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HEALTH AMONG CLASSIC-PERIOD URBAN AND RURAL MAYA: A REGIONAL PERSPECTIVE

Vera Tiesler [a] and Raúl López Pérez [b]

[a]Facultad de Ciencias Antropológicas, Universidad Autónoma de Yucatán, km 1 Carretera Mérida Tizimín Cholul, Mérida 97305, Mexico
[b]Department of Postgraduate Studies, Universidad Autónoma de Yucatán, km 1 Carretera Mérida Tizimín Cholul, Mérida 97305, Mexico

Abstract

Health benefits among the members of state-level societies may vary depending on sex, social privilege, and whether the individual resides in an urban or rural setting. Human skeletal remains are prone to express individual life experiences and, ultimately, well-being. This research elaborates on these correlates by contextualizing the physiological stresses among Classic Maya hinterland populations in comparison to their urban peers. Comparisons are made using the frequencies and expression of enamel hypoplasia, caries, porotic hyperostosis, infectious osteomyelitis/subperiosteal reaction and osteoporosis in 842 adult skeletons of both sexes from 63 peripheral and centric, inland, lowland settlements. The results suggest problematic inland weaning diets and higher infectious load among rural populations. While comparisons between urban and rural lifeways show inconsistent load differences, our results indicate repeated distinctions between the sexes. We cautiously interpret this pattern as an indication of a physically demanding regime of rural life compared to a more sedentary routine among urban peers and gendered lifestyles in general. We conclude that apart from these distinctions (and potential sample biases), the health costs versus benefits impacted rural lifestyles in a complex and non-uniform fashion during the first millennium A.D., rejecting clear-cut hierarchical conceptualizations while inviting more nuanced causal explorations.

INTRODUCTION

Human populations have always lived in dependence with close interaction within and beyond their sociopolitical networks and specific environments, including rurality. Embracing the full range of settlement populations and networks is key in our efforts towards understanding the complexity of rural life among the ancient Maya. Traditionally scholars have directed their attention to the elite populations of large-site centers; only in recent decades has rural society gained visibility within Maya research (e.g., Freter 2004; Hutson 2016; Iannone and Connell 2003; Lamb 2020; Lohse 2013; Lohse and Valdez 2004; Robin 2012; Sheets 2002; Somerville et al. 2013; Webster and Gonlin 1988; Yaeger 2000).

The explorations of ancient Maya rurality would not be complete without an admixture of information of skeletal and mortuary datasets. Bioarchaeological approaches to the physically embodied lifestyles of rurality are attracting the attention of the Mayanist community due to the interdisciplinary mindsets among the younger generations of scholars coupled with novel analytical possibilities. In the past 20 years, the analyses of skeletal materials have diversified, set forth by multidisciplinary or actor-based agendas, which benefit the integration of populational and cultural datasets. Despite their limitations—specifically the uncertainty that surrounds the identification of rural settlements and inferring residence from an individual's burial location—such research schemes have evolved to enable direct measurements of health burdens among hinterland populations towards an ever-more integrated understanding of regional dynamics and scaled settlement interactions (Cucina and Tiesler 2003; Novotny 2012, 2015; Reed 1999; Scherer 2015; Somerville et al. 2013; Tiesler 1997; Tiesler et al. 2020; Whittington 1988, 1999; Whittington and Reed 1997; Wright 2006; Wrobel 2014).

This article approaches the capital topic of this timely dossier on ancient Maya rurality not by looking at specific urban versus hinterland populations (at a given time or a given site). Instead, we conceive a multisite perspective which encompasses rural Maya lowland health and lifestyle in the context of urbanization and settlement growth (Figure 1). The inherent challenges that Maya rural settlements bore within a centralized settlement pattern of a state-level society set agendas and assumptions for studying rural health impacts and living conditions. In this vein, we start out by asking ourselves if small versus large urban aggregations, *sensu* Marcus (2004), would have affected lifestyle and well-being differently. Despite sharing a similar geography and subtropical climate conditions, their access to resources and the degree of crowding should be diverse, resulting in differences between urban and rural residential layouts, and accordingly, varied life experiences.

Concretely, we assume the settler's physical well-being should be the combined outcome along the ranges of the following three contrasting expectations. The first pair of opposing scenarios proposes that hierarchically organized settlement systems shall replicate inequality in rural populations; however, such inequality should be counteracted by the active participation in regional networks of rural populations. Second, hierarchically organized urban strongholds should provide lifestyle benefits among central

E-mail correspondence to: vtiesler@yahoo.com

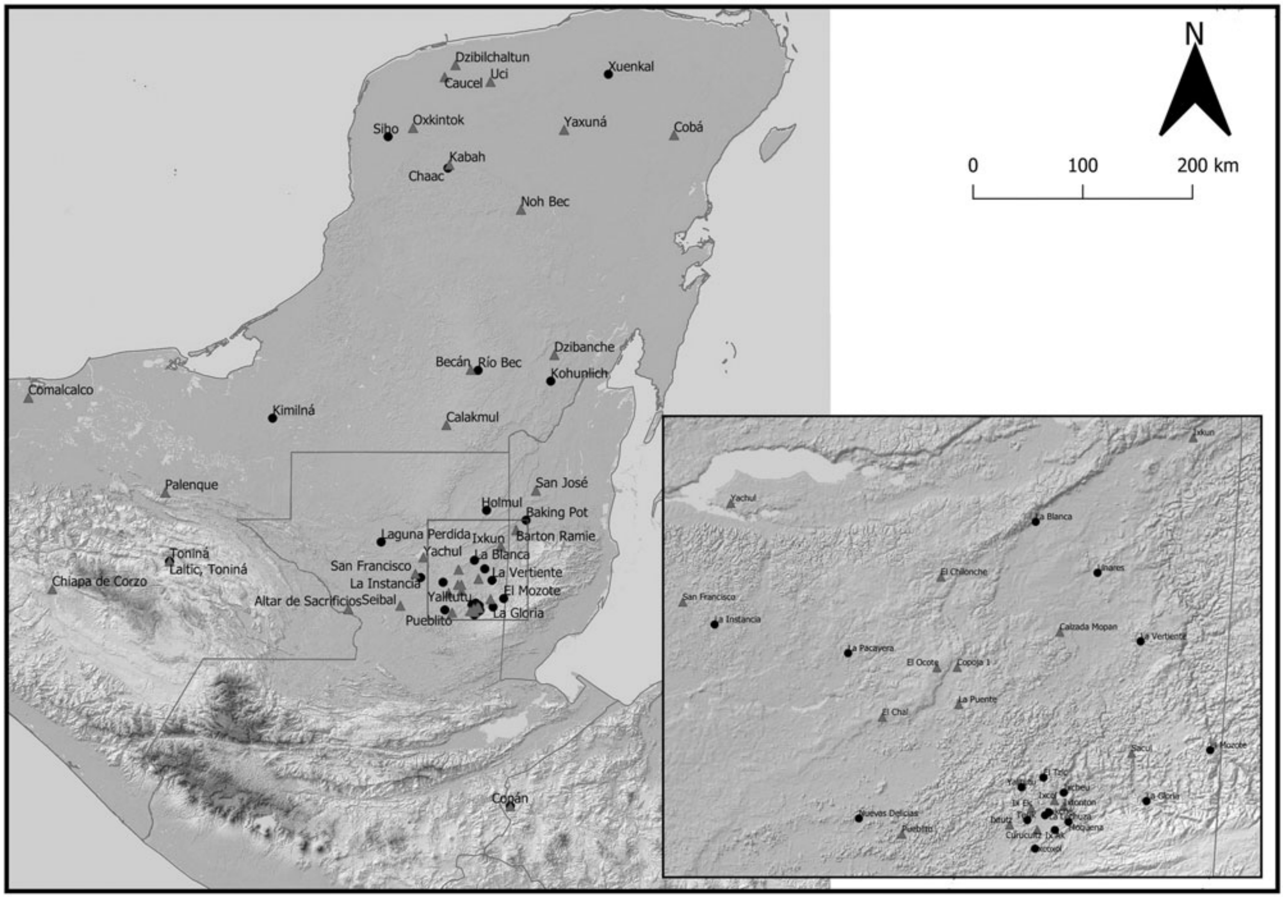

Figure 1. Map of the Maya area indicating the locations of the urban and rural settlement populations included in this study. Circles represent rural sites (>2) and triangles represent urban sites (≤2). Map by Charles Golden, modified by Laboratory of Bioarchaeology/ Universidad Autónoma de Yucatán.

core populations by sparing them from physical exertion and trauma loads; conversely, the dissipated layouts of rural hamlets should spare inhabitants from the infectious loads among the dense and highly populated urban living spaces. Third, we ask whether the nutritional conditions among Classic-period Maya hinterland populations would be adverse when considering their socioeconomic dependence and exploitation by the central urban strongholds. On the other side, rural populations would be relatively spared from the nutritional stresses exerted by urban monostaple dietary supplies, which in the Maya Lowlands would translate into a high maize intake especially in the urban masses. In summary, this set of assumptions measures the weight of political centralization in alternative scenarios of exploitation and food intake versus active rural participation in a complex cultural landscape.

We contend that the three contrasting pairs of assumptions should materialize in distinctive stress loads between dispersed *hinterland* populations and urban neighborhoods, as measured by the expressions of deficiency and degenerative disease and nonspecific physiological stress markers in representative skeletal populations (Steckel 2008). With this trifold of bioarchaeological expectations, we wish to infer and measure how differently sized sites may have impacted the lifestyles, diets, and state of health of their populations.

STUDYING RURALITY FROM THE SKELETAL RECORD

For this study, we screened a regional Maya burial database accrued at the Laboratory of Bioarchaeology of the Universidad Autónoma de Yucatán during the past two decades as part of ongoing collaborative work. A control cohort of adult burials from large sites (centrality levels 1 and 2) was confronted with another pool of residential populations from small, rural sites (centrality levels 3 and 4).

In order to distinguish settlement size, we adapted the settlement classification by Garza and Kurjack (1980) for the Yucatan peninsula and a further, similar ranking system, designed by Juan Pedro Laporte (Laporte and Mejía 2005) for the Guatemaltecan Peten. Similarly structured as the Mexican taxonomy devised by the Instituto Nacional de Antropología e Historia, the terminology by Laporte is based on regional archaeological reconnaissance for which a geographical information system was used. In their research, they differentiate the settlement patterns by the functions and meaning of the architectural type (ceremonial, residential, workshops, among others), as well as artifact assemblages and site volumetry. This multivariable approach distinguishes the centralized urban settlements from dispersed rural hamlets across the central Maya lowlands of Guatemala. The present study combines both classification systems in order to categorize and then confront the rural populations with their urban counterparts.

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Table 1. Frequencies of skeletal conditions among urban adults from Copan.

	Porotic Hyperostosis (%)	Total	Osteomyelitis (%)	Total	Osteoporosis (%)	Total
Copan Urban Males	25 (83.3)	30	30 (54.5)	55	7 (12.3)	57
Copan Urban Females	39 (95.1)	41	33 (62.3)	53	19 (36.5)	52

We acknowledge that the resulting dichotomy of settlement categories is a proxy at the most, a shortcoming that we hope to overcome at least partly with our systematic settlement coverage of the Maya lowlands. One futher caveat of which we are aware relates to the uncertainty that surrounds the location of burial, which does not necessarily coincide with the last residence nor childhood residence.

The present survey includes burial series that span the first millennium A.D. (150–900 A.D.) from lowland settlements that are located away from the coastline and therefore share semitropical inland climate and physiography. Apart from coastal burials, we excluded all cave assemblages along with otherwise problematic human assemblage categories. Over half of the resulting study population originates from the central and southern lowlands. An additional 25 percent correspond to core and non-core populations of the Copan pocket in Honduras. The remaining individuals included are from the Yucatecan peninsula, the Usumacinta basin and the area located still further west (Toniná and Palenque, Chiapas).

The overall series was adapted in response to the methodological requirements of paleodemographic research. All individuals which could not be sexed were excluded to clarify specific lifestyles regarding sex and the size of sites. Subadults were also excluded to reduce the analytical biases implied by positive population growth (as represented by higher proportions of infants and juveniles in the burial record; Wood et al. 1992). These filters left us with a series of sexed adult skeletons with an ascribed age range beyond 15 years old.

One further potential bias is implied by social status itself, which could confound the comparison of urban and rural living conditions, especially thinking of the protected lifestyle among Classic Maya royals. To cope with this issue, we inferred each individual's social standing from a set of mortuary attributes, correlated to funeral architecture, body treatments, and prestige offerings. Our ranking adapts a set of status markers originally proposed by Krejci and Culbert (1995; see also Price et al. 2014; Tiesler 1999). This taxonomy was developed for this specific area and timeline (Classic-period lowland Maya). It considers the presence and quantity of specific artifacts known as "status markers" and distinguishes between commoner burials [status scores 0 and 1], elite burials [status scores 2 and 3], and high elite [status scores 4 and 5] (see Price et al. 2014:Table 1). Although the scores are by no means meant to be a precise expression of each individual's social status during life, they do offer a broad view of social insertion ranges when applied to mortuary populations on the scales of neighborhoods, sites, and cultural landscapes.

To set the stage and scale for our regionally borne comparisons between urban versus rural physiological stress indicators, we implemented a case study of the central urban health hazards from the dense residential areas within one km of distance from Copan's Main Group (Sanders 1990, 2000; Webster 2018; Webster et al. 2000).

The Burial Population

The final number of individuals selected for this study totals 842 people who were buried in 63 Maya sites from urban and rural environments (Figure 1). Our urban case study of central Copan includes a total of 143 individuals (Tables 1 and 2). All members of this population were interred within the radius of one km from the Main Group and are meant to represent Maya urban health conditions (Sanders 1990, 2000; Webster 2018; Webster et al. 2000). This numerically large and well-documented skeletal population sets the benchmark for validating the subsequent comparisons of regional stress frequencies between urban and rural lowland populations and is roughly in line with the regional urban cohort, except for its higher osteoporotic load among women (Figure 1 and Table 2).

From the overall regional sample, some 216 individuals from small sites were compared with 626 individuals buried in tier-1 and tier-2 urban centers (Figure 1 and Tables 3–6). Status scores could be assigned to 679 of the 842 individual contexts (which were not looted or otherwise altered in contents and arrangement). The status scores are more diverse among the urban populations as expected. While only three rural individuals scored 4, some 28 urban dwellers scored 4 or 5, among them, Palenque's ruler Janaab' Pakal and Calakmul's Lord Yuknoom Yich'aak K'ahk' (Jaguar Paw). Nevertheless, the urban status scores are not significantly different from the rural scores in the overall collective comparison. Urban neighbors from the regional sample display a slightly higher average (0.78, N = 521) when compared to the 143 individuals of Copan's central urban sample (0.67). The hinterland peers of the regional cohort display an average score of 0.74 (N = 158). In tandem are the sexed status scores: urban males score slightly higher on average (0.83, N = 293) when compared to rural males (0.81, N = 91). Urban females present an average status score of 0.73 (N = 228), while rural females (N = 67) show a lower ascribed score on average of 0.65. More specifically in urban Copan, the average status score in males is 0.74 (N = 71), whereas females from the same series score lower (0.6, N = 72).

Sex and Age-at-Death

In a subsequent step, we extracted the information of sex and age-at-death as independent variables for measuring five nonspecific physiological stress markers from our systematically documented database, following a standardized protocol for all individuals included in this study. Age-at-death and sex were estimated macroscopically and relied mainly on gross morphological parameters of the pelvis, cranium, teeth, and the mandible (Buikstra and Ubelaker 1994). When possible, the macroscopic sex determination was aided by metric discrimination of single and multiple variables adapted from a regional Maya sample (Tiesler 1999). The general skeletal robustness was recorded and dimorphic measures of long bones with a specific reference to the Mesoamerican populations were taken (Wrobel et al. 2002).

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Table 2. Level of significance (p-values) obtained from chi-square comparison of disease according to sex among urban settlers from Copan. Statistically significant differences are displayed bold. Level of significance p ≤ .05.

Disease	Urban Males versus Females	Urban Males Copán versus Urban Males Regional Sample	Urban Females Copán versus Urban Females Regional Sample
Porotic hyperostosis	.213	.832	**.032**
Osteomyelitis	.415	.521	.464
Osteoporosis	**.002**	.116	.531

Table 3. Number of teeth affected by caries and frequency of caries according to sex and settlement size.

	Caries per Tooth (%)	Total Teeth
Urban males	277 (13.5)	2,054
Urban females	219 (19.2)	1,141
Rural males	90 (9.9)	902
Rural females	80 (16.9)	472

Table 4. Enamel hypoplasia expression according to sex and settlement size.

	Absent <2 [0–4]	Present ≥2 (%) [0–4]	Average Score [0–4]	Total
Urban males	2,879	394 (12.0)	.73	3,273
Urban females	2,081	192 (8.4)	.63	2,273
Rural males	1,085	131 (10.8)	.7	1,216
Rural females	572	82 (12.5)	.68	654

The individual age-at-death ranges were clustered according to age categories: adult (≥ 15) when age estimation range was impossible, late adolescent/early young adult (15–24.9), young adult (25–34.9), middle adult (35–44.9), mature adult (45–54.9), and elderly adult (≥ 55).

Caries and Enamel Hypoplasia

Enamel hypoplasia defects (in the form of grooves, lines, and pits) are acquired during tooth development. These defects are visible during the remainder of the individual's lifespan (or until premortem tooth loss) because enamel does not remodel once formed. The enamel microdefect patterns, displayed between and within teeth, may materialize congenital abnormality, local trauma, and more so systemic stress episodes in the form of acute disease and/or dietary shortages (Goodman et al. 1984, 1988).

Table 6. Level of significance (p-values) obtained from chi-square intergroup comparison of disease according to sex and site size. Statistically significant differences appear as bold. Level of significance p ≤ .05.

Disease	Urban Males versus Females	Rural Males versus Females	Urban Males versus Rural Males	Urban Females versus Rural Females
Porotic hyperostosis	.569	**.016**	.424	.104
Osteomyelitis/periosteal reaction	.593	.483	.734	.459
Osteoporosis	**<.002**	.872	.138	.434
Caries	**<.002**	**<.001**	**.007**	.291
Enamel hypoplasia	**<.001**	.2518	.241	**.001**

Cariogenic lesions result from dental enamel, dentine and/or cement demineralization, caused by bacterial activity in the dental plaque and mediated by acid pH levels. Caries prevalence is the end result of a set of complex processes that involves the interplay of internal and external stimuli. Diet and oral care are considered the two main factors that play a role in the cariogenic process. A diet enriched in sugars, such as staple carbohydrates and honey, is bound to produce an unbalanced oral pH and elevated bacterial activity, which in turn cause carious lesions (Hillson 1996).

For the present study, caries and enamel hypoplasia were scored by tooth rather than by individual, following standard procedure in dental anthropology and acknowledging the poor state of preservation of the samples. Carious lesions and enamel hypoplasia (in the form of linear defects) were recorded on all permanent teeth (Figures 2a and 2b). All teeth that did not allow systematic scrutiny because of advanced attrition, calculus, and/or dental modification were excluded from this study. In the remaining study cohort, carious defects were registered as present when the cavity had invaded the dentine, corresponding in each case to category '2' and beyond in a range of defect expressions from '0' (absent) to '4' (crown severely deformed; Schultz 1988). In the case of caries, "presence" indicates defects that are at least two mm wide and reach the dentine. Enamel pits that possibly could be confused with early stages of caries were previously excluded from the count. In total, 4,569 permanent teeth were analyzed for caries and 7,416 permanent teeth for enamel hypoplasia (Tables 4 and 6).

Table 5. Number of scored individuals and frequencies according to sex and settlement size.

	Porotic Hyperostosis (%)	Total	Osteomyelitis (%)	Total	Osteoporosis (%)	Total
Urban males	129 (83.8)	154	104 (59.4)	175	37 (21.8)	170
Urban females	90 (81.1)	111	71 (56.3)	126	52 (41.6)	125
Rural males	52 (88.1)	59	33 (56.9)	58	14 (32.5)	43
Rural females	26 (68.4)	38	23 (50)	46	12 (34.3)	35

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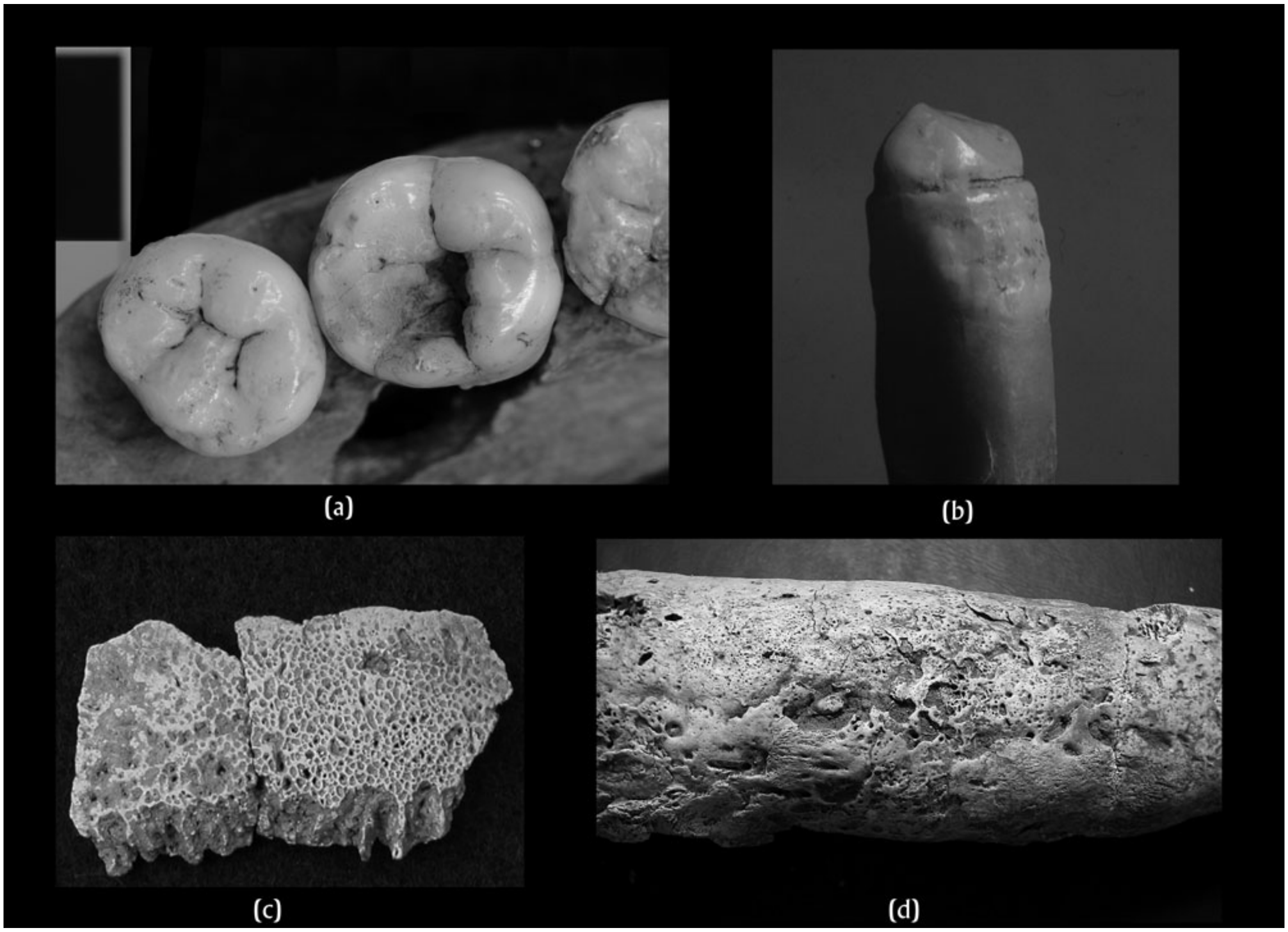

Figure 2. (a) Carious lesions affecting a mandibular second molar (Yaxuna, PIPCY). (b) Linear enamel hyploplasia in a mandibular canine (Yaxuna, Proyecto Arqueológico Yaxuná, Yucatán, México (Selz Foundation). (c) Porotic hyperostosis in parietal bones (Atlas de Guatemala/Instituto de Antropología e Historia de Guatemala). (d) Severe chronic osteomyelitis/ subperiosteal reaction in an adult tibia (Laltic, Tonina/Clausto de Sor Juana). Photographs courtesy of Laboratory of Bioarchaeology.

Porotic Hyperostosis

Childhood stress episodes were inferred from the presence of healed porotic hyperostosis (Figure 2c). Porotic hyperostosis is defined as abnormal porosities on the external surface of the cranial vault. These lesions are the product of reorganization and radially oriented enlargement of the diploic tissue or the apposition of bone on top of the external lamina of the cranial vault. Active remodeling will occur only in infants but will leave visible porotic lesions in those individuals surviving through adult age. Although porotic hyperostosis may relate to inflammatory conditions and the ossification of a subperiosteal hematoma, it is likely related to childhood anemia (Schultz 2003). The scoring system used in this study follows the taxonomy and criteria proposed by Schultz (1988) and dichotomizes grades of '2' and above as "present" (Table 5).

Osteomyelitis/ Subperiosteal Reaction

Infectious diseases were a common cause of chronic suffering and death in pre-antibiotic populations. Nonspecific osteomyelitis is an infectious disease caused mostly by the introduction of a bacteria through a traumatic injury, either infiltrating from a tissue already infected or by the blood stream (Ortner 2003). The prevalence of osteomyelitis/subperiosteal reaction along the skeletonized body of the ancient Maya is an approach to evaluate the health risk during their life due to association with poor hygienic conditions and an adverse living environment.

For the purposes of this study, all bone surfaces were examined systematically for subperiosteal accretions and abnormal porosities under a bright light and magnifier, following the criteria described by Brickley and Ives (2008) and Ortner (2003; Figure 2d). Undamaged surfaces were distinguished from those that showed longitudinal, fine to coarse striation (when at least one half of the diaphysis was scoreable). Additional isolated or diffuse patches of bone apposition and general swelling of bone segments were also noted in this category (Table 5), as well the dense versus porotic nature of the bone accretions. In the literature (Ortner 2003), this set of reactions is usually correlated with open and infected wounds that result in chronic systemic (nonspecific bacterial) osteomyelitis with a subperiosteal component.

Osteoporosis

Osteoporosis is catalogued as a degenerative disease that occurs due to an unbalanced or poorly balanced remodeling process, resulting

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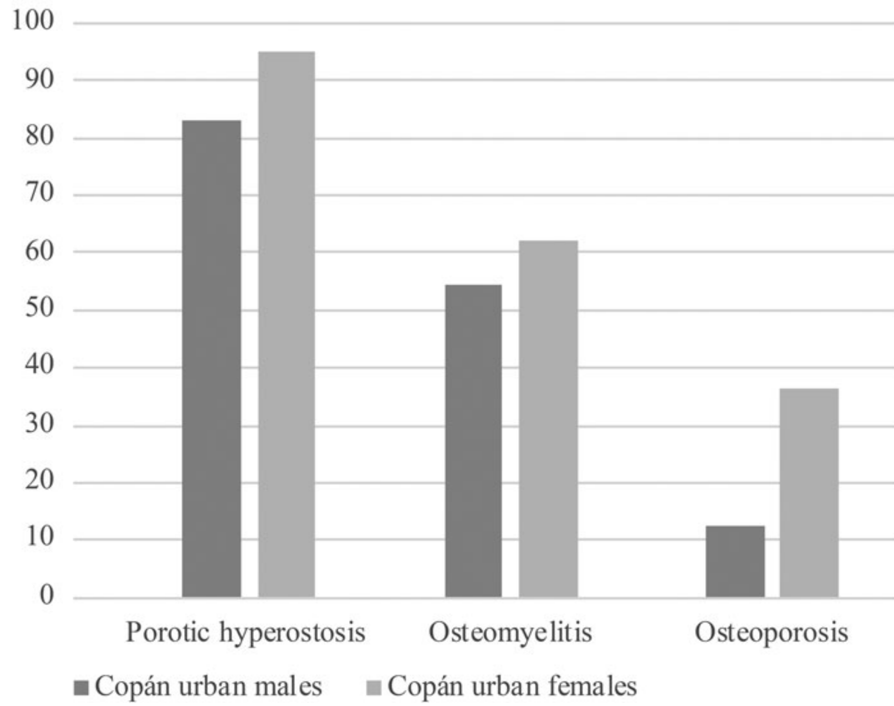

Figure 3. Frequency of skeletal conditions among central urban females and males from Copan, Honduras. Graph by López Pérez.

in the progressive loss of calcified substance and, with it, a reduced skeletal resistance (Ortner 2003; Schultz 1988). This weakness in the bone tissues can increase the vulnerability to trauma among the affected individuals, most of whom are mature or elderly. Osteoporosis, as the other pathologies described above, is a multifactorial illness, although most noticeably triggered by hormonal shifts during female menopause. Some of the general factors involved in the prevention of premature osteoporosis is physical activity. Factoring in sex, human females are more likely to manifest osteoporotic bones than males (Brickley and Ives 2008; Ortner 2003). After excluding all incomplete and poorly preserved postcranial skeletons, we scored the macroscopic osteoporotic lesions (Table 5) on a scale of '0' (absent) to '3' (severely osteoporotic) based on the macroscopically visible rate of reduction in compact tissue thickness of long bones.

SETTING THE STAGE: PHYSIOLOGICAL STRESS LOADS AMONG THE ADULTS OF COPAN'S CENTRAL NEIGHBORHOODS

To provide a benchmark for subsequent regional comparisons and discussion on potential urbanization impacts, we obtained stress frequencies in a numerically elevated, sexed, and individually contextualized skeletal cohort from the largest site series of our regional database. It comes from Copan, Honduras, the main Classic-period urban stronghold on the Maya southeastern peripheral area. Some 207 adults make up this cohort, all of whom had been buried beneath the dense residential units within one km from Copan's Main Group. For the purposes of this research, we pooled the scores obtained from three archaeologically-retrieved collections from this site (PAC-Phase I, PAC-Phase II, and the holdings of the Peabody Museum of central Copan tombs and burials; Figure 3 and Table 1).

In tandem with the overall regional age-at-death trend (Figure 4), the male and female collective from Copan's central quarters shows a slight death peak between the fourth and fifth life decade. The assessment of dental stress indications in the Copan samples was excluded due to inconsistencies among the recording methods and low rates of scored teeth due to decay. Higher female stress ratios were noted among all three skeletal stress indications. Porotic hyperostosis frequencies sustained by boys and girls who survived to adulthood from Copan's central neighborhoods are 83.3 percent and 95.1 percent, respectively. No statistically significant difference was documented between the sexes (Figure 3, Tables 1 and 2). In the postcranial skeleton, the frequency of osteomyelitis was lower among central urban males (54.5 percent) when compared to their female counterparts (62.3 percent) without there being statistically significant differences (Figure 3, Tables 1 and 2). The frequencies of osteoporosis are displayed in Figure 3 and Table 1. According to our results, some 12.3 percent of Copan's male settlers were affected, while females triplicate this frequency (36.5 percent), indicating statistically significant differences (Table 2).

REGIONAL TRENDS

In the following, we address the results obtained among the scored adulthood and childhood stress frequencies on a regional scale (Figure 1), comparing each ratio according to settlement size and sex.

Sex and Age-at-Death

The adult mortuary population from urban centers is slightly older than the one derived from small sites (Figure 4). Although this trend is apparent both in women and men, we shall not generalize on this aspect due to potential biases that may have been introduced by fertility and population shifts (which in practice come to produce

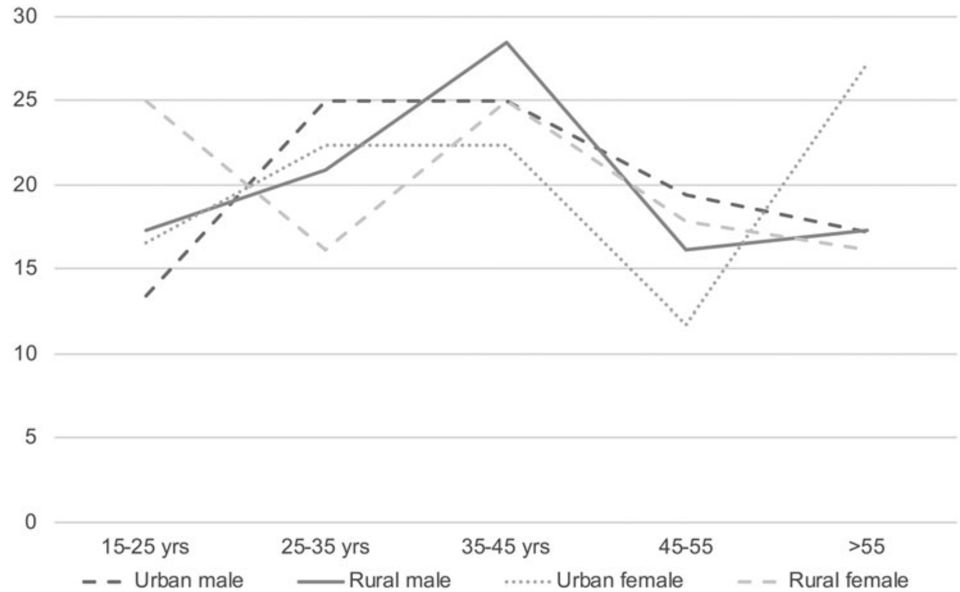

Figure 4. Age-at-death profile distribution of the Classic-period adult burial population from rural and urban sites according to sex. Graph by López Pérez.

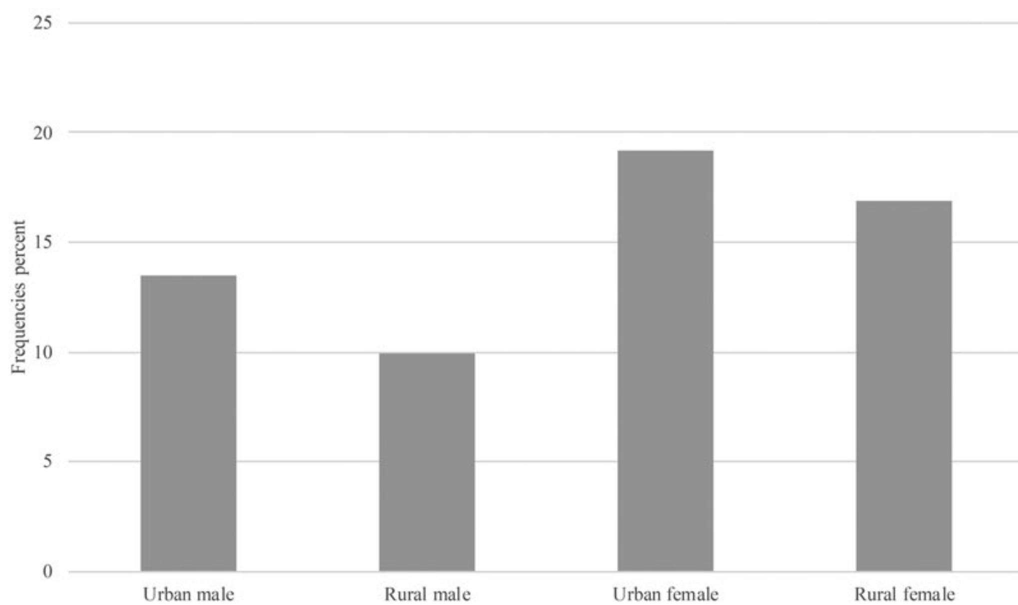

Figure 5. Caries frequencies according to sex and settlement size. Graph by López Pérez.

"artifacts" in the adult age distributions that would be unsubstantiated in an equivalent stationary population, i.e., with no positive or negative population growth; see Wood et al. 1992). Age-at-death profiles, according to sex and centrality category, are provided in Figure 4 and broadly reflect the adult age-at-death distribution described for Copan's central neighborhood populations. It is noteworthy that urban females and males are more evenly dispersed across the middle adult age ranges than their rural peers. While the urban age distribution shows a platform of dead young and middle-aged adults (third through fifth life decade), their rural peers of both sexes display a peak in their late thirties and early forties. Only the urban female series shows a rise in elderly age ranges (beyond the 50-year threshold).

Caries and Enamel Hypoplasia

Frequencies of caries and enamel hypoplasia are listed in Tables 3 and 4, respectively. The prevalence of carious teeth ranges from 9.9 percent among rural males to 16.9 percent in rural females. Higher are the cariogenic frequencies among urban male adults (13.5 percent) and urban females (19.2 percent) when compared to their rural neighbors (Figure 5 and Table 3). This difference is statistically significant (Table 6).

The frequencies of enamel hypoplasia defects according to dichotomized centrality and sex appear in Table 4. Figure 6 displays the percentage of teeth with enamel defects per number of evaluated teeth. Enamel defects among rural and urban boys who lived to be

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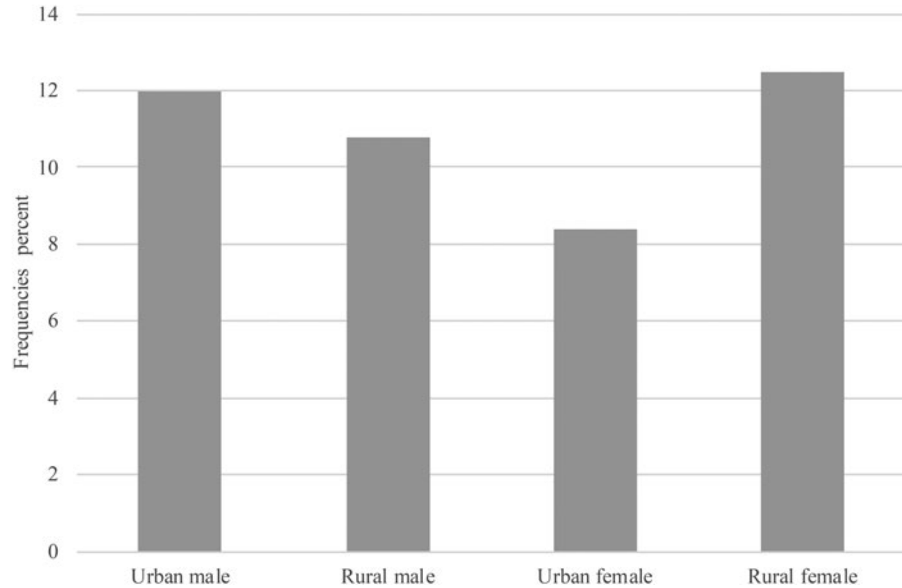

Figure 6. Frequency of enamel hypoplasia according to sex and settlement size. Graph by López Pérez.

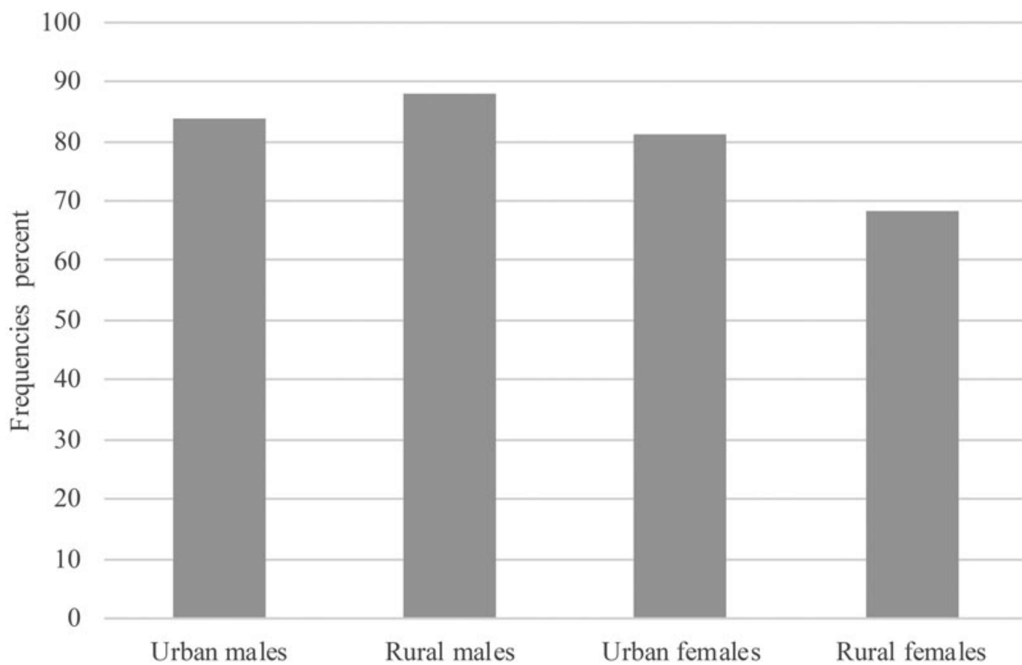

Figure 7. Frequency of porotic hyperostosis according to sex and settlement size. Graph by López Pérez.

adults are similar. Infant boys, however, experienced slightly more stress growing up in urban areas when they are compared to boys from the rural villages and hamlets (12.0 percent and 10.8 percent, respectively). The average expression of enamel defects in a range of '0' (no sign) to '4' (highly deformed) shows that urban males suffered an average of 0.73 in expression, which is slightly higher when compared to their rural male peers (0.70). Inverse to the boys' enamel microdefect trend, urban girls represent the lowest nonspecific stress indicator in their enamel (8.4 percent, 0.63), while the most severely affected were rural girls who had survived to adulthood (12.5 percent, 0.68). Thus, it appears that the combined effects related to sex and site centrality led to significantly more childhood stress among rural females than any other group (Table 6).

Porotic Hyperostosis

The prevalence of skeletal childhood stress by sex and settlement size is represented in Table 5 and Figure 7. The overall frequency of porotic hyperostosis ranges between 88.1 percent among the rural boys and 68.4 percent among those rural girls who survived through adulthood. Statistically significant differences were found when comparing rural males with rural females (Table 6). Relatively lower is the ratio frequency among urban boys, an 83.8

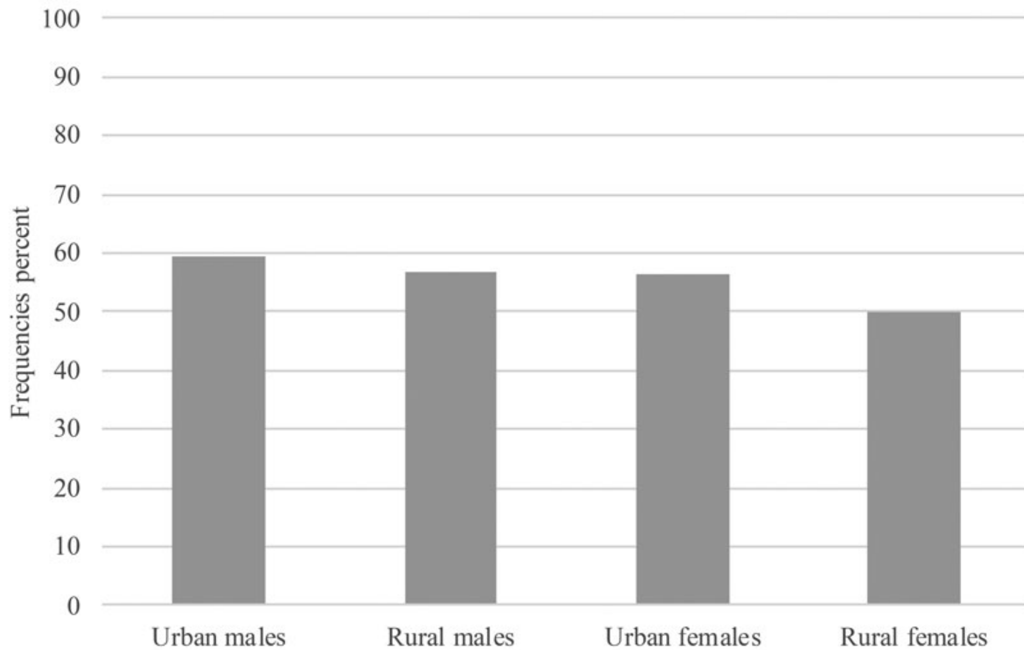

Figure 8. Frequency of osteomyelitis/subperiosteal reaction according to sex and settlement size. Graph by López Pérez.

percent of whom show healed lesions, and higher for the urban girls, among whom an 81.1 percent show signs of analogous lesions (Figure 7). Still higher is the ratio among Copan's female core settlers. Only one out of 20 female grown-ups (4.9 percent) do not show the scars of porotic hyperostosis (Figure 3, Tables 1 and 2).

Osteomyelitis/ Subperiosteal Reaction

According to the present results, half (50 percent) of the rural females displayed reactive osteomyelitis, compared to a slightly higher rate of 56.9 percent of the rural males. The sexed urban frequencies are similar at 56.3 percent among females and 59.4 percent among males (Figure 8 and Table 5). No statistically significant differences were found regarding either sex or centrality (Table 6). Again, the frequencies of systemic osteomyelitis among the women of central Copan are comparatively higher (62.3 percent; Figure 3, Tables 1 and 2).

Osteoporosis

Some 12.3 percent of Copan's central male residents are affected by systemic bone loss, while females triplicate this frequency (36.5 percent), indicating statistically significant differences (Figure 3 and Table 1). Similar to the sex differences among Copan's core settlers are those from the regional urban settlements. Urban males present the lowest ratio of osteoporosis (21.8 percent), while urban females (41.6 percent) display twice their frequency (Figure 9 and Table 5). Again, statistically significant differences were obtained when both sexes are compared (Table 6). Interestingly, a sex difference is not apparent when osteoporosis frequencies among rural females (34.3 percent) are compared to rural males (32.5 percent). The latter are much higher than the osteoporosis frequencies measured among urban males (21.8 percent) and almost triple the ones among Copan's urban males (12.3 percent).

DISCUSSION

Unfortunately, low sample sizes hamper lowland Maya bioarchaeological explorations by way of invalidating most generalizations about health and lifestyle when calculated from reduced archaeologically-retrieved burial series. The shortcoming becomes apparent in our own study cohort in which the available individual count per site averages only seven individuals per rural settlement and 18 individuals per urban settlement. This was the point of departure for the present, more regionally geared examination in which we used close to 1,000 sexed adult individuals from systematically selected burials for the collective scrutiny of physiological stresses.

This research builds on prior bioarchaeological studies that have focused on specific settlements or circumscribed areas within the Maya sphere, where the archaeological landscapes have been systematically surveyed and excavated, leading to the recovery of large skeletal series. An example of such work is the continuing regional survey of southeast Peten, Guatemala, by the Archaeological Project Atlas of Guatemala (Instituto de Antropología e Historia, Laporte and Mejía 2005). In the course of these efforts, some 400 systematically documented skeletons from 50 sites were made available for systematic skeletal analysis. East of the southeastern Peten lies the Belize Valley, which has similarly benefited from intense scholarly coverage and includes numerous well-documented skeletal series (Novotny 2012, 2015). Further south, the Río de la Pasión region has been extensively surveyed and reported by Wright (2006). The Copan pocket, extending in length some 40 kilometers, adds to the list of such regional surveys. Although more restricted in territory than the previously mentioned areas, the pocket of Copan, Honduras, has been among the most intensely studied Maya settlement networks with approximately 1,000 recorded burials and a standing nomenclature of settlement sizes and types spanning the Copan Valley (Whittington 1988).

Before comparing our results with further scrutiny of rural and urban living conditions, some cautionary remarks apply due to

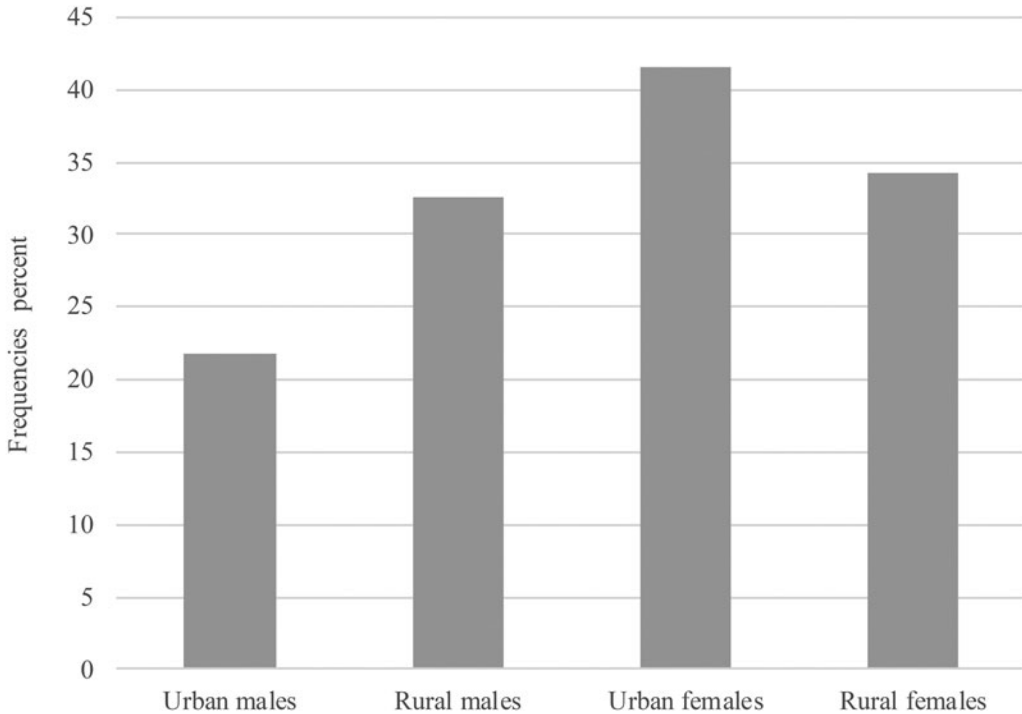

Figure 9. Frequency of osteoporosis according to sex and settlement size. Graph by López Pérez.

the potential biases implied by generalizing about Classic-period rural versus urban well-being across the Maya lowlands. The first bias adheres to the sex distribution of our overall series with its slight male predominance (56.8 percent). This is to be expected and most probably is the final outcome of excavating the central portions of sites which are prone to harbor more males than females. Other potential causes of bias are related to preservation issues due to the fact that male sex is easier to determine than female sex when dealing with the deteriorated skeletal remains that characterize Maya lowland burials, as discussed in other research (Krejci and Culbert 1995; Tiesler 1999). Given the slight male predominance, our results are valid only when we separate male from female health profiles. Therefore, we have limited our comparisons to urban and rural females and urban and rural males and shall do so in this discussion.

An additional bias relates to the divergent social insertion among some urban dwellers, as represented by a higher proportion of urban dwellers in the royal elite category of '4' and '5', which in other work has shown to display discrepant, mostly reduced, stress frequencies (Tiesler 1999; Wright 2006). Fortunately, the overall consideration for this bias is negligible on the grounds of the reduced portions of such burials in each stress category, as expressed by the overall averages of status scores. Still a further shortcoming has to do with section points in our approach. Dichotomize trends, according to presence and absence, do not ideally represent the nuanced conditions underlying health and stress loads. As we acknowledge, the heterogeneous corpus of information limits the problematization of urban and rural sites.

After reducing the above biases at least partly by sample exclusion versus inclusion strategies, however, a number of general trends become apparent when confronting the regional database with the scores of adults buried in central Copan (Figure 3 and Table 2). The latter shows higher female stress loads in all three skeletal markers. Regarding porotic hyperostosis and osteomyelitis, this trend signals that female residents were less buffered against stress and disease than their male co-residents. Given the relatively uniform study cohort, this result points to local differences between the sexes in principle and potentially so, discrimination against female inhabitants. Less apparent is this gap within the sexes among the regional urban cohort.

No clear-cut differences are apparent between urban and rural living conditions *per se*. Instead, the ratios of the nonspecific stress markers and systemic conditions draw a heterogeneous picture when confronted according to sex. With all the above, we think that the multifarious nature of our trends dismisses any ad hoc simplifications regarding benefits versus costs of living in small villages. At least, the projected picture highlights a differentiated set of costs and benefits among rural lifestyles, which is still more evident when considering the statistically significant differences only in female enamel hypoplasia defects (and not male) and in male caries (Table 4). It seems to follow that some health trends are clearly based on the sex of the individuals. This gendered quality apparently shows that lifestyles would have been played out differently according to centrality. Despite a shared geography and a subtropical setting, this aspect potentially translates distinctions in the ascribed occupations and social roles of women and men in differently sized sites, "snapshots" of the complexities involved in the different lifestyles and living conditions throughout the first millennium A.D.

Such a case could be made for the similar osteoporotic ratios among rural men and women. Given the analogous age-at-death distributions (Figure 4), this trend makes us suspect that an elevated physical regimen was part of these men's and women's daily routine both within the domestic and agricultural sphere. Conversely from the hinterlands, urban males and females show lower ratios. Compared among urban adults, the frequencies are highly discrepant in their expressions of systemic bone loss both in our regional study cohort and in Copan's core population.

Copan's female residents suffer three times more from osteopenia than their male peers. In the regional urban series, twice as many women are noted for bone loss when compared to urban men, this being a statistically significant difference. This contrasting trend is well explained in tandem with the correlated age-at-death profiles. We assume that the benefit of females living in urban environments is related to a relatively high life expectancy as they reach their mortality peak long past menopause (Figure 4). Within the context of lifestyle and physical regime, it appears that both men and women living and dying in urban centers would experience a more sedentary lifestyle than their rural peers.

Beyond the skeletal biomechanics of daily physical exercise and its role in preventing premature and specifically osteoporosis past the female reproductive age; there can be only speculation with the present data about the specific biocultural conditions behind this and the four other physiological health burdens among the Classic-period lowland Maya. We will therefore attempt to trace a number of these trends, starting out with stress indications that were shared among inland populations without distinctions of their urban or rural residence. Such a shared health burden was apparently expressed by healed lesions of porotic hyperostosis, which in the literature are associated mainly to the scars of childhood anemia, as produced by an insufficient weaning diet or extrinsically conditioned by parasites of the intestine. Both urban and rural inland series of this study showed high levels of exposure that surpass 70 percent among the scored adult populations. Whittington (1988:300, 313–314) documents similar affliction rates among inland Maya buried in and around Copan. Whittington specifies that some 60 percent of Copanecan adults had suffered from hyperostosis episodes during their infancy and further poses that type 1 (rural) sites were the most affected by this post-weaning stress condition. Note that such rates of porotic hyperostosis are high across the inland Maya lowlands when compared to the frequencies recorded from coeval coastal sites. As an example, we cite the study by Cetina and Sierra (2005; Sierra et al. 2014) of a large skeletal series of over five hundred well-preserved skeletons from the small coastal port of Xcambo, Yucatan. Using an equivalent scoring system to the one used in this study, hyperostotic affliction of cranial vaults scored below the 25 percent mark. Faced with this significant difference between coastal and inland frequencies, we ask whether coastal populations exploited more successfully the diverse ecological niches and therefore enjoyed a better balanced diet, which would benefit their children. Why did poor inland weaning diets induce anemia in childhood similarly among urban and rural populations?

By combining oxygen and carbon isotopic analyses in tooth enamel, Wright and Schwarcz (1998) inferred the timing of weaning among Kaminaljuyu's infants happened during the first year of life while the breastfeeding continued through the fifth year. Consequently, the health risk induced through contaminated food and water during the introduction of solid food could have caused anemia, as the authors discuss. Although not focused on the effects of post-weaning diets in infants, *per se,* a number of additional studies on dietary isotopes among Classic Maya lowland sites have successfully demonstrated that the diversity in food intake among grown-ups depended on their environments (Gerry 1997; Gerry and Krueger 1997). Independently from settlement centrality, Somerville and colleagues (2013) showed that commoners kept a constant food menu throughout the Classic period, whereas elite inhabitants evidenced more variability in consumed food sources in comparison with commoners over the same period. Similar trends are sustained by the bone and enamel geochemistry among Belize River (Freiwald 2011), the Copan pocket (Whittington 1988), and the settlers from Río de la Pasion (Wright 2006).

Differences between urban and rural living conditions are more apparent among postcranial infectious loads (osteomyelitis/ periostosis). In the overall populations, the majority of lesions are healed and concentrate in both lower legs (fibulas and tibias). This is explained by the low rate of blood circulation, which makes this part of the organism susceptible to infectious propagation and therefore visible subperiosteal reaction. Over half of the urban adult populations show the vestiges of such condition either active or (in most cases) healed. Inversely, only half of rural females displayed such osteomyelitic lesions. We follow that they were apparently spared from some of the loads that affected their urban peers, such as open inflammatory trauma. Similar to our findings, Whittington (1988:334; 342, Table 11.6) identifies that half of the adult tibias from Copan display lesions and points out that the urban core population was more affected than the non-core population. Analogous disease loads, tied to chronic infectious conditions, have been recorded by Storey (1992, 1999) and Whittington (1992, 1999) for the central urban population of Copan's Las Sepulturas neighborhood and interpreted as the health cost of specialization and loss of diversity of food staples.

Similar trends appear among the statistically significant comparisons of enamel defects and cariogenic frequencies. The difference of enamel hypoplasia ratios according to centrality and female may indicate varied disease hazards and stress loads among urban children. In this scheme, girls growing up and surviving in urban residential units were predisposed to more stressors while boys appear to have buffered the impact of general stressors. Therefore, we must engage the possibility of cultural gender discrimination during breastfeeding, weaning and later upbringing practices of girls. A cautionary note for this interpretation regards the multi-etiological nature of enamel hypoplasia, of course, which renders any direct causal association of childhood stress problematic.

Finally, cariogenic defects express higher female exposure in our study sample. This trend is expected in most agricultural populations due to the combined effect of pregnancies and active role in daily processing of cariogenic staple foods, mainly maize (Cucina et al. 2011). Independent of the differences between both sexes, females and males signal a lower rural exposure in our sample population when compared to their urban counterparts. Urban neighbors appear to express either a lower collective level of oral hygiene or a higher reliance on monostaple crops with a (cariogenic) carbohydrate content (Cucina and Tiesler 2003; although see Cucina et al. [2011] for a cautionary note on equaling carbohydrates to cariogenic frequencies).

While the focus and scope of this research—i.e., the biocultural analyses of human remains from archaeological contexts of hinterland communities all over the Maya inland lowlands— has not been pursued so far among studies of rural Maya bioarchaeology, there have been noteworthy efforts in this direction already. To illustrate this point, we single out the research by Wright and White (1996; see also Wright 2006), who put to work systematic regional coverage to measure the evolving population impacts of infectious disease and malnutriton among Classic populations, and possible late shifts during and after the collapse of inland kingdoms. These authors concluded their studies by demonstrating geographic variability among a number of stressors, such as porotic hyperostosis (Wright and White 1996:160). Still more important, Wright and White do not encounter significant increases in stress frequencies in more recent prehispanic Maya populations and conclude that their stressors were buffered similarly to earlier ones. Hence, Wright and White reject the ecological model as the main explanation for the Maya collapse (at least for the Pasion Region; see also work by Wright [2006]) and instead explore the viability of sociopolitical conditions as the main dynamic behind the collective crisis and abandonment of immense areas inside the Peten. Our regional results, although static, are analogous to those of Wright and White in that they do not show a clear-cut pattern of ranking. Beyond the 'crisis' label, our results underscore some additional health trends for Classic-period Maya populations that have not been explored in this form in prior research. For example, we demonstrated that stress loads during the Classic period affects both sexes differently while apparently not being driven as much by settlement size.

One further point of discussion concerns the low occupational densities among Maya settlements, even within cities. The dispersion of living spaces has been related to Maya urban design (clustered residential zones as urban aggregates) and the multifaceted and non-intensive appropriation of the semitropical agricultural landscapes by Maya farmers (Isendahl and Smith 2013; Smith et al. 2015). Even more dispersed are the rural Maya villages, hamlets, and farmsteads (Lemonnier and Arnauld 2022). From this functional and ecological approach, the urban versus rural dichotomy seems problematic to uphold.

Finally, within the dynamic network of differently sized settlements, Maya peasant mobility equally awaits systematic exploration (Smith 2014), considering a number of related questions: how did rural immigrants integrate into the social structure of their new first or second tier urban locality? How did migration modify the social fabric of the settlements during and after out-migration? Beyond categorically affirming their presence and impact on ancient Maya society (Freiwald 2011; Price et al. 2008, 2010, 2014; Suzuki et al. 2020; Wright 2012), more specific inferences regarding the motivations and social dynamics behind the elevated intra- and interregional mobility still remain speculative, at least for the era before the so-called Maya collapse.

CONCLUSIONS

This study has utilized a bioarchaeological and comparative approach to explore health-related aspects of well-being and health benefits versus costs among Maya rural populations as opposed to Maya populations living in large urban aggregations. Beyond its purely exploratory nature, this research has adopted a series of concepts, formulated by Marcus (2004:260–270) on Maya urban/rural relationships, that may have affected lifestyle both positively and negatively. Our study has tested these assumptions by comparing the frequencies of nonspecific stress markers among the burial populations documented from 63 differently sized Classic-period sites. At the beginning of this research, we have proposed that the living conditions among Classic-period Maya hinterland populations would be adverse when considering the socioeconomic dependence, degree of political centralization and urban benefits. In an alternative scenario of active rural participation in a complex cultural landscape, rural populations would not be as much affected by the health cost of the dietary stresses experienced by urban aggregations from their urban monostaple dietary supplies, which in the Maya Lowlands would translate into a high maize intake. Furthermore, we expected that rural hinterlands were spared from the high infectious loads associated with living in densely populated urban strongholds.

After scoring and discussing the expressions of each of the five deficiency conditions and nonspecific physiological stress markers under study, our results show inconsistency with most of our prior expectations, except for confirming a relationship between rural residence and a more physically demanding regime among men and women. Beyond bone biomechanics, the dietary stresses (as expressed by porotic hyperostosis) appear to affect a similar number of children raised in rural and urban environments. This trend proves our pair of opposing previous assumptions invalid or irrelevant. Also, caries frequencies among adults are correlated with sex rather than with settlement size (although the latter does factor in), and only the frequency and expression of enamel hypoplasia appear to be correlated to site size but not by sex. Equally inconsistent were our results regarding the infectious loads (as expressed by nonspecific subperiosteal reactions) among urban neighbors versus rural settlers. Both series display similarly elevated frequencies among males, while females from hinterland communities appear to be relatively spared. Beyond the biases imposed by the different social profiles among the funerary samples, this is by itself a health indication. We follow from all of the above that cultural, social, and population changes have impacted the potential health benefits and costs of inland populations in a complex and nonuniform fashion. This finding, by itself, is extraordinary given that the natural environments and broader subsistence regimes remained stable over the centuries during the first millennium A.D. across the inland Maya lowlands.

We close by acknowledging that, despite the systematic research design and the large sample population, our survey does not escape the inherent shortcomings of engaging in static dichotomies instead of more nuanced trends. The multifactorial mechanisms involved in lifestyles and stress loads come to deny any categorical affirmative statement or causal explanation regarding the relationship between well-being and rurality (or urbanism, for that matter). This leaves us with an added heuristic value for future Maya rurality research. These should be aided by equally broad but more nuanced settlement validations, ideally guided by systematic LiDAR coverage across the ancient urban and rural Maya landscapes (Garrison et al. 2019; Lemonnier and Arnauld 2022). Still more important, we wish to have incited new questions and thoughts regarding the intricate dynamics among the semitropical settlement landscapes of the Maya Lowlands.

RESUMEN

Las condiciones de salud varían entre los miembros de las sociedades estatales, dependiendo del género, los privilegios sociales y su residencia urbana versus rural. Como tales, estas condiciones son propensas a expresar las experiencias de vida individuales y, en última instancia, su bienestar. En este artículo se exploran dichos correlatos, examinando y poniendo los marcadores de estrés fisiológico de poblaciones rurales mayas en contexto con sus pares urbanos. Para ello, comparamos las frecuencias y las expresiones de la hipoplasia del esmalte, la caries, la hiperostosis porótica y la osteomielitis infecciosa /reacción subperiosteal, medidas en 842 esqueletos adultos de ambos sexos que proceden de 63 asentamientos periféricos y céntricos de las Tierras Bajas mayas alejados de la costa. Nuestros resultados sugieren dietas de destete problemáticas y cargas infecciosas elevadas entre poblaciones rurales. La mayoría de los resultados marcan distinciones entre hombres y mujeres y, en general, muestran cargas de salud inconsistentes cuando se comparan entre los medios de vida urbanos y rurales. Desprendemos de nuestros resultados que, aparte de los potenciales sesgos de la muestra habrán influido los costos y beneficios de la salud en los estilos de vida rurales. Estas condiciones fueron complejas diferenciadamente durante el primer milenio d.C., lo cual rechaza cualquier conceptualización jerárquica a priori al tiempo de invitar futuras exploraciones sobre las condiciones y dinámicas multicausales detrás de las tendencias encontradas.

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