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A Review of Bioarcheological Investigations in Iron Age Cambodia

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ABSTRACT

Archeological research within Cambodia is quite extensive, with significant projects led by both Cambodian archeologists and international researchers alike. Many of these projects have uncovered human skeletal remains. This article reviews archeological human skeletal studies in Cambodia, synthesizing published and unpublished data, primarily from the Iron Age (500 BCE–500 CE) across Angkor and the northwest and southeast regions. This synthesis includes discussions of demography, stature and enamel hypoplasia, dental health, diet, skeletal trauma, migration, and infectious diseases. The demographic data are limited, with sex, age at death, and stature often not estimated for individuals because of the fragmentary nature of the remains and the lack of specific population metric methods. Current data show no correlation between stature and enamel hypoplasia. Dental health appears to have declined in Iron Age Cambodia compared to earlier periods across Southeast Asia. A notably high prevalence of perimortem sharp and blunt force trauma, mostly to the head, was observed in the northwest region. Because of the poor preservation of the remains, pathological lesions were infrequently observed. Further bioarcheological research in Cambodia is recommended to enable a full understanding of the health and lifestyle of past populations. Understanding the relationship between general patterns across time and place in a broader context will be important in the next stage of research. This review also highlights the importance of local bioarcheological researchers and research education—these are the researchers who will be crucial to developing bioarcheology in Cambodia.

1 | Introduction

Archeological research within Cambodia is quite extensive, with significant projects led by both Cambodian archeologists and international researchers. Much focus over the past century has been on the Angkorian period (9th–15th centuries CE), well-known internationally by its remarkable temples. However, several key periods are important: the Funan period (1st–6th centuries CE), the Chenla period (7th–8th centuries CE), the Angkorian period, and the post-Angkorian period (15th–18th centuries CE). The pre-Angkorian periods (Funan and Chenla) overlap with the latter half of the Iron Age (*c.* 500 BCE–500 CE), and it is within this time period that the majority of prehistoric burials have been discovered to date (O'Reilly and Shewan 2016b). During the Angkorian period, however, burial practices shifted primarily to cremation, as seen in mortuary jars at Sras Srang (Courbin 1988). In the post-Angkorian period, jar and coffin inhumations appeared in the Cardamom Mountains, associated with highland indigenous groups (Beavan et al. 2012).

Only three sites with human remains have been excavated in Cambodia prior to the Iron Age: Samrong Sen, Laang Spean, and Koh Ta Meas. The finds are generally similar to those from Hoabinhian, Neolithic, and Bronze Age sites in Thailand and elsewhere in Southeast Asia (SEA) (Frelat and Souday 2015; Ly 2002; Zeitoun et al. 2024). Neighboring regions, such as

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northeast Thailand, have also had a focus on the investigation of the "rise of state" during the Iron Age (e.g., Higham and Kim 2022; Manguin and Stark 2022). Concomitantly, the more recent Iron Age excavations in Cambodia have provided an opportunity to study the prehistoric people themselves through their skeletal remains. It is, therefore, timely to synthesize this work to improve our understanding of Iron Age demography, diet, disease, and trauma and consider the future of bioarcheology in Cambodia. This synthesis is vital for advancing bioarcheological research in Cambodia. It also provides valuable insights into broader Iron Age patterns across SEA.

2 | The Iron Age Context (Pre-Angkor)

Social change, including increasing complexity and inequality (e.g., social hierarchy), is widely recognized during the late Bronze Age and early Iron Age in SEA (Higham 2022). In Cambodia, the Iron Age coincided with broader regional developments and represents a crucial period of sociopolitical transition. The Iron Age saw expanding long-distance trade and technological advancements alongside growing social complexity and a pattern of climatic changes, such as increasing aridity and seasonality (Castillo et al. 2018; Higham 2022; Wohlfarth et al. 2016). Archeological and bioarcheological evidence from Iron Age burial sites in Cambodia is primarily concentrated within three regions: Angkor, the northwest, and the southeast (Table 1 and Figure 1). The Angkor region shows agrarian moated settlements and trade-linked burials with rice offerings and imported goods (O'Reilly et al. 2020; O'Reilly and Shewan 2016a). The northwest emphasizes iron weaponry, conflict, and regional exchange (Carter et al. 2022; Domett, O'Reilly, and Buckley 2011). The southeast reflects Funan's urban and maritime networks, with isotopic evidence of rice-based diets and burials rich in gold, bronze drums, and exotic ornaments (Carter 2015; Ikehara-Quebral et al. 2017; Reinecke et al. 2012).

2.1 | Angkor Region

The Angkor region contains significant archeological sites from the late Iron Age, including Prei Khmeng and Phum Lovea. Prei

TABLE 1 | Iron Age burials in Cambodia.

Site (location on map)	Date	*N*[a]	Burial type	Skeletal preservation	Reference
Angkor region					
Prei Khmeng (3)	*c.* 1–650 CE	21	Extended supine/flexed	Extremely poor to good	O'Reilly et al. (2020), Pottier et al. (2009), and Whiteford (2015)
Phum Lovea (3)	*c.* 130–350 CE	14	Extended supine	Extremely poor	O'Reilly and Shewan (2016b)
Northwest region					
Phum Snay (4)	*c.* 380 BCE–239 CE	85 (+134 MNI)	Extended supine/flexed	Very poor to good	Domett and O'Reilly (2009) and Matsushita and Matsushita (2013)
Krasang Thmei (4)	*c.* 51 BCE–341 CE	8	Extended supine	Extremely poor	Domett (2005) and Sok (2006)
Phum Sophy (5)	*c.* 87–526 CE	20 (+37 MNI)	Extended supine/flexed	Very poor to good	O'Reilly et al. (2015)
Kok Treas (6)	*c.* 264–502 CE	6	Flexed	Very poor	Heng et al. (2013)
Koh Krabas (7)	Iron Age	18 MNI	Unknown	Very poor to good	Wallwork (2006)
Southeast region					
Wat Komnou (8)	*c.* 200 BCE–200 CE	111	Extended supine	Very poor to excellent	Ikehara-Quebral (2010)
Phum Prohear (9)	*c.* 500 BCE–100 CE	42	Jar burials and some extended supine	Very poor	Krais et al. (2012) and Reinecke et al. (2012)
Phnom Borei (8)	*c.* 350–100 BCE	9	Extended supine	Unknown; likely very poor	Phon (2004)
Village 10.8 (10)	*c.* 400–100 BCE	56	Jar burials, extended supine?	Unknown; likely very poor	Reinecke et al. (2009)

Abbreviations: MNI, minimum number of individuals (includes the unprovenanced bones only); *N*, number of individuals.
[a]The total number of individuals from Phum Snay and Prei Khmeng does not correspond to the numbers presented in Tables 2 and 3, as some individuals either were not selected for analysis or lacked comprehensive reporting.

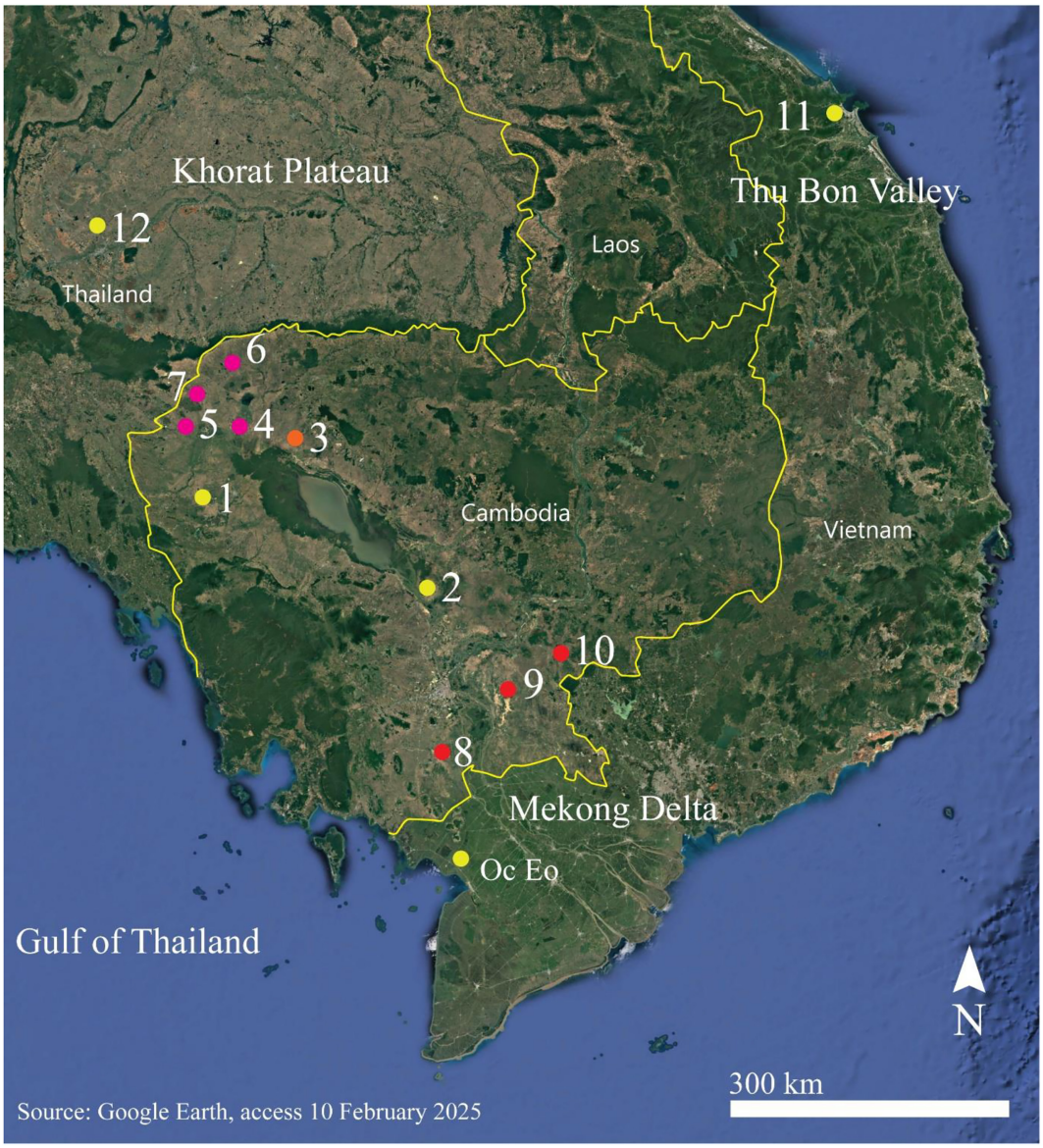

FIGURE 1 | Partial Map of Southeast Asia. Sites mentioned in the text are indicated as follows: yellow dots—(1) Laang Spean, (2) Samrong Sen, (11) Lai Nghi, and (12) Noen U-Loke and Non Ban Jak. Orange dots (Angkor region)—(3) Koh Ta Meas, Prei Khmeng, and Phum Lovea. Pink dots (northwest region)—(4) Phum Snay and Krasang Thmei, (5) Phum Sophy, (6) Kok Treas, and (7) Koh Krabas. Red dots (southeast region)—(8) Wat Komnou and Phnom Borei, (9) Phum Prohear, and (10) Village 10.8. [Colour figure can be viewed at wileyonlinelibrary.com]

Khmeng is a settlement and cemetery site located to the southwest of the West Baray in the Siem Reap Province. The site has been dated to between *c*. 1 and 650 CE (O'Reilly et al. 2020; Pottier et al. 2009). The excavations yielded 21 burials interred in simple pit graves in an extended supine or semiflexed position with the head to the east, northeast, or west (Chhem et al. 2004; O'Reilly and Shewan 2016b; Whiteford 2015). Graves were generally furnished and included iron tools, bronze jewelry, ceramic vessels, glass and stone beads, and faunal remains (O'Reilly et al. 2020; Pottier et al. 2009). Burial rituals included graves filled with rice and pig skull offerings. A young adult male was interred with 1700 glass and stone beads, which were indicative of trade and exchange between South Asia and SEA (Carter et al. 2022).

Phum Lovea is a circular settlement and cemetery site with double moats, located approximately 8 km northwest of Prei Khmeng. The double moats and embankments were probably designed as early water management systems for an agrarian community (O'Reilly et al. 2017). It was morphologically like other moated sites found on the Khorat Plateau (Figure 1) (Higham et al. 2014). Twelve burials were exhumed and dated to *c*. 130–350 CE (O'Reilly and Shewan 2016a). Individuals were buried in simple pit graves with the head to the south or southeast. Accompanying grave goods comprised iron tools, bronze jewelry, a marble bangle, a Chinese coin, carnelian and agate beads, clay pellets, spindle whorls, and ceramic vessels (O'Reilly and Shewan 2015, 2016a). A Chinese coin, an imported item, is similar to a coin from the short-lived Xin Dynasty (*c*. 9–23 CE) (O'Reilly and Shewan 2015).

2.2 | Northwest Region

The northwest region encompasses various settlements and cemetery sites, including Phum Snay, Krasang Thmei, Phum

Sophy, Kok Treas, and Koh Krabas. Phum Snay is situated on a natural mound, 3 km in diameter, in the Banteay Meanchey Province, northwest of the Angkor region. Phum Snay is dated between *c.* 380 BCE and 239 CE (Miyatsuka and Yasuda 2013; O'Reilly, Domett, and Pheng 2006). A total of 85 individuals were excavated and analyzed from Phum Snay, along with unprovenanced remains from looting, together representing a minimum number of individuals (MNI) of 134 (Domett and O'Reilly 2009; Matsushita and Matsushita 2013). Individuals from Phum Snay were interred in extended supine and flexed positions with the head to either the east or west (Matsushita and Matsushita 2013; O'Reilly and Shewan 2016b). Some graves were filled with rice as at Prei Khmeng and Noen U-Loke, and blackware ceramics were present, similar to what is known as Phimai Black in northeast Thailand (O'Reilly, Domett, and Pheng 2006). Apart from ceramic vessels, inhumations were buried with iron weaponry (arrowheads, spearpoints, and swords), iron tools (adzes, sickles, and blades), iron and bronze ornaments (rings, bangles, and torcs), ceramic epaulets and iron-made water buffalo horns, glass and stone beads, carnelian and agate beads, animal teeth, and ivory ornaments (Nojima 2013). Disc-shaped spiral objects were made of semiprecious stone and carnelian, which were probably imported from South Asia (Nojima 2013). Common types of glass beads, also probably imported from South Asia, were identified (Carter 2015). The prevalence of iron tools and weaponry, along with the exceptional evidence of traumatic injury (see below), suggests that the Phum Snay community may have been involved in endemic conflict (Domett, O'Reilly, and Buckley 2011; Lapteff 2013).

Krasang Thmei is located approximately 2 km north of Phum Snay and is dated to *c.* 51 BCE–341 CE (Sok 2006). Ten burials were excavated in simple pit graves, with individuals in an extended supine position, heads oriented northwest or southeast. Accompanying grave goods included iron weaponry (swords, arrowheads, and spearheads), small iron knives, iron and bronze ornaments (rings, bangles, and necklaces), beads, epaulets, and clay materials (spindle whorls, clay pellets, and ceramic vessels) (Sok 2006). These artifacts are similar to those found in Phum Snay, although only a few beads were observed at Krasang Thmei.

Phum Sophy is located in O'Chrov District, Banteay Meanchey Province, approximately 40 km west of Phum Snay. The site was dated to between *c.* 87 and 526 CE (O'Reilly et al. 2015). Fourteen burials containing 20 individuals were excavated, whereas looted remains represented an additional MNI of 37 (Domett, Newton, et al. 2011; O'Reilly et al. 2015). Individuals were interred in four orientations: south, southeast, west, and northwest (O'Reilly and Shewan 2016b). Grave goods included iron tools (knives and sickles), iron weaponry (spears and projectile points), bronze tools (bells and projectile points) and bronze ornaments (bangles and rings), agate, carnelian and glass beads, clay objects (spindle whorls and pellets), ceramic vessels, shell ornaments (bangles), an animal tooth pendant, and other faunal remains (O'Reilly et al. 2015). Accompanying grave goods are indicative of a community based on an agricultural lifestyle that involved rice cultivation, hunting, and fishing. In addition, craftsmanship was also evidenced by the presence of spindle whorls and metal slag (O'Reilly et al. 2015). However, metal production was not confirmed because of the absence of any furnaces, clay molds, or crucibles. Iron spears and projectile points were possibly used for hunting or community defense. Regional trade was indicated by the presence of agate, carnelian, and glass beads (Carter et al. 2022).

Kok Treas is a burial site located in Thmar Pouk District, Banteay Meanchey Province, approximately 50 km north of Phum Snay. This site dated between *c.* 264 and 502 CE (Heng et al. 2013). Six individuals were recovered from the excavation at Kok Treas. Individuals were interred in simple pit graves in a flexed position with the head to the southeast, east, and west (Heng et al. 2013). Accompanying grave goods included iron tools (spearheads, spades, and sickles), bronze bracelets, bronze plates, a gold finger ring, stone, and glass beads (Heng et al. 2013). A subadult individual (12–15 years old) was the most adorned burial, possibly indicating affiliation with a high-status family within the community. This individual was interred along with a piece of grinding stone, two agates, one carnelian and more than 300 black glass beads, a gold finger ring, half of a bronze plate beneath the head, an iron spearhead, an iron spade and an iron sickle, four ceramic vessels, and both feet lying on a bronze plate. In contrast, the other subadult (approximately 11 years old) was interred only with an iron tool and three ceramic vessels (Heng et al. 2013).

Koh Krabas is also located in Thmar Puok District, Banteay Meanchey Province. A site report noted looted artifacts suggesting an Iron Age site and unprovenanced human remains with an MNI of 18 (Wallwork 2006).

2.3 | Southeast Region

The southeast region comprises settlement and cemetery sites, including Wat Komnou, Phum Prohear, Village 10.8, and Phnom Borei. Wat Komnou is a cemetery site located in Angkor Borei, Takeo Province (Stark 2006). Angkor Borei was an urban center dated from at least the Funan period (1st–6th centuries CE), according to Chinese records and archeological and other historical research (Manguin and Stark 2022). This urban setting was believed to have a close connection with its possible port of Oc Eo in present-day southern Vietnam (Malleret 1959). The port was where the Kingdom of Funan may have had relations with China and India through maritime trade (Manguin and Stark 2022). The cemetery site of Wat Komnou was dated between *c.* 200 BCE and 200 CE (Stark 2001, 2006). A total of 111 individuals were examined at Wat Komnou (Ikehara-Quebral 2010; Ikehara-Quebral et al. 2017; Pietrusewsky and Ikehara-Quebral 2006). Individuals from Wat Komnou were generally interred in an extended supine position with the head to the southwest (Ikehara-Quebral 2010). Graves were furnished with earthenware globular jars and pig skulls. At Wat Komnou, there were two individuals that were oriented differently from the others with the head to the northeast or northwest and furnished with high-quality glass, stone, and gold beads (Ikehara-Quebral 2010). Furthermore, strontium and oxygen isotopic analysis suggests that these two individuals may have been nonlocal (Krigbaum et al. 2008).

Phum Prohear is located in the Svay Antor District, Prey Veng Province, approximately 84 km northwest of Wat Komnou.

The first period is dated between *c*. 500 and 150 BCE and the second period between *c*. 150 BCE and 100 CE (Reinecke et al. 2012). A total of 76 burials, which include 69 inhumations and 7 jar burials, were excavated (Reinecke et al. 2009, 2012). Krais et al. (2012) analyzed 42 individuals from Phum Prohear. Inhumations were interred in an extended supine position with the head to the east or west in the first period, whereas the orientation changed in the second period to south or southwest (Reinecke et al. 2012). Compared with other cemetery sites in the northwest region and other sites in SEA, Phum Prohear exhibited the richest accompanying grave goods during the early Iron Age. Individuals were buried with bronze drums, iron objects, gold and silver jewelry (earrings, finger rings, slit rings, and bracelets), gold foil tubes, glass and stone beads, and earthenware vessels (Reinecke et al. 2012). The gold ornaments were comparable with the site of Lai Nghi in central Vietnam (Schlosser et al. 2012). There were 33 looted and excavated bronze drums found at Phum Prohear. These bronze drums possibly originated from southern China and northern Vietnam (Reinecke et al. 2012).

There are two other cemetery sites (Village 10.8 and Phnom Borei) in the southeast region that contain human burials. Village 10.8 (*c*. 400–100 BCE) is located in Kampong Cham Province, approximately 60 km northeast of Phum Prohear. This cemetery contained at least 56 burials, including 11 jar burials. The burials were oriented mostly with the head to the southeast (Reinecke et al. 2009). Phnom Borei (*c*. 350–100 BCE), located in Takeo Province, is approximately 4 km south of Wat Komnou. Nine burials with the head to the southwest were excavated (Phon 2004). However, the human skeletal remains from these two cemeteries were poorly preserved, and biological studies have not yet been conducted.

2.4 | Diet

Studies of diet in the Angkor and northwest regions have also been based on archeological evidence from grave goods, which include rice, fish, and animal remains as a general proxy for overall diet (O'Reilly, Driesch, and Voeun 2006; Voeun 2013). However, more direct evidence of diet in the southeast region has been revealed by carbon and nitrogen stable isotopes. The isotopic evidence from Wat Komnou has indicated that dietary habits of this community were based on C_3 plants, such as rice (Ikehara-Quebral et al. 2017). Overall, although it seems clear that rice is a carbohydrate source for these communities, it is unclear whether there was a similarly timed mid-to-late Iron Age transition to more intensive wet-rice agriculture as has been argued for northeast Thailand (Castillo et al. 2016). Flood recession agriculture has been argued to have begun by the first millennium BCE in the Angkor Borei region, which may represent an even more intensive agricultural industry in southern Cambodia and Vietnam at this time (Manguin and Stark 2022).

2.5 | Migration

There is no direct genetic evidence from skeletal remains that can confirm migration into the Angkor and northwest regions. Cranial and dental morphological analyses at Phum Snay indicate admixture of Hoabinhian and East Asian groups, with populations retaining indigenous traits, unlike modern mainland SEA populations that reflect a stronger, later East Asian gene flow (Matsumura et al. 2011; Matsushita and Matsushita 2013). In addition, there was evidence of glass and stone bead trade between South India and SEA (Carter et al. 2022). Phum Sophy, Phum Lovea, and Prei Khmeng, and, crucially, all of mainland SEA were interacting with those trade networks during the first half of the first millennium CE. Strontium and oxygen isotope analyses at Phum Prohear and Wat Komnou indicate significant immigration and integration, revealing nonlocal individuals of both sexes (Ikehara-Quebral et al. 2017; Krais et al. 2012). These nonlocal groups may have emigrated from the Khorat Plateau or other regions (Ikehara-Quebral et al. 2017). One ancient DNA (aDNA) sequence from a male individual at Wat Komnou showed an association with South India rather than East Asia (Changmai et al. 2022). This demonstrates a biological component of the reorientation toward South Asia during the Iron Age, in contrast to an earlier orientation toward East Asia. This is consistent with the artifactual evidence, such as the beads, across the region as already noted.

3 | Bioarcheology

The Iron Age is known for significant social change with regard to increasing long-distance trade and early state formation (Higham 2022). These changes may have adversely affected the way of life of individuals and communities, potentially influencing their everyday decisions and actions within a transforming society. For instance, the marked decline in dental health and the high incidence of skeletal trauma in the northwest region of Cambodia illustrate the harmful consequences of conflict and shifting subsistence practices (Domett, O'Reilly, and Buckley 2011; Newton et al. 2013). To better understand this interplay between the individual and society, we look more closely at Iron Age Cambodian skeletal remains studies, alongside well-studied examples from neighboring countries, via six main themes: demography, stature, linear enamel hypoplasia (LEH), dental health, skeletal trauma, and disease.

3.1 | Demography

The number of individuals excavated across Iron Age Cambodia is small; thus, discussions around demography are unlikely to give an accurate picture (Tables 2 and 3 and Figure 2). For a skeletal sample to potentially represent the living population from which it came, the subadult sample (≤14.9 years) is expected to be at least one-third of the total cemetery sample (Waldron 1994). Cambodian sites ranged from 0% to 40%, with most at around one-third. Phum Lovea and Krasang Thmei included no subadults, possibly due to children being buried in other places, but given the poor preservation of the adults, it is likely that subadult fragile remains simply did not preserve. Prei Khmeng and Phum Sophy both included 40% subadults. Iron Age communities in SEA often show high subadult mortality rates, such as 64.1% at late Iron Age Non Ban Jak in northeast Thailand, likely reflecting high fertility and/or childhood infectious disease (Buckley et al. 2020).

TABLE 2 | Demographic data of subadult individuals.

Site	Subadult individuals								
	Subadult age					Total			
	< 0.5 years	0.6–5 years	6–10 years	11–14.9 years	Unknown age	*N*	%	Total *N*[a]	Reference
Prei Khmeng	1	2		1	1	5	41.7	12	O'Reilly et al. (2020) and Chhem et al. (2004)
Phum Lovea								14	Domett and Newton (2013)
Phum Snay		5	1	1	2	9	10.8	83	Domett and O'Reilly (2009) and Matsushita and Matsushita (2013)
Krasang Thmei								8	Domett (2005)
Phum Sophy	1	4	3			8	40.0	20	O'Reilly et al. (2015)
Kok Treas					2	2	33.3	6	Heng et al. (2013)
Koh Krabas		1		3		4	22.2	18	Wallwork (2006)
Wat Komnou	3	9	12	7		31	27.9	111	Ikehara-Quebral (2010)
Phum Prohear	1	3	7	2		13	31.0	42	Krais et al. (2012)
Total	6	24	23	14	5	72	22.9	314	

Note: Subadults ≤ 14.9 years (% of total number individuals).
Abbreviation: *N*, number of individuals.
[a]The total number of individuals includes both subadults and adults.

A 1:1 female-to-male sex ratio is indicative of an unbiased sample (Poston and Bouvier 2016) but was observed at only a few sites (Table 3; Phum Snay and Phum Sophy). Many sites diverged from this, with some only having males or individuals of indeterminate sex (Table 3; Phum Lovea and Kok Treas). These inconsistencies are most likely due to the fragmentary nature of the remains and relatively small sample sizes available at most sites. However, it is of note that Wat Komnou, with one of the larger sample sizes, had twice as many males as females. These imbalances may result from sampling error, variations in mortuary practices, the emigration of females, or the immigration of adult males (Ikehara-Quebral 2010). The latter is supported by aDNA evidence (Changmai et al. 2022) and strontium and oxygen isotopes, but there were also some female immigrants (Krigbaum et al. 2008).

The number of individuals with a biological sex estimate is relatively small compared to other Southeast Asian sites. Given the commingled and fragmentary remains, discriminant function analysis using long bone measurements could aid in sex estimation. This method has been recently developed based on prehistoric populations from Thailand and Cambodia (Nhoem and Domett 2025). Estimating age at death from fragmentary remains is also challenging, particularly for adults, with existing studies categorizing individuals as young, middle-aged, or older. Recent advancements in population-specific aging methods have provided new avenues for enhancing our understanding of skeletal aging across a broader range of specific populations (Pedersen and Domett 2022).

3.2 | Stature and LEH

Growth disruptions in children, often caused by inadequate nutrition or disease during critical developmental periods, can be assessed through the analysis of LEH. LEH manifests as linear defects in tooth enamel, indicating periods of physiological stress (e.g., Armelagos et al. 2009; Goodman et al. 1984; Hillson 2005). Previous studies have documented LEH at Phum Snay and Phum Sophy (Newton 2014); however, no individual-level analyses have examined its relationship with long bone lengths or stature (as an indicator of growth). The current LEH data, collected macroscopically, may underestimate prevalence, highlighting the need for advanced

TABLE 3 | Demographic data of adult individuals.

	Adult individuals																	
	Females						Males						Unknown sex		F:M ratio	Total		
Site	*N*	%	Young	Middle-aged	Older	Unknown age	*N*	%	Young	Middle-aged	Older	Unknown age	*N*	%		*N*	%	Reference
Prei Khmeng	2	28.6	1	1			4	57.1	2	2			1	14.3	1:2	7	58.3	O'Reilly et al. (2020) and Chhem et al. (2004)
Phum Lovea							7	50.0	3		3	1	7	50.0		14	100.0	Domett and Newton (2013)
Phum Snay	22	29.7	3	4		15	26	35.1	2	3		21	26	35.1	1:1.2	74	89.2	Domett and O'Reilly (2009) and Matsushita and Matsushita (2013)
Krasang Thmei	3	37.5		1	2		2	25.0		1	1		3	37.5	1:0.7	8	100.0	Domett (2005)
Phum Sophy	4	33.3	1	1		2	3	25.0		1		2	5	41.7	1:0.8	12	60.0	O'Reilly et al. (2015)
Kok Treas							3	75.0	1	2			1	25.0		4	66.7	Heng et al. (2013)
Koh Krabas	3	21.4		3			1	7.1		1			10	71.4	1:0.3	14	77.8	Wallwork (2006)
Wat Komnou	26	32.5	15	6		5	49	61.3	24	7	1	17	5	6.3	1:1.9	80	72.1	Ikehara-Quebral (2010)
Phum Prohear	1	3.4		1									28	96.6		29	69.0	Krais et al. (2012)
Total	61	25.2	20	17	2	22	95	39.3	32	17	5	41	86	35.5	1:1.6	242	77.1	

Note: Adult ≥ 15 years (% of total adult individuals).
Abbreviations: F:M, female-to-male; *N*, number of individuals.

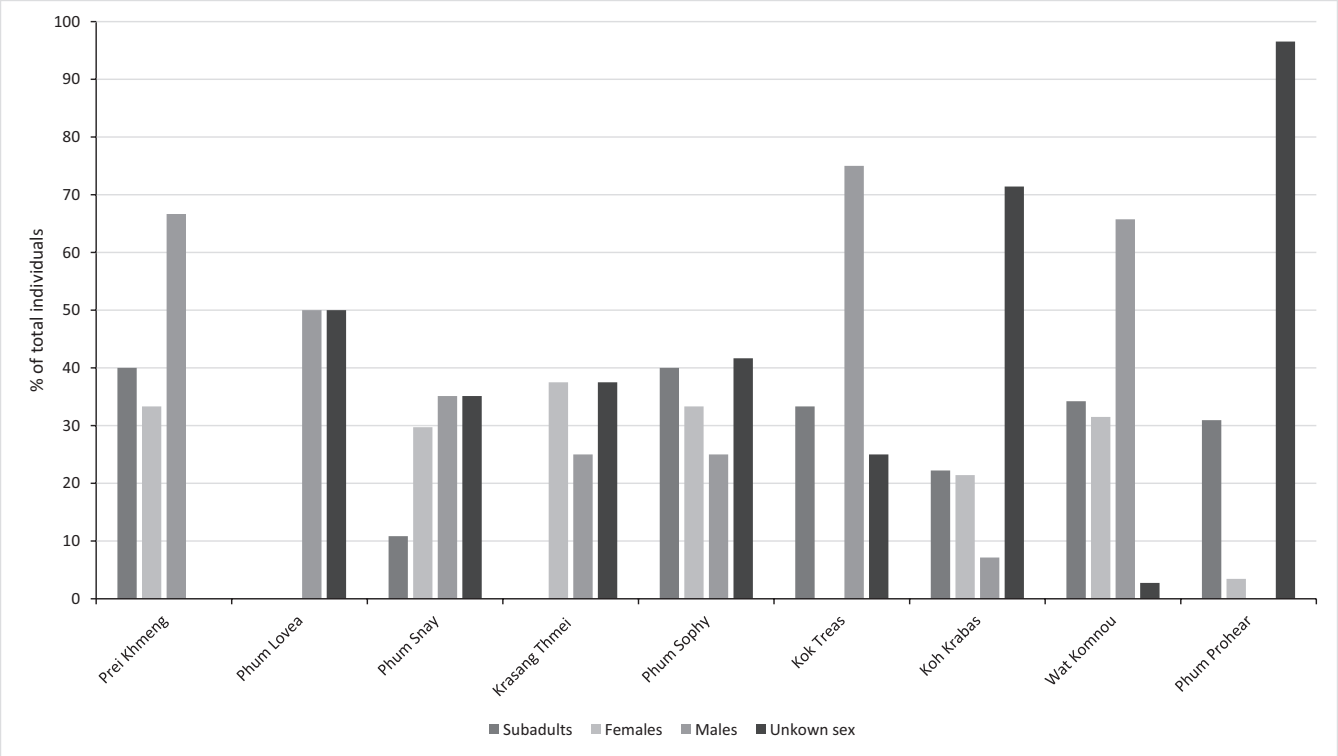

FIGURE 2 | Demography of Cambodian Iron Age sites discussed. Subadults ≤ 14.9 years (% of total number of individuals); adults ≥ 15 years (% of total adult individuals). Sources are listed in Tables 2 and 3.

microscopic techniques in future research (e.g., Cares Henriquez et al. 2023; Cares Henriquez and Oxenham 2020; Dąbrowski et al. 2021).

A comparison of stature (Table 4 and Figure 3) and LEH (Table 5 and Figure 4) frequencies reveals distinct patterns. Stature was recalculated using raw data when possible, based on Pureepatpong et al. (2012) regression equations due to their lower standard error, whereas stature estimates from Wat Komnou were used as published (based on the equations of Sangvichien et al. 1985, n.d.), given the lack of access to raw data (Table 4). Phum Sophy females exhibited a shorter average stature (151.7 cm) and a lower LEH frequency (7.9%) compared with Phum Snay, suggesting overall good health and potential genetic or environmental influences on stature. In contrast, Phum Snay females had a taller average (156.1 cm) but had a higher LEH frequency (16.4%), which may indicate resilience and catch-up growth following early-life stress (e.g., Bogin et al. 2007; Vercellotti et al. 2014). A similar pattern was observed in males. This suggests that Phum Snay individuals may have experienced early growth disruptions but later compensated for this through improved nutrition that may reflect sociopolitical changes. Future research should assess LEH at the individual (and microscopic) level to further investigate its relationship with long bone lengths and stature.

3.3 | Dental Health

Dental health is shaped by multiple factors, including diet, environment, age, sex, genetics, disease, and cultural dental modification. Diet alone is not linearly related to dental health, with rice processing methods also influencing dental health (Newton et al. 2013; Tayles et al. 2000, 2009; Willis and Oxenham 2013). Most dental pathology also increases with age, and sex-based differences have been widely observed, partly influenced by female hormonal changes (Lukacs and Thompson 2008; Zhao et al. 2024).

Dental health in the Cambodian Iron Age shows a general decline relative to other Southeast Asian groups, though with variation by sex, age, and region (Newton et al. 2013). Advanced tooth wear (ATW) was more frequent in males and increased over time (Table 6), possibly reflecting differences in tooth use or diet, similar to patterns in prehistoric Vietnam (Oxenham et al. 2006). Females generally exhibited higher caries frequencies than males, except for people from Wat Komnou (Figure 5), consistent with broader SEA trends often linked to fertility-related physiological demands (Willis and Oxenham 2013; Zhang et al. 2025). Antemortem tooth loss (AMTL) in the Iron Age was lower in Cambodia than in Thailand and Vietnam, suggesting improved health through enhanced environmental adaptation (Domett and Tayles 2006; Newton et al. 2013). Causes of AMTL include intentional tooth ablation or filing (present at a range of Cambodian sites) (Domett, Newton, et al. 2011), trauma, or dental pathology (Newton et al. 2013).

Interpretation is complicated by small, fragmentary samples that limit sex and age attribution, as seen at Phum Prohear and Krasang Thmei, or samples restricted to males, as at Phum Lovea. Nevertheless, sex-based differences likely

TABLE 4 | Comparison of estimated adult stature[a] (cm) in Iron Age sites.

Site	Females							Males							Reference
	N	Mean	Median	Min	Max	Range	SD	*N*	Mean	Median	Min	Max	Range	SD	
Prei Khmeng	1	152.2						4	159.7	162.3	148.9	165.3	16.5	7.42	Whiteford (2015)
Phum Lovea	0							3	164.6	165.3	162.1	166.5	4.5	2.31	Domett and Newton (2013)
Non Ban Jak	18	157.1	156.8	150.0	164.5	14.5	4.32	24	169.0	169.9	153.3	182.1	28.8	6.42	Buckley et al. (2020)
Phum Sophy	23	151.7	151.9	144.0	160.2	16.2	4.08	22	164.6	164.9	156.9	171.5	14.6	3.75	Nhoem (unpublished thesis)
Wat Komnou[b]	8	154.8	153.9	151.1	159.9	8.8	3.15	11	165.4	164.9	157.9	172.7	14.8	5.13	Ikehara-Quebral (2010)
Noen U-Loke	4	154.5	152.2	151.6	162.2	10.6	5.13	9	170.7	169.9	166.3	178.2	11.9	4.00	Domett and Tayles (2006)
Phum Snay	23	156.1	155.0	150.0	173.8	23.8	5.24	83	165.9	165.3	157.5	178.7	21.2	4.78	Nhoem (unpublished thesis)

Note: Cambodian Iron Age sites are in bold.
Abbreviations: Max, maximum; Min, minimum; *N*, number of individuals; SD, standard error.
[a]Estimated stature was recalculated using raw data, following Pureepatpong et al. (2012), as these formulae yielded the lowest standard error.
[b]Estimated stature was reported using Sangvichien et al. (1985, n.d.); however, recalculations were not feasible because of the lack of access to raw long bone length data from this site.

reflect activity-related dietary habits and reproductive factors (Lukacs 2011). Overall, the decline in dental health during the Iron Age suggests sociopolitical changes and the transition toward state formation negatively affected community well-being (Newton et al. 2013).

3.4 | Skeletal Trauma

Most skeletal trauma evidence in Cambodia derives from the northwest. At Phum Snay, 26.4% of individuals exhibited sharp and blunt force trauma, primarily cranial and often healed, an unprecedented rate to date in prehistoric SEA (Domett and O'Reilly 2009; Domett, O'Reilly, and Buckley 2011). This anomaly has been interpreted as resistance to emerging sociopolitical changes, linked to the rise of Funan in the Mekong Delta (Manguin and Stark 2022) or alternatively as evidence of a Funan-aligned military frontier garrison. The absence of fortifications and the presence of distinctive material culture such as unique epaulets and iron buffalo horn decoration, however, complicate these interpretations. A third hypothesis attributes the injuries to interpersonal violence related to unspecified internal conflicts or ritual (Domett, O'Reilly, and Buckley 2011).

In contrast, trauma prevalence at Wat Komnou (13.5%)—a site associated with Funan—is lower and largely attributed to occupational stress rather than conflict (Ikehara-Quebral 2010), similar to patterns at Non Ban Jak in northeast Thailand (Pedersen et al. 2019). Other Cambodian sites, despite the limited sample sizes, show even lower rates: Phum Sophy (2.8%) (Domett, O'Reilly, and Buckley 2011), Koh Krabas (5.6%) (Wallwork 2006), Phum Lovea (7.2%) (Domett and Newton 2013), and Prei Khmeng (14.3%) (O'Reilly et al. 2020; Venkatesh et al. 2004). These findings highlight Phum Snay as a regional outlier, raising questions about center–periphery dynamics, peer–polity competition, and the role of violence in the late Iron Age. Further study of unexamined remains, particularly from Prei Khmeng and Phum Snay, is needed to clarify trauma patterns and their implications for conflict in Iron Age SEA.

3.5 | Infectious Diseases

A comprehensive bioarcheological assessment must include a discussion of infectious disease; however, such investigations are often constrained by issues of preservation. A differential diagnosis of possible infectious disease of an adult female cranium was conducted at Phum Snay (Domett and Buckley 2012). Detailed descriptions of the lesions suggest that they might be treponemal disease, but Langerhans cell histiocytosis or multiple myeloma was deemed more likely (Domett and Buckley 2012). At Wat Komnou, a chronic infectious disease, which included possible treponemal infection, was observed on five (4.5%) male individuals (four adults and one adolescent) (Ikehara-Quebral 2010). Further radiological investigations would be beneficial. Molecular and ancient treponemal DNA methods (Baker et al. 2020) would also further our research on the origins and transmission patterns of the treponemal disease in prehistoric SEA.

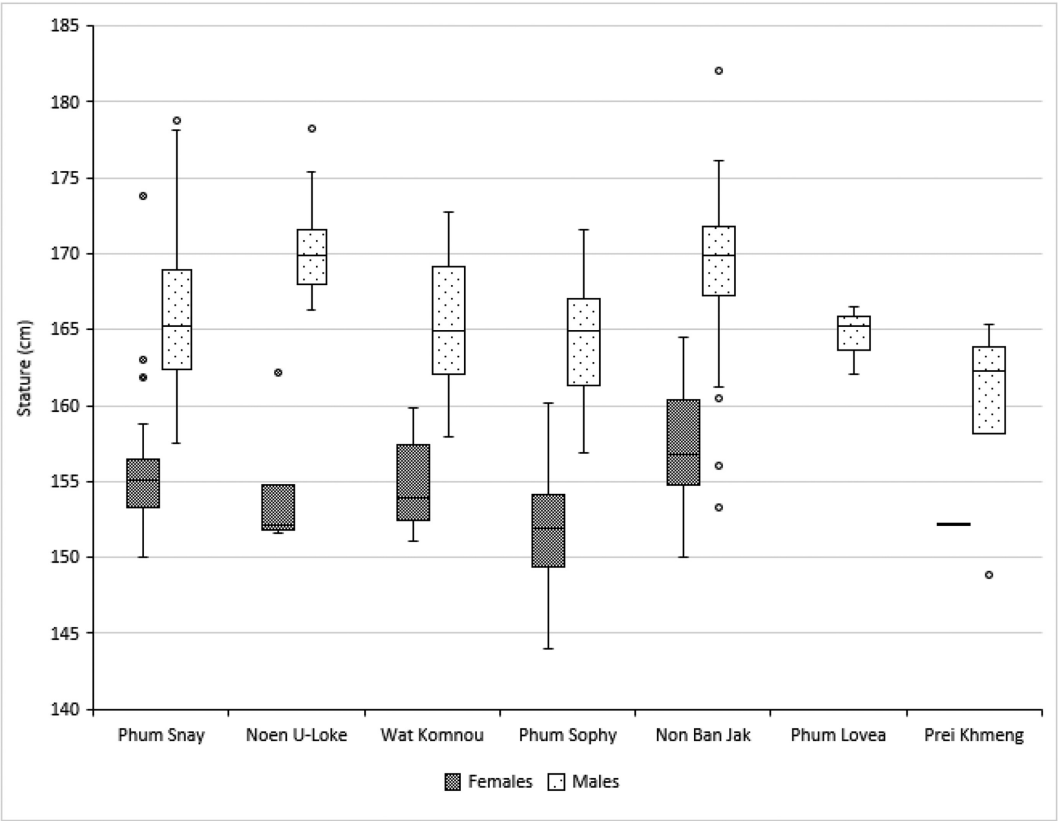

FIGURE 3 | Comparison of stature discussed in the text. The boxplot shows the median, minimum and maximum stature (cm), and outliers. Sources and further information are listed in Table 4.

TABLE 5 | Percentage of LEH of adult teeth in Iron Age sites.

	Females		Males		
Site	**A/O**	**% LEH**	**A/O**	**% LEH**	**Reference**
Phum Sophy	12/151	7.9	3/143	2.1	Newton (2014)
Wat Komnou	16/197	8.1	23/248	9.3	Ikehara-Quebral (2010)
Noen U-Loke	39/258	15.1	20/304	6.6	Tayles et al. (2007)
Phum Snay	36/219	16.4	22/130	16.9	Newton (2014)

Note: Cambodian Iron Age sites are in bold.
Abbreviations: A/O, affected/observable teeth; LEH, linear enamel hypoplasia.

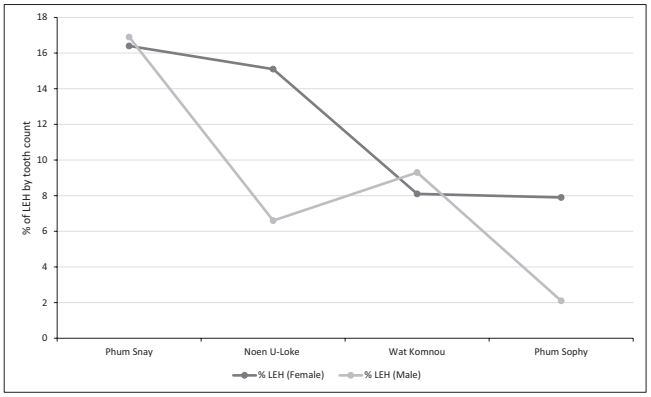

FIGURE 4 | Comparison of linear enamel hypoplasia percentage (LEH). Sources are listed in Table 5.

3.6 | Integration, Limitations, and Recommendations

Considered together, these six themes suggest a rich diversity of biology and health in prehistoric Cambodia. Examining how biological variation and health patterns relate to the culture and lifestyles of early Cambodians can provide deeper insights into their diet, morbidity rate, physical activity, social organization, and overall adaptation to their environment. The array of gold grave goods at Phum Prohear is remarkable, for example, as is the unprecedented, to date, prevalence of violent trauma at Phum Snay. Mortality rates, health, diet, and stature all provide some level of insight into the everyday lives of these people and their communities. Evidence of migration, exchange networks, and interpersonal violence hints

TABLE 6 | Comparison of dental health and cultural dental modification for adult individuals in the Cambodia Iron Age.

Site/sex	ATW		Caries		AMTL		Ablation	Filing	Betel chewing	Reference
	A/O	%	A/O	%	A/O	%				
Females										
Phum Sophy	31/271	11.4	26/253	10.3	7/537	1.3	Y	Y		Domett, Newton, et al. (2011) and Newton et al. (2013)
Wat Komnou	19/213	8.9	9/214	4.2	5/254	2.0		Y	Y	Ikehara-Quebral (2010)
Phum Snay	22/315	7.0	38/364	10.4	20/895	2.2	Y	Y		Domett, Newton, et al. (2011) and Newton et al. (2013)
Males										
Phum Lovea	6/97	6.2	2/58	3.4	5/145	3.4				Domett and Newton (2013)
Phum Sophy	37/233	15.9	17/237	7.2	2/427	0.5	Y	Y		Domett, Newton, et al. (2011) and Newton et al. (2013)
Wat Komnou	33/285	11.6	16/283	5.7	18/393	4.6		Y	Y	Ikehara-Quebral (2010)
Phum Snay	29/250	11.6	13/288	4.5	14/743	1.9	Y	Y		Domett, Newton, et al. (2011) and Newton et al. (2013)
Unknown sex										
Krasang Thmei	4/55	7.3	9/62	14.5	27/98	27.6		Y?		Domett (2005)
Phum Prohear	111/209	53.1	9/259	3.5	6/68	8.8		Y?	Y	Krais et al. (2012)

Abbreviations: A/O, affected/observable teeth; AMTL, antemortem tooth loss; ATW, advanced tooth wear; Y, yes present; Y?, yes probably present.

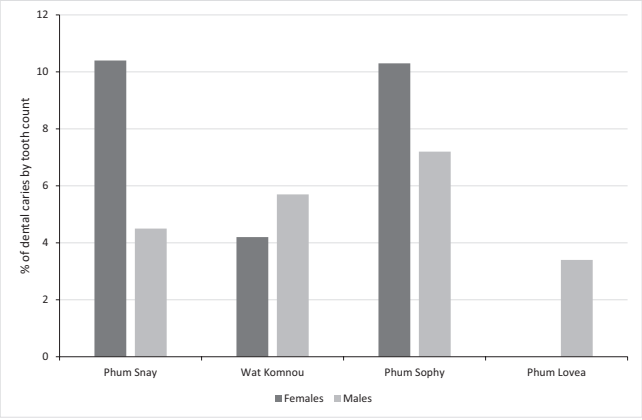

FIGURE 5 | Comparison of dental caries prevalence in Iron Age sites. Sources are listed in Table 6.

at broader forces at play in the region. However, it is also clear that the evidence remains fragmentary and somewhat scarce. In many cases, cemetery sites only became known after looting activities by villagers were reported. These activities have not only partially destroyed the sites but also led to a number of unprovenanced skeletal remains whose original context is lost, losing the detail of funerary practices and associated artifacts.

Another major challenge in skeletal analysis is the inconsistency of methods used by researchers from different backgrounds. For example, French teams applied methods from Thai and French populations (Zeitoun et al. 2012), whereas German teams used German methods (Krais et al. 2012). At Phum Snay, Australian researchers relied on Thai and Buikstra and Ubelaker's (1994) methods (Domett and O'Reilly 2009), whereas Japanese

researchers applied American Indian and Japanese methods (Matsushita and Matsushita 2013). Notably, the Japanese team applied stature regressions developed for Japanese populations (Fujii 1960), which may produce inaccurate stature estimates for Iron Age Cambodian samples. It would be beneficial if population-specific methods for the analysis of human skeletal remains from prehistoric Cambodia and SEA could be developed (e.g., Nhoem and Domett 2025), at least in terms of the basic measurements that should be published and made freely available.

3.7 | Local Research Education and Facilities

Education and research resources have been limited in Cambodia (e.g., Carter et al. 2020; Heng et al. 2023). Although local archeologists and archeology students are invited to join most excavation campaigns, it remains the case that international bioarcheologists are called upon during the recovery of human skeletal remains to conduct bioarcheological and anthropological studies both at the excavation site and in the temporary laboratory. There is no equipped biological anthropology laboratory in Cambodia; therefore, samples of human skeletal remains are at times sent abroad for further research to be conducted.

For truly collaborative research in the future, well-trained Cambodian bioarcheologists are needed with sufficient resources at hand. These specialists can be trained to work independently, especially as "first responders" in rescue excavation contexts, as well as integrating with international research teams in archeological research projects. For this collaboration to be achieved, sustained investment in education, capacity-building initiatives, and access to advanced technologies will be essential, ensuring that Cambodian bioarcheologists can contribute effectively on both local and global research platforms. Furthermore, support from the international bioarcheological community should include the provision of educational opportunities and initial resources, facilitated through partnerships with governmental and nongovernmental sectors.

3.8 | Summary

The Iron Age in Cambodia, characterized by significant sociopolitical transitions, witnessed the expansion of long-distance trade and technological advancements. Archeological evidence from three key regions—Angkor, the northwest, and the southeast—provides valuable insights into this transformative period. In the Angkor region, sites such as Prei Khmeng and Phum Lovea shed light on burial practices, trade goods, and agricultural activities. The northwest region, with prominent sites like Phum Snay and Krasang Thmei, revealed evidence of conflict and trade, with burials containing iron tools, weaponry, and imported materials. In the southeast region, sites such as Wat Komnou and Phum Prohear demonstrate the influence of maritime trade, as evidenced by the presence of prestigious grave goods, including bronze drums and gold jewelry. These sites underscore the increasing social complexity, expansion of trade networks, and integration of diverse cultural influences during the Iron Age in SEA.

These substantial social changes, influenced by the growth of trade and the early development of states, had a profound impact on individuals and communities. This review synthesizes bioarcheological data, focusing on aspects such as diet, migration, demography, stature, LEH, dental health, skeletal trauma, and disease. The skeletal remains from Phum Snay indicate high levels of early-life stress and trauma, suggesting the presence of conflict. A decline in dental health and a reliance on a rice-based diet were also evident. Migration patterns point to interactions with Hoabinhian, East Asian, and South Asian populations. However, the limited bioarcheological evidence concerning disease necessitates further investigation. Overall, the process of early state formation introduced significant social and biological challenges, shaping the health, demographic profiles, and instances of interpersonal violence within these communities.

4 | Final Thoughts

Bioarcheology is a specialist discipline central to understanding the past. It connects us directly with the individuals that built, produced, and reproduced societies and culture. In Cambodia, a full realization of its potential is still some time away. There are limited sites to draw on, and many of the sample sets are flawed in one or more ways. Further, the lack of local specialists in Cambodia limits future data collection. The ongoing threats to many archeological sites from looting mean that early intervention and assessment are imperative. Work is under way to develop more appropriate analytical techniques and standards in Cambodia, alongside similar work in Thailand and Vietnam. This continued work will detail the biological evidence of nutrition, migration, disease, and skeletal trauma throughout prehistory in Cambodia. In addition, these same techniques can be applied to investigate the remains from the recent atrocity of the Cambodian genocide. Training Cambodian students in these skills, supported by research and government institutions, will benefit long-term research and studies on human skeletal remains both in Cambodia and across SEA as a whole.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article, as no datasets were generated or analyzed during the current study.

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