusewsky 1976	0.8352
Honokahua	228/5753	4.0	Pietrusewsky *et al*. 1991; Pietrusewsky & Douglas 1994	1.0000
Apotguan	31/477	6.5	Pietrusewsky *et al*. 2003; Douglas *et al*. 1997	0.0860

1. A/O = Affected/Observed
2. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.

Table 24. *Comparison of advanced degenerative joint disease (by articular surface) in the mandibular fossa of the temporal bone in adult skeletons from the Pacific Islands.*

Skeletal Series	A/O[1]	%	Reference	P-Value[2]
Sigatoka	8/50	16.0	this study	
Honokahua	18/221	8.1	Pietrusewsky *et al.* 1991; Pietrusewsky & Douglas 1994	1.0000
Mariana Islands	6/71	8.5	Pietrusewsky *et al.* 1997	0.1374

1. A/O = Affected/Observed
2. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.

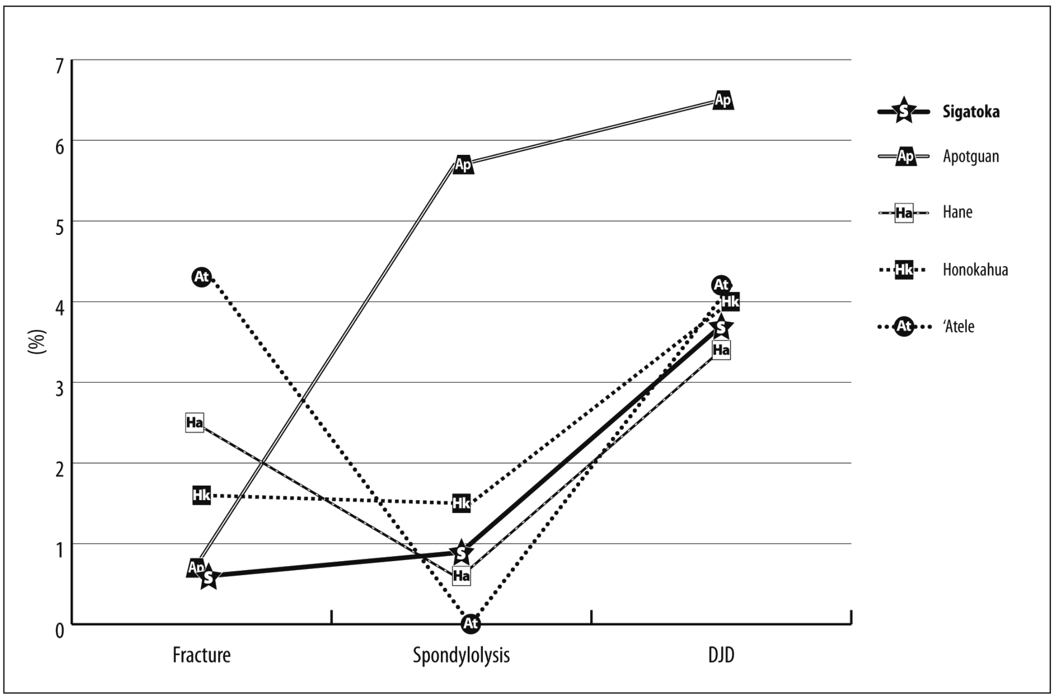

Figure 6. Comparison of limb bone fracture, spondylolysis, and degenerative joint disease (DJD) in the adult (male and female combined) skeletons from the Sigatoka Sand Dunes and four Pacific Island samples.

Table 25. *Comparison of* AMTL*, dental caries, and alveolar defects (by tooth/tooth socket) for permanent teeth in adult Pacific Island skeletons.*

Series	Antemortem tooth loss		P-value[1]	Caries		P-value	Alveolar defect		P-Value	Reference
	A/O	%		A/O	%		A/O	%		
Sigatoka	114/1124	10.1	—	57/942	6.1	—	14/889	1.6	—	this study
Bourewa	84/364	23.1	0.0001*	37/229	16.2	0.0001*	3/302	1.0	0.5835	Stantis & Tayles *et al.* 2016
'Atele	37/657	5.6	0.0008*	34/488	7.0	0.0002*	12/494	2.4	0.1850	Pietrusewsky[2]
Honokahua	852/8897	9.6	0.5805[3]	985/7309	13.5	0.0001*	381/7629	5.0	0.0001*	Pietrusewsky *et al.* 1991; Pietrusewsky & Douglas 1994
Rima Rau, Cook Is.	28/308	9.1	0.6670	9/107	8.4	0.3973	5/295	1.7	0.7958	Stantis & Tayles *et al.* 2016
Wairau Bar	54/660	8.2	0.1799	19/399	4.8	0.4382	54/468	11.5	0.0001*	Buckley *et al.* 2010
Mariana Islands	346/6014	5.8	0.0001*	242/4153	5.8	0.8178	167/3313	5.0	0.0001*	Pietrusewsky *et al.* 2014, 2016

1. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.
2. Data recorded by Pietrusewsky in 1992.
3. Chi-square value = 0.305 with 1 d.f.; two-tailed P value = 0.5805, which is not significant.

Table 26. *Comparison of dental calculus, alveolar resorption, and dental attrition (by tooth/tooth socket) for permanent teeth in adult Pacific Island skeletons.*

Skeletal Series	Calculus[1]		P-Value[2]	Alveolar Resorption[3]		P-Value	Attrition[4]		P-Value	Reference
	A/O	%		A/O	%		A/O	%		
Sigatoka	10/768	1.3		70/515	13.6		698/933	74.8		this study
Honokahua	489/7167	6.8	0.0001*	3721/7194	51.7	0.0001*	3456/7365	46.9	0.0001*	Pietrusewsky *et al*. 1991; Pietrusewsky & Douglas 1994
Mariana Islands	608/3851	15.8	0.0001*	836/2164	38.6	0.0001*	1267/3859	32.8	0.0001*	Pietrusewsky *et al*. 2014, 2016

1. Frequencies of moderate and marked levels of calculus deposits.
2. P-values obtained when Fisher's Exact Test (FET) was used to compare frequencies obtained for Sigatoka skeletons with other groups; * indicates a statistically significant difference.
3. Frequencies of moderate and marked levels of alveolar resorption.
4. Frequencies of moderate (dentin exposed) and advanced (reaching the pulp and root) dental attrition.

dental caries in the Sigatoka series revealed significantly higher frequencies of this dental pathology for Bourewa, ʻAtele and Honokahua. The frequency of dental caries in the Mariana Islands series is most similar to the frequency reported for Sigatoka. The lowest frequency of dental caries (4.8%) is that reported for the Wairau Bar site from New Zealand.

The frequency of alveolar defect ranges from 1.0 per cent (Bourewa) to 11.5 per cent (Wairau Bar). The frequency of this dental pathology in the Sigatoka teeth (1.6%) is one of the lowest frequencies reported. Compared to Sigatoka, significantly higher frequencies of alveolar defect were found for Honokahua, Wairau Bar, and the Mariana Islands series.

The frequencies of dental caries and alveolar defect in the Sigatoka series are most similar to those reported for the skeletons from ʻAtele, Tongatapu. Differences in diet, cultural factors, and/or hereditary factors may help to explain the unusually high frequencies of AMTL and dental caries observed in the Bourewa series.

Comparisons of advanced levels of dental calculus, alveolar resorption, and dental attrition are limited to three skeletal series, including Sigatoka (Table 26). The frequencies of dental calculus and alveolar resorption for Sigatoka are significantly lower than those reported for Honokahua and the Mariana Islands. The frequency of advanced dental attrition in the Sigatoka teeth (74.8%) is significantly higher than the frequencies for two other groups.

Overall, regional comparisons of dental pathology indicate that, with the exception of higher frequencies of AMTL and dental attrition, the dental health of the Sigatoka skeletons was relatively good. Higher frequencies of AMTL and attrition may be due to dietary differences, use of teeth in non-dietary behaviors, and age. The frequencies of many of the dental pathologies observed in the Sigatoka skeletons are most similar to skeletal series from Tonga and Hawaii. The skeletal and dental profile for the Sigatoka skeletal series is consistent with a horticultural subsistence strategy, which may explain the similarities with skeletal series from Tonga and Hawaii.

CONCLUSIONS

Using skeletal and dental indicators, this paper examines the health, diet, and lifestyle in 42 adult and six subadult skeletons excavated from the coral cairn cemetery at the Sigatoka Sand Dunes site, VL 16/1, on Viti Levu, one of the largest samples of prehistoric skeletons from Fiji. The skeletons are from Level 2, whose dates span the time period ca. 1700 to 1300 cal yr BP, a time period during which large-scale movements of people were likely occurring in the Fijian archipelago.

Comparisons of skeletal and dental indicators of health in adult males and females indicate few differences. A somewhat higher frequency of LEH observed in males, suggests males may have experienced greater stress during childhood than females, a difference, which appears, not have negatively impacted the health of males. Higher frequencies of temporo-mandibular degenerative changes are observed in males and advanced dental attrition is observed to be greater in females than in males.

Regional comparisons indicate that adult males buried in the Sigatoka Sand Dunes were tall statured, similar to Tongans. The average stature of females was most similar to that of Taumako Island, a Polynesian Outlier in the eastern Solomon Islands. Low frequencies of linear enamel hypoplasia, cribra orbitalia, and bone infections in the Sigatoka skeletons indicate relatively good health for these early inhabitants of Fiji, frequencies that are closest to those reported for skeletal series from Tonga and the Hawaiian Islands. One remarkable finding was the very low prevalence of bone infection in these remains and the absence of lesions characteristic of yaws, a disease that was once highly prevalent in Fiji and the western Pacific. Likewise, skeletal injury and trauma were very rare in these remains suggesting accidental or self-inflicted violence was rare. Relatively low levels of advanced osteoarthritis in the postcranial skeleton indicate nothing out of the ordinary with respect to normal biomechanical wear and tear. The frequencies of fractures, spondylolysis, and DJD in the Sigatoka skeletons are most similar to those for a skeletal series from the Hawaiian Islands and Tonga, traditional horticultural island communities.

With few exceptions, the dental health of these early inhabitants of Fiji was good. The frequencies of two dental pathologies, caries and alveolar defect, are closest to those reported for ʻAtele on Tongatapu in the Tongan Islands. Overall, the health of these early inhabitants was remarkably robust and not unlike other skeletal series from Polynesia. Limited observations of deciduous dental pathology, LEH, and the absence of cribra orbitalia in the subadult skeletons from the Sigatoka Sand Dunes indicate good health *in utero* and during infancy. The absence of evidence yaws in the skeletons from the Sigatoka Sand Dunes is unexpected and deserves further scrutiny. The information reported in this study, based on the largest sample of prehistoric skeletons from Fiji now available, adds to the ever-increasing body of knowledge of the bioarchaeology of the Pacific Islands.

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